FINAL REPORT

SIX-MONTH POST-CONSTRUCTION SEAFLOOR MAPPING SURVEY
A COMPONENT OF THE BENTHIC MONITORING STUDY
FOR THE
LONG ISLAND REPLACEMENT CABLE PROJECT

WINTER 2009

SHEFFIELD HARBOR AND LONG ISLAND SOUND
NORWALK, CONNECTICUT

OSI REPORT NO. 07ES077.4A

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1.0 INTRODUCTION

During the period 12 January through 14 February 2009, Ocean Surveys, Inc. (OSI) conducted various oceanographic, biological, hydrographic, and geophysical tasks in and around Sheffield Harbor, Norwalk, CT and in portions of Long Island Sound. These tasks were part of a benthic monitoring program designed to assess the environmental and biological characteristics of the area and to evaluate potential environmental impacts that may result from the Long Island Power Authority (LIPA)/The Connecticut Light and Power Company (CL&P) Long Island Replacement Cable Project ("LIRC" or "Project") which extends from Norwalk, CT to Northport, NY in Long Island Sound. This investigation is the six-month post-construction study conducted for this Project and was performed under contract to ESS Group, Inc. (ESS) on behalf of CL&P. The results included in this report are a component of the Monitoring and Mitigation Plan required by regulatory agencies overseeing the Long Island Replacement Cable Project.

The primary objectives of this investigation were to (a) assess the quality of benthic habitats and communities (b) provide data for monitoring the health and viability of the shellfish population (c) aid in the servicing and redeployment of in situ instrumentation for physical oceanography and sediment transport processes and (d) provide a post-construction record of the seafloor morphology in designated areas representing the different marine environments throughout the cable corridor. These investigations were conducted by OSI in association with Dr. Robert Whitlatch (benthic and shellfish biologist) and Dr. W. Frank Bohlen (physical oceanography and sediment processes), both of the University of Connecticut. This report will focus on the six-month post-construction seafloor morphology results while benthic biology and physical oceanographic results completed in association with Dr. Whitlatch and Dr. Bohlen will be submitted under separate cover.

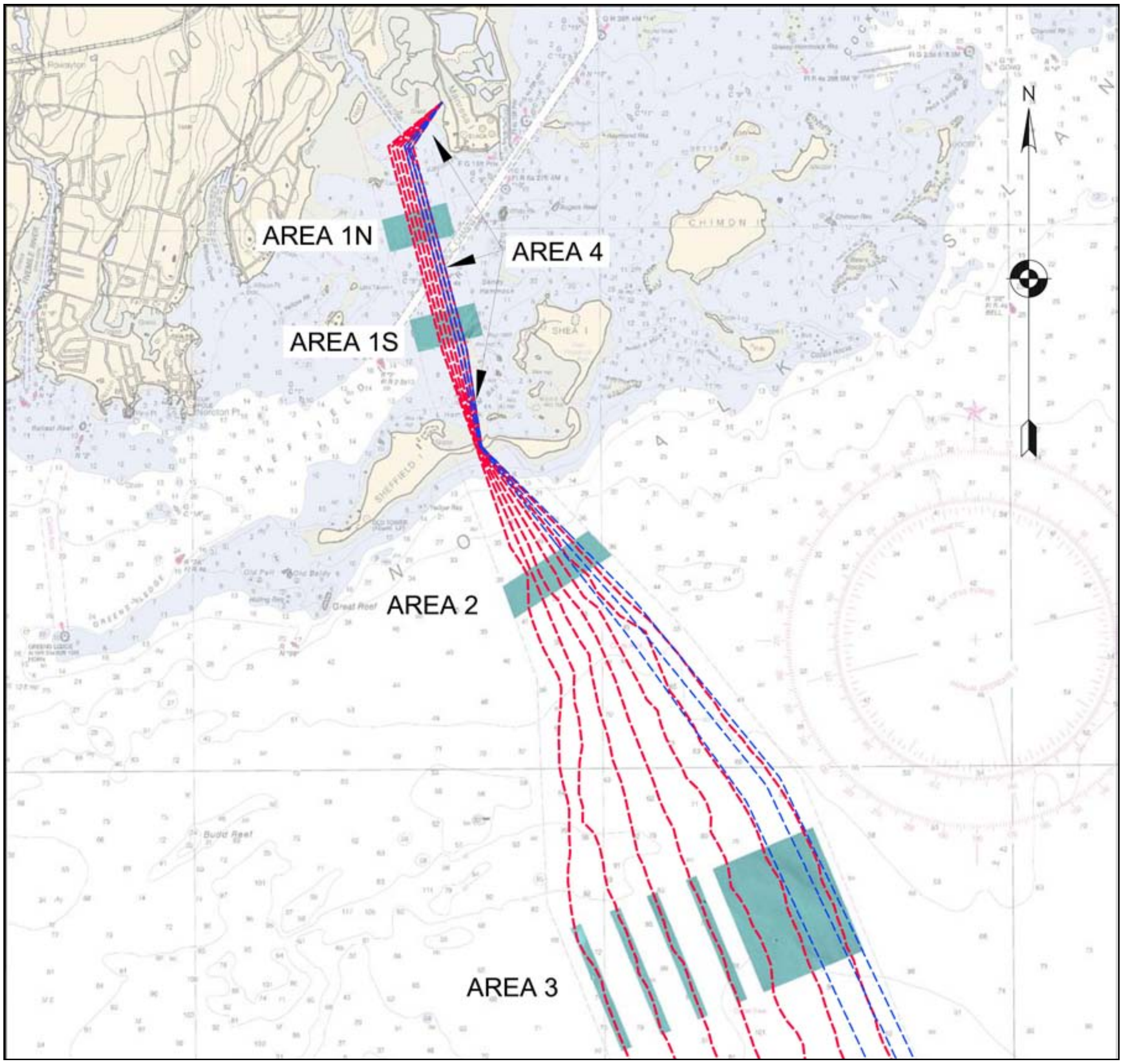

Figure 1: Five monitoring areas designated for remote sensing surveys.

1.1 Project Background

The LIRC Project involves the replacement of seven fluid-filled submarine transmission cables installed in 1969, with three new solid-core dielectric copper conductor cables. The new cables are expected to maintain 300 megawatts of transmission capability at 138 kilovolts. The Connecticut Department of Environmental Protection (CTDEP) and the Connecticut Siting Council (CSC) have required CL&P to monitor the effect of the Project on the seafloor and shellfish resources by conducting periodic investigations for 24 months after the completion of construction. The U.S. Army Corps of Engineers (USACE) also has a parallel requirement.

OSI conducted a benthic habitat mapping survey and shellfish assessment within the existing cable corridor between Manresa Island and south of Sheffield Island in November 2001 (Ocean Surveys, Inc. 2002) utilizing geophysical data previously collected during the Fall of 2000 (Ocean Surveys, Inc. 2001). In January 2007, this being in advance of any construction, OSI conducted a follow-up investigation and verified that seafloor conditions had not changed significantly since 2001 (Part I – Pre-Construction Survey Reports, Report 1 submitted in July 2008) (Ocean Surveys, Inc. 2007).

The LIRC monitoring plan was developed between December 2006 and September 2007 in consultation with the Bureau of Aquaculture (BOA) and was submitted to CTDEP and CSC for their approval. In September 2007, NU obtained final plan approval and required permits prior to initiation of fieldwork. OSI completed the pre-construction benthic habitat surveys from 27 September through 10 October 2007 (Part I – Pre-Construction Survey Reports, Report 2) (Ocean Surveys, Inc. 2008). Construction surveys were conducted from October 2007 through May 2008 during in-water cable removal and cable installation activities in Connecticut waters. These results were presented in Part II - Construction and Early Post-Construction Survey Reports submitted in November 2008. OSI completed the initial post-construction benthic habitat surveys from 24 July through 15 August 2008 where Task 8 (Remote Sensing Surveys) results were presented. The initial post-construction report was entitled "Post-Construction Seafloor Mapping Survey – A Component of the Benthic Monitoring Study of the Long Island Replacement Cable Project, Summer 2008" and was submitted in May 2009. Additional post-construction surveys have been and will continue to be conducted at 6-month intervals through June of 2010.

1.2 Project Tasks

A summary of the post-construction monitoring tasks and their purpose is provided below. The Task 8 results for the six-month post-construction survey conducted in January and February 2009 are the subject of this report. Tasks 1, 3 and 4 were conducted in association with Dr. Whitlatch and Task 2 was conducted in association with Dr. Bohlen and will be submitted under separate cover.

Task 1: Benthic Habitat Ground-Truthing (Dr. Whitlatch & OSI)

1a: Benthic Sediment Grab Sampling*:* to quantify benthic populations and provide ground-truthing data for benthic habitat mapping

1b: Quantitative Shellfish Quadrat Sampling*:* to assess potential changes in shellfish abundance and size distribution

1c: Underwater Video-camera Surveys: to verify habitat types and quantify shellfish populations

Task 2: Physical Oceanography and Sediment Processes (Dr. Bohlen & OSI)

2a: *In situ* Current and Suspended Sediment Monitoring: to monitor velocity and volume of suspended sediments

Task 3: Deployment & Monitoring of Calibrated Oyster Trays (Dr. Whitlatch & OSI)
to assess the impact of construction activities on shellfish growth and mortality

Task 8: Remote Sensing Surveys (OSI)

8a: Multibeam Hydrographic Survey: to map the existing bottom topography

8b: Side Scan Sonar Survey: to identify geomorphologic features on the seafloor

8c: Sediment Profile Imagery: to obtain detailed information on the physical, chemical, and biological parameters

**Tasks 4-7 were completed during the pre-construction, construction and initial post-construction periods.*

2.0 SURVEY AREAS AND CONTROL INFORMATION

2.1 Survey Areas, Tracklines, and Sample Locations

The remote sensing surveys (Task 8) were conducted in Connecticut waters, across the northern part of the cable corridor around Sheffield Island where the cable corridor crosses the shellfish beds, and in one area approximately 2 miles south of Sheffield Island in Long Island Sound, outside the shellfish beds (see Figure 1).

2.1.1 Remote Sensing Survey (Task 8)

The effect of the Project on seafloor morphology was monitored using data collected with three instruments: a multibeam depth sounder, a side-scan sonar, and a sediment profile imagery (SPI) camera. Monitoring data were collected in areas representative of the three marine environments associated with the cable corridor within Connecticut waters (Figure 1) as follows:

- Areas 1-North and 1-South represent shallow water zones within Sheffield Harbor.
- Area 2 is an exposed coastal zone south of Sheffield Island.
- Area 3 represents the deep-water zones of mid-Long Island Sound.
- Area 4 runs the entire length of the existing cable corridor across Sheffield Harbor following the path of the new center cable.

With the exception of Area 4, each area encompasses the entire width of the existing cable corridor, including the areas where the old cables were removed. Survey Area 3 is discontinuous because of the wide spacing between cables and was designed to focus on the cable areas. Individual survey corridors were centered over old Cables 1-4, and since the new cables were installed in the vicinity of old Cables 5, 6, and 7, a single survey area was designed to include old Cables 5, 6, and 7 as well as the path of the three new cables.

An additional monitoring area (Area 4) runs the entire length of the existing cable corridor across Sheffield Harbor following the path of one of the new cables (the center cable). The four other monitoring areas will show variations in the seafloor recovery from one cable to the next, while Area 4 will indicate whether the recovery is variable along a single cable.

Multibeam survey lines were established based on water depth to correspond with the multibeam system swath of approximately three times the depth. Side scan sonar imagery typically provided over 200% coverage of the bottom utilizing a 165-foot (50 meter) sweep range. Tracklines were designed to place existing cables near the center of the sonar sweeps to obtain the highest quality imagery. A description of the remote sensing tasks required and conducted in each study area is provided in Table 1.

Sediment profile imagery (SPI) was collected at fourteen locations in three of the five study areas (42 total), as summarized in Table 1. One image was collected in the immediate vicinity of each of the old cables (based on as-built locations), one halfway between each cable, and one at the eastern limit of the existing cable corridor. Each station lies along one of two transects spaced 75 feet apart; the northern line was used for images collected in the vicinity of each cable and the southern line was used for the images halfway between each cable.

Table 1. Remote Sensing Tasks Required in Each of the Study Areas

Area	Location	Water Depths	Multibeam	Side Scan	SPI Data
1-North	Sheffield Harbor, north of the federal navigation channel	8-13	Yes	Yes	Yes
1-South	Sheffield Harbor, south of the federal navigation channel	7-22	Yes	Yes	Yes
2	Long Island Sound, 0.4 miles south of Sheffield Island	40-43	Yes	Yes	Yes
3	Long Island Sound, 1.7 miles south of Sheffield Island	71-98	Yes	Yes	No
4	Oriented north-south along new Cable #2 in Sheffield Harbor	0-24	Yes	No	No

2.2 Horizontal Control

Horizontal positioning of all survey vessels supporting this project was accomplished by utilizing a Trimble survey grade Global Positioning System (GPS) that outputs geodetic coordinates referenced to the WGS-84 datum (World Geodetic System established in 1984), and equivalent to NAD 83 (North American Datum established in 1983). Differential corrections were received from either the U.S. Coast Guard reference station at Moriches, Long Island, New York or a shore-based reference station set on a known control point (for the multibeam survey). The computer navigation software utilized aboard the survey vessel converts the geodetic positions (latitude-longitude) to state plane coordinates (easting-northing) for navigation while logging these positions along survey tracklines. The survey was conducted in the Long Island Lambert coordinate system, New York State Plane (Zone 3104), referenced to NAD 83 with all coordinates in feet.

For the multibeam survey, the shore-based GPS reference station was installed at point “RTK Base” on NRG power plant property on Manresa Island in Norwalk. An initial verification of horizontal and vertical position data was performed on point “XYZ Check” nearby on plant property. Subsequent daily navigation checks were done to verify system accuracy at points established at the Norwalk Cove Marina by each survey vessel. These checks show that the positioning equipment was operating properly and delivering the positioning accuracy required for investigations. A listing of all control points utilized for these investigations with point coordinates and descriptions is provided below in Table 2.

2.3 Vertical Control

Vertical control for the multibeam data was established by referencing all depth data to the North American Vertical Datum of 1988 (NAVD 88) using real time kinematic (RTK) tide corrections based on the elevation of the shore-based GPS reference station, “RTK Base” (Table 2). In this manner, the real time elevations of the boat, GPS antenna, multibeam transducer, and subsequent depth points are measured continuously along each trackline.

The vertical accuracy of the RTK system was checked at least twice daily, using the "sheet pile" temporary benchmark, to verify proper elevation data were being recorded.

Table 2. Control Points Used for this Investigation

Control Point	Position *	NAVD88 Elevation	Description
"RTK Base"	N 331090.99 E 1147428.56	8.13 feet	Point is located on the east face of bulkhead in the canal adjacent to the power plant; point is the southwest corner of a steel I beam support piling positioned next to the first cleat from the north end of the bulkhead
"XYZ Check"	N 331076.31 E 1147426.18	9.22 feet	Corner of steel cleat plate located approximately 15 feet farther south along the bulkhead
"Norwalk Cover Marina Fuel Dock"	N 335416 E 1150001	N/A	4th cleat from the South at the fuel dock of Norwalk Cove Marina
"Sheet Pile"	N 336169.31 E 1150521.10	8.55 feet	Temporary benchmark installed on the western side of the North Bulk head at Norwalk Cove Marina near the floating docks.

* Coordinates referenced to NY State Plane, Long Island Lambert, Zone 3104, NAD 83 in feet

3.0 SUMMARY OF FIELD INVESTIGATIONS

Investigations were performed by multiple crews from different vessels, specifically configured for individual project tasks. The following provides a synopsis of crews, equipment, and a chronology of survey activities.

3.1 Survey Crews and Vessels

The following OSI personnel comprised the field teams assembled to perform the pre-construction investigations:

Benthic Monitoring Operations and Sediment Profile Imagery, ***R/V Ready II***

Stephen C. Bodak Jr.	Oceanographic Project Manager
Michael D. Lincoln	Oceanographic Scientist

Multibeam Hydrographic Survey, ***R/V Willing***

Robert M. Wallace	Hydrographic Project Manager
Kerry H. Cutler	Hydrographic Scientist

Side Scan Sonar Imagery Collection, ***R/V Able***

Emerson G. Hasbrouck	Geophysical Project Manager
George M. Slusher Jr.	Geophysical Scientist

Task 8 remote sensing surveys were completed using OSI's ***R/V Ready II, R/V Willing II* and *R/V Able.*** Each vessel was equipped with navigation and all the instrumentation to complete the targeted tasks. A two-person OSI field team consisting of a project manager and a project scientist staffed each vessel. The ***R/V Willing II*** completed Task 8A, the ***R/V Able*** completed Task 8b, and the ***R/V Ready II*** completed Task 8c.

3.2 Survey Equipment

The major equipment systems utilized for this investigation are listed below. The operational procedures employed to collect the data for this project are described in Appendix 1.

Table 3. Summary of Survey Equipment

Equipment System	Description
Applanix POS MV GPS with onsite Differential Base Station *Appendix 1-2*	Satellite positioning system which uses correctors from a shore-based reference station provide reliable, high level (6-10 cm accuracy) three-dimensional positioning. The system outputs position fixes at a rate of 5-10 per second to an onboard navigation and data logging computer. System includes inertial motion sensor (pitch, roll, heave) and compass for reliable heading measurements.
Trimble 7400 RTK GPS Receiver *Appendix 1-3*	Global positioning system receivers capable of tracking up to 9 satellites simultaneously; interfaced with a shore-based reference station (Model 7400) to achieve desired positioning accuracy; manufacturer stated 6-10 centimeters for RTK.
HYPACK navigation computer and software *Appendix 1-4*	Software runs on a desktop or notebook computer providing real time trackline control, digital data logging, and many survey utility functions; this package allows the efficient simultaneous acquisition of data from multiple systems.
KVH AutoComp 1000 Flux Gate Compass *Appendix 1-5*	Digital, automatically compensating fluxgate compass accurate to within 0.5 degree; provides precision magnetic heading measurements (side scan sonar ops).

Equipment System	Description
Reson SeaBat 8125 Digital Multibeam Echo Sounder *Appendix 1-5*	Sophisticated digital depth sounder producing full bottom coverage from 240 simultaneous soundings per swath within a 120 degree beam, up to 15 swaths per second; swath width equivalent to approximately two times the water depth.
Sea-Bird 19*plus* CTD profiler *Appendix 1-6*	The next generation vertical profiler which measures conductivity, temperature, and density 4 times per second in up to 600 meters of water. For this project, the CTD profiler is critical for obtaining sound velocity measurements through the water column for adjusting the depth values obtained by the multibeam system.
Klein 3000 Dual Frequency Side Scan Sonar System *Appendix 1-7*	Sonar system providing acoustic imagery of the bottom out to either side of the trackline; dual-frequency technology allows acquisition of high-resolution images (500 kHz) and extended sweep ranges (100 kHz).
Hulcher Sediment Profile Imagery Camera *Appendix 1-8*	Device used to obtain a cross-sectional photograph of the sediment-water interface down to maximum of 25 cm (~10 inches) below the bottom; provides detailed imagery and biological data on the benthos.

3.3 Chronology of Survey Tasks and Data Acquisition Summary

Using the survey plan and methods described above, the field crews completed the survey tasks as detailed in the following table. See Section 1.2 for task discussions.

Table 4. Summary of Field Operations in January-February 2009

Date	*R/V Ready II* Task	*R/V Able* Task	*R/V Willing* Task
14-Jan	Begin SPI Operations		
15-Jan	Complete SPI Operations		
22-Jan			SSS Compass Calibration, Site Recon
23-Jan			SSS Survey of Areas 1A & 2
25-Jan			SSS Survey of Area 1B
26-Jan			SSS Survey of Area 3
27-Jan			Complete SSS Survey of Area 3 Survey
9-Feb		Arrive in Norwalk, Confirm all Settings	
10-Feb		Patch Test, Inshore Survey	
11-Feb		Offshore and Inshore Survey	
12-Feb		Weather Day, Wind 20-40 kt	
3-Feb		Offshore Survey	
14-Feb		Complete Surveys	

4.0 DATA PROCESSING AND DELIVERABLES

Upon completion of Task 8, multibeam and side scan sonar data were brought back to the OSI office in Old Saybrook, CT for processing and review. SPI was forwarded to the Virginia Institute of Marine Science for analysis and interpretation by Dr. Robert Diaz. All images analyzed for this report are provided in the digital appendix. Processing techniques and the methods used for analysis of these data sets are included in Appendix 2.

Final drawings presenting the results of the Task 8 investigation are included in Appendices 3-7 (separated by survey area) and as digital files on CD-ROM in Appendix 8.

5.0 SURVEY RESULTS

The following discussion is based on the analysis/interpretation of Task 8 as presented in Appendices 3-8. All water depths discussed are referenced to the project datum (NAVD 88). Analysis of sediment profile camera imagery was conducted by Dr. Diaz and has been incorporated into the following discussions. This included a written summary of results, tables, and SPI photographs

5.1 Area 1-North

Area 1-North (Appendix 3) is representative of shallow water environments within Sheffield Harbor. This area is located immediately north of the federal navigation channel within Sheffield Harbor, to the southwest of Manresa Island. The area spans the entire width of the previously defined cable corridor on nautical chart # 12368 and approximately 850 feet along the length of the existing power cables (Figure 1). The majority of Area 1-North is located within the CT state regulated recreational shellfishing area.

5.1.1 Seafloor Geomorphology

The seafloor in Area 1-North is generally flat with water depths between 8 and 13 feet (Figure A3-1, Appendix 3). The side scan mosaic indicates two different bottom types within the area (Figure A3-4 Appendix 3), which correspond to benthic habitats identified during previous investigations (OSI Report # 01ES088). Dark gray represents areas of high acoustic reflectivity and indicate fine silty sand with shell debris. Light gray corresponds to low acoustic reflectivity and indicates silt with small patches of fine sand and scattered shell debris. Three distinct trenches are still present over the three new submarine cables and are associated with the cable embedment process (Figure A3-1, Appendix 3). Numerous linear and point features which were not present during the pre-construction monitoring, but were evident during the initial post-construction survey, are still evident throughout this area. These features are generally between 0.5 and 1.0 feet deep.

5.1.2 Seabed Change

The Seabed Change plan view drawing comparing the pre-construction survey to the current survey (Figure A3-2, Appendix 3) shows trenches associated with the three new cables which resulted from the cable embedment process. The trenches from new Cables 1, 2 & 3 are approximately 1 foot in depth and approximately 3-5 feet wide. Several linear drag marks (approximately 0.5 feet deep) are still present on the seafloor near the new cables. Drag marks associated with fishing activity were observed during the pre-construction survey (Ocean Surveys, Inc. 2008) but appeared less distinct during the initial post-construction survey (Ocean Surveys, Inc. 2009a).

The current survey shows an increase in circular drag marks near the center/western portion of the area indicating an increase in fishing activity. The Seabed Change plan view drawings show no noticeable change in bathymetry when comparing the initial post-construction survey to the six-month post-construction survey (Figure A3-3, Appendix 3).

5.1.3 Sediment Profile Imagery

Sediments in Area 1-North appear to be a mix of fine sand-silt-clay and fine sand-silt with shell mixed in (Figure A3-5, Appendix 3). The sediment compaction in this area is greater than Area 1-South but less than Area 2, with an average prism penetration of 6.1 cm (4.9 cm standard deviation). The average apparent color redox potential discontinuity (RPD) layer depth was 1.8 cm (0.5 standard deviation), which reflects a moderate level of biogenic activity. Shell at the sediment surface was the second most common biogenic feature. Shell beds are present at eight of the stations (4, 5, 6, and 10-14) in Area 1-North. Results of the sediment profile imagery for Area 1-North are summarized in a table in Appendix 3.

The six-month post-construction survey showed no differences in sediment type or sediment surface composition when compared to the pre-construction survey or initial post-construction survey. However, a decrease in biogenic activity was observed and was evident by a decrease in tube density. The pre-construction sediment profile photographs revealed tube density ranged from 10 per image to 100s per image while the six-month post-construction survey and the initial post-construction survey both had tube densities which ranged between 1 to less than 25 per image.

5.2 <u>Area 1-South</u>

Similar to Area 1-North, Area 1-South (Appendix 4) is representative of shallow water environments within Sheffield Harbor. This area is located immediately south of the federal navigation channel within Sheffield Harbor, and to the east of Shea Island. A small portion of the northwest corner of the survey area actually lies within the federal navigation channel. The area spans the entire width of the previously defined cable corridor on nautical chart #12368, and approximately 850 feet along the cable route (Figure 1).

5.2.1 Seafloor Geomorphology

Similar to Area 1-North, the seafloor is relatively flat lying with water depths between 7 and 22 feet (Figure A4-1, Appendix 4). A large rock (approximately 10 feet of relief), which appears to be part of Dog Island, is present in the southeastern corner of the area. The hydrographic data show a channel cut into the rock that was evidently made during the installation of the original cables. The side scan sonar mosaic shows irregular acoustic reflectivity across the eastern half of the survey area (Figure A4-4, Appendix 4). The high reflectivity (dark gray on the side scan mosaic) is related to shell-fishing activities and increased shell debris (as documented by the underwater video). In addition, three distinct trenches are still evident directly over the newly installed power cables. Numerous linear and point features which were not present during the pre-construction monitoring, but were evident during the initial post-construction survey, are still visible in the current survey. These features were generally between 0.5 and 1.0 feet deep

5.2.2 Seabed Change

The locations of the three new cables show trenches directly over the cables resulting from the cable embedment process. The trenches are generally 0.5 to 1.0 feet in depth, approximately 3 to 5 feet wide and span the length of the survey area. Four isolated spots along the trenches reached depths of 3 to 4 feet consistent with the previous survey in the summer of 2008. Further south along the trenches for Cables 2 & 3, toward Dog Island, the scars are less distinct reaching depths less than 0.5 feet. Along the western side of the trench scar associated with Cable 3 there is still an increase in seabed elevation of approximately 1 foot as compared to the pre-construction survey. Throughout the entire survey area there are depressions and small drag marks that are approximately 1 foot in depth. These depressions and drag marks could have been caused by construction or fishing activities (Figure A4-2, Appendix 6).

A comparison between the initial post-construction survey and the six-month post-construction survey show various small changes in seabed elevation. The biggest change between the two survey periods is the presence of what appears to be a debris pile located west of the new cables most likely from nearby oyster fishing operations. The pile is approximately 75 feet long and about 60 feet wide and approximately 0.5 feet high (Figure A4-3, Appendix 4). Several smaller seabed changes occurred along the trenches for new Cables 2 & 3 in four isolated locations. The changes are approximately 10 feet long and 2-3 feet wide and provide an elevation change that ranges between +/- 0.5 feet.

5.2.3 Sediment Profile Imagery

Sediments in Area 1-South are all fine sand-silt-clay (Figure A4-5, Appendix 4). This area contains the least compact sediments among the three areas investigated with the SPI camera, with an average prism penetration of 12.0 cm (3.2 cm standard deviation). The average RPD layer depth was 1.1 cm (0.2 standard deviation), which reflects a moderate level of biogenic activity. Results of the sediment profile imagery for Area 1-South are summarized in a table in Appendix 4.

The six-month post-construction survey showed no differences in sediment type or sediment surface composition when compared to the pre-construction survey or the initial post-construction survey. However, similar to Area 1-North, a decrease in biogenic activity was observed and was evident by a decrease in tube density. The pre-construction sediment profile photographs revealed tube density ranges from 10 per image to 100s per image while the initial post-construction survey and the six-month post-construction survey tube densities ranged between 1 to less than 25 per image.

5.3 <u>Area 2</u>

Area 2 (Appendix 5) is an open exposed coastal site subject to wave action. The survey area is located in Long Island Sound, 0.4 miles south of Sheffield Island. The area spans the entire width of the previously defined cable corridor on nautical chart # 12368 and approximately 750 feet along the length of the cable route (Figure 1).

5.3.1 Seafloor Geomorphology

The seafloor in this area is extremely flat with a slight north-to-south slope and water depths between 39 and 45 feet (Figure A5-1, Appendix 5). There are no large-scale topographic features although several small-scale depressions exist throughout the site. The side scan sonar mosaic along with the multibeam shows a generally featureless bottom except for a dense array of circular drag marks in the south-western corner of the survey area (Figure A5-1 & 4, Appendix 5) suggesting clam dredge operations. These circular drag marks, when compared against the pre-construction survey data, have extended an additional 750 feet northeast. A close comparison with the initial post-construction survey shows new circular drag marks on the current survey indicating more recent fishing operations. Three trenches are still evident directly over the new cables and extend the length of this survey area. A few irregular drag marks are still present in the center of Area 2 and may have been caused by either fishing or construction activities.

5.3.2 Seabed Change

The multibeam image still shows small features over each of the old cables. The depressions are most likely from the cable removal process and are less than 0.5 feet in depth. The three new cable locations still exhibit trenches directly over the cables resulting from the cable embedment process. The Seabed Change plan view drawing comparing the pre-construction survey to the six-month post-construction survey showed trenches that were 0.5 to 3 feet in depth, approximately 3 to 5 feet wide and for the most part were continuous throughout the survey area (Figure A5-2, Appendix 5). Two areas along the trenches showed small amounts of sediment accumulation. The northwest end of the new Cable 2 showed accumulations of sediment of upwards of 2 feet on either side of the cable, while the new Cable 1 had a small pile of sediment directly over the cable at about 1 foot above pre-construction conditions. As mentioned in the prior section, irregular drag marks approximately 200 feet in length are present in the center of Area 2. The Seabed Change plan view drawing comparing the initial post-construction survey to the six-month post-construction survey (Figure A5-3, Appendix 5) shows no significant change in bathymetry.

5.3.3 Sediment Profile Imagery

Sediments in Area 2 appear to be slightly coarse to fine sand-silt (Figure A5-5, Appendix 5). This area contains the most compact sediments among the three areas investigated with the SPI camera, with an average prism penetration of 5.8 cm (0.6 cm standard deviation). The average RPD layer depth was 1.6 cm (0.2 standard deviation), which reflects a moderate level of biogenic activity. Results of the sediment profile imagery for Area 2 are summarized in a table in Appendix 5.

The six-month post-construction survey revealed no differences in sediment type when compared to the initial post-construction survey and the pre-construction survey. Differences were seen in biogenic activity and surface composition. During the pre-construction survey two out of the fourteen stations had shell at the sediment surface, while the current survey had shell at the sediment surface at four stations. The pre-construction sediment profile photographs revealed tube density ranges from 10 per image to 100s per image. During the initial post-construction survey and the six-month initial post-construction survey, tube density ranged between 1 to less than 25 per image.

5.4 <u>Area 3</u>

Area 3 (Appendix 6) represents mid-Long Island Sound bottom conditions. The survey area is 1.7 miles South of Sheffield Island. Area 3 is comprised of 5 separate monitoring areas, four of which are located along the old Cables 1-4 (Areas 3A-3D) and the fifth spans approximately 2,500 feet across Cables 5-7 and the new Cables 1-3 (Area 3E). All five areas span approximately 3,000 feet along the length of the power cables (Figure 1). Sediment profile imagery was not collected in this monitoring area.

5.4.1 Seafloor Geomorphology

Water depths in Area 3 range from 71 to 98 feet (Figure A6-1, Appendix 6) and generally increase from west to east between Areas 3A and 3D, then shoal back up to the northeast corner of Area 3E. There appears to be several large-scale undulations in the seafloor oriented northwest to southeast. Three isolated topographic features (each ~7 feet high) were evident during the pre-construction, initial post-construction and current survey. Two features are evident in the hydrographic data (one in Area 3A and another in Area 3D) and appear to be asymmetrical mounds. A third feature, a large depression, is evident in Area 3E (~ 3.5 feet deep) but unlike the other two features, the depression has a highly irregular shape. With the exception of these three features (which were imaged by the side scan), the mosaic shows a generally featureless bottom. Coring data that were collected approximately 1,400 feet from Area 3, during a previous investigation on behalf of Keyspan Energy (OSI Report# 00ES088), suggest the seafloor is composed of silty sand. Changes in reflectivity, evident on the side scan mosaic (Figure A6-4 Appendix 6), in Area 3A and the northeast corner of Area 3E may indicate changes in grain size (darker gray corresponds to an increase in acoustic reflectivity which could be associated with increased grain sizes). Trenches are visible over the new power cables and extend across the survey area.

5.4.2 Seabed Change

The multibeam data still shows faint features over each of the old cables. These features are less than 0.5 feet in depth and are most likely associated with the cable removal process. Trenches created during the cable embedment process are still present over each of the new cables. The Seabed Change plan view drawing comparing the pre-construction survey and the current survey (Figure A6-2, Appendix 6) reveals trenches over new Cables 1 & 2 that are 0.5 to 1.5 feet in depth and approximately 2 to 4 feet wide throughout the survey area. The trench over new Cable 3 was more significant with trench depths upwards of 6 feet in the northern sections of Area 3E. The Cable 3 trench depth decreases gradually in the southern portion of Area 3E and ranges between less than 0.5 feet to 1 foot. There are several small areas of sediment accumulations of around 0.5 feet on either side of Cable 3.

A Seabed Change plan view drawing comparing the initial post-construction survey and the current survey (Figure A6-3, Appendix 6) revealed sedimentation in the trenches of Cables 2 and 3. The amount of accumulated sediment was approximately 0.5 feet for both of the trenches but was upwards of 1 foot near the deepest sections of the Cable 3 trench. A slight increase in trench depth (0.5 feet) was observed in the Cable 1 trench which is likely a result of natural compaction of the sediment over the cables.

5.5 Area 4

Area 4 (Appendix 7) is a 50-foot wide corridor, centered on the new Cable 2 (old Cable 6) from the shoreline of Manresa Island to the shoreline of Sheffield Island (approximately 8,200 feet long). Multibeam was the primary tool utilized to investigate this area, although side scan and the sediment profile imagery from Areas 1-North and 1-South overlap. Area 4 transitions through various environments and sediment types, including intertidal zones, fine silty sand with shell debris, and silt with small patches of fine sand and scattered shell debris.

5.5.1 Seafloor Geomorphology

Water depths across Area 4 range from 0 to 24 feet, with the deepest water located in the federal navigation channel. The survey of Area 4 was centered on the trench formed over the new Cable 2 during cable embedment operations.

5.5.2 Seabed Change

The Seabed Change plan view drawing comparing the initial post-construction survey to the current survey shows a 50-ft corridor following new Cable 2 from Manresa Island to the shoreline of Sheffield Island (Figure A7-2, Appendix 7). The trench associated with Cable 2 is approximately 3-5 feet wide and depths vary throughout the survey area between less than

0.5 feet deep to isolated spots up to 3.0 feet deep. On Panel C of Figure A7-2 a depression still appears to the east of the cable trench and just south of the federal channel. The depression is approximately 1 to 2 feet deep and extends 75 feet along the trench. The depression extends to the edge of the survey area (~ 25 feet wide) and may extend beyond. This appears to be from the embedment process and may indicate the transition zone where the cable was armored to cross the federal channel. In Panel D, approximately two-thirds of the way down the route from Sheffield Island, the trench is less distinguishable. Adjacent to this area was a small object or debris pile about 20 feet long by 5 feet wide, which projects off the bottom about 2 feet. The Seabed Change plan view drawing shows no significant change in bathymetry comparing the initial post-construction survey to the six-month post-construction survey (Figure A7-3, Appendix 7).

6.0 CONCLUSIONS

The multi-task investigation conducted by Ocean Surveys, Inc. provides six-month post-construction survey data for monitoring the effects of the cable replacement project. This investigation is part of an on-going study to monitor the recovery/re-colonization of the benthos and the Project's effect on seafloor morphology. This report focuses on patterns and features in seafloor geomorphology observed in the multibeam hydrography, side scan sonar, and SPI imagery. While some biological data can also be derived from the SPI survey, the primary purpose of the SPI survey was to document sedimentation layers distributed by the embedment process. Additional biological survey data collected during this field effort under Tasks 1-3 will be delivered and discussed under separate cover.

6.1 Seafloor Geomorphology

Multibeam and side scan sonar data revealed the seafloor morphology in each site, which could be characterized as typical for each marine environment. Circular drag marks were evident in Areas 1-North, 1-South, and 2, which are the result of shellfishing activity in the area. When comparing the data collected during the pre-construction survey to the six-month post-construction survey many of the differences seen were also observed in the initial post-construction survey. The main difference between the two surveys is the presence of the new cable trenches. The trenches for the new cables are evident in the side scan images but an actual change in seabed elevation between the pre-construction and six-month post-construction surveys can be best quantified in the Seabed Change maps. The seabed elevation change was typically less than 2 feet, depending on the area and trench as anticipated in the Project application. Eight isolated exceptions within Sheffield Harbor (Areas 1N, 1S, and 4) and two outside the Harbor in Area 2 were greater than 2 feet, and one depression in Area 3 reached depths of six feet (Appendix 3-7). At all the areas surveyed there appears to be no evidence of the cable removal process on the side scan sonar data but the multibeam data revealed a slight depth change in the vicinity of the old cables in Areas 2 and 3 (<0.5 feet).

When comparing the initial post-construction survey with the six-month post-construction survey, the biggest difference is an apparent debris pile located in Area 1 south (Figures A4-1 to 4, Appendix 4). In addition, in Area 3, specifically Area 3E (Figure A6-3, Appendix 6), the trenches over Cables 2 & 3 appear to have filled in by approximately 0.5 feet.

The data again suggested continued fishing activity in Areas 1-North and Area 2 with fresh drag marks visible in both the side scan and multibeam data. Area 1-South still shows signs of fishing activity, but significant new drags marks have not been observed since the initial post-construction survey in the Summer of 2008.

The data from the multibeam survey of Area 4, which extends the entire length of Sheffield Harbor, allowed for a statistical comparison of the trench depths of the center cable. The data from the pre-construction (Fall 2007), initial post-construction (Summer 2008) and 6-month post construction (Winter 2009) surveys were compared to calculate the cumulative linear distance of trench depths (Table 5). Data were broken down to trench depth between 0.0-0.5 ft, 0.6-1.0 ft, 1.1-2.0 ft, 2.1-3.0 ft, and greater than 3.0 ft. This table reveals a slight reduction in trench depths over the last six months, indicating that the trenches are filling in naturally.

Table 5. Cable #2 Trench Depths within Sheffield Harbor

Survey	Depth of Trench (ft)				
	0.0-0.5	**0.6-1.0**	**1.1-2.0**	**2.1-3.0**	**>3.0**
Summer 2008	3620	2680	1704	88	28
Winter 2009	4226	2374	1460	48	12
	Cumulative Linear Distance (ft)				

6.2 Sediment Profile Imagery

The sediment profile camera imagery indicates finer-grained sediments and less compaction present within Sheffield Harbor relative to the sites located south of Sheffield Harbor. Biogenic activity of epifauna and infauna was a predominant factor in structuring the surficial sediments in the areas investigated with the SPI camera. The RPD measurement indicates a moderate level of biogenic activity.

Small tubes were the most common surface biogenic feature that occurred in the images. Densities of small tubes ranged from about 1 per image to less than 25 per image. Shell at the sediment surface was the second most common biogenic feature. Possible shell beds were observed at eight stations (4, 5, 6, 10, 11, 12, 13, and 14) in Area 1N and at Station 28 in Area 1S. Miscellaneous shell debris was seen at another six stations.

SPI data collected from the pre-construction to the six-month post-construction surveys indicate the sediment type did not change for all 42 stations and there were no noticeable layers of newly distributed sediment. The most significant difference involved the most common biogenic feature, small tubes. During the pre-construction survey the tube density ranged between 10 per image to 100s per image yet in the initial post-construction survey and the current survey, tube density ranged from about 1 per image to less than 25 per image. In addition, the area with the most biogenic activity changed. During both the pre-construction and initial post-construction surveys Area 1 South had the most biogenic activity. This changed during the current survey; where Area 2 had the highest biogenic activity as seen in the mean values of infauna, burrows, and oxic voids listed in Table 5.

Table 6. Statistical Summary of Sediment Profile Imagery

		Infauna		**Burrows**		**Oxic Voids**		**Anaerobic Voids**	
Area	*N*[1]	*Mean*[2]	*Std Dev*	*Mean*[2]	*Std Dev*	*Mean*[2]	*Std Dev*	*Mean*[2]	*Std Dev*
1-N	14	0.02	0.09	0.05	0.12	0.26	0.51	0.36	0.68
1-S	14	0.07	0.19	0.17	0.22	0.36	0.46	0.81	0.66
2	14	0.19	0.28	0.71	0.41	0.52	0.50	0.05	0.12

[1] N is the number of stations per area (three images were collected at each station)
[2] Mean number of biogenic features observed per station.

The continued surveys of the benthic habitats and associated organisms will provide a better understanding of the variability of the organism's lifecycles in these environments. The only minor biological change detected from the geophysical surveys was that of tube densities, which might prove to be seasonal or sporadic in nature as further surveys develop a more detailed time history.

7.0 REFERENCES

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APPENDIX 1

SURVEY INSTRUMENTATION & DATA PROCESSING

- Applanix POS MV GPS Interfaced with an Onsite Differential Base Station *(Task 8a)*
- Trimble 7400 GPS Interfaced with an Onsite Differential Base Station *(Task 8b & 8c)*
- HYPACK® Navigation Software
- KVH AutoComp 1000 Flux Gate Compass
- Reson SeaBat 8125 Digital Multibeam Echo Sounder
- Sea-Bird Model SBE19 SeaCat CTD profiler
- Klein 3000 Dual Frequency Side Scan Sonar System
- Hulcher Digital Sediment Profile Camera

Applanix POS MV Global Positioning System Interfaced with an Onsite Differential Base Station

The Applanix POS (**P**osition and **O**rientation **S**ystem) MV provides reliable, high-speed and high-precision positioning that utilizes the latest developments in aided inertial technology. The system components include a POS computer system (PCS), inertial measurement unit (IMU), primary and secondary GPS antennae, and all power, antenna, and interconnecting data cables. The system not only provides the highest precision DGPS positioning, but also includes motion and compass measurements normally separate from other manufactured GPS systems. The POS MV delivers a full six degree-of-freedom position and orientation solution to provide the following parameters: position (latitude, longitude, elevation), velocity (north, east, vertical), attitude (roll, pitch, true heading), heave (real-time, delayed), acceleration vectors, and angular rate vectors. The POS MV was engineered specifically for areas of problematic GPS/DGPS reception and demanding motion compensation applications, using inertial measurements during GPS dropouts or degraded differential correctors to maintain accurate navigation solutions.

In the local differential configuration, the POS MV unit is mounted on the survey vessel and continuously receives differential satellite correction factors via radio link from a second GPS receiver (such as Trimble 4000) setup as a reference station on a known horizontal control point onshore. The POS MV accepts the correction factors via radio link (Pacific Crest modems) and applies the differential corrections to obtain continuous, high accuracy, real time position updates. Centimeter level positioning is computed five times per second ensuring the response and accuracy necessary for precise dynamic applications on moving equipment. The Trimble system is interfaced to the OSI navigation system running HYPACK software for trackline control.

Trimble 7400 GPS Interfaced with an Onsite Differential Base Station

The Trimble 7400 satellite positioning system provides reliable, high-precision positioning and navigation for a wide variety of operations and environments. The system consists of a ship-based 7400 receiver, a GPS volute antenna and cable, RS232 output data cables, radio link with antenna, and a secondary shore-based reference station. The shore-based reference station consists of a 7400 receiver, a volute antenna and cable, and RS232 interface to the radio link with antenna. In this system configuration position accuracy of better than +/- 1 meter is typical.

Fully automated, the Trimble 7400 provides means for 9-channel simultaneous satellite tracking with real-time display of geodetic position, time, date, and boat track if desired. The Trimble unit is mounted on the survey vessel and continuously receives differential satellite correction factors via radio link from the reference station set on a known horizontal control point onshore. The Trimble 7400 accepts the correction factors via radio link and applies the differential corrections to obtain continuous, high accuracy, real time position updates. The Trimble 7400 system is interfaced to the OSI navigation system running HYPACK software for trackline control.

HYPACK Navigation Software

Survey vessel trackline control and position fixes were obtained by utilizing a PC-based navigation system utilizing HYPACK software interfaced with the GPS positioning system. The navigation system consists of a Pentium notebook computer with a customized version of HYPACK software and a color, external VGA monitor for the helmsman. Geodetic coordinate information from the DGPS positioning system was updated regularly and input to the navigation computer which processes the geodetic position data into State Plane Coordinates used to guide the survey vessel accurately along pre-selected tracklines. The incoming data are logged on disk and processed in real time allowing the vessel position to be displayed on a video monitor and compared to each pre-plotted trackline as the survey progresses. Digitized shoreline and the locations of existing structures, buoys, and control points can also be displayed on the monitor in relation to the vessel position. The navigation system using HYPACK software thus provides an accurate visual representation of survey vessel location in real time, combined with highly efficient data logging capability and post-survey data processing and plotting routines.

KVH AutoComp 1000 Flux Gate Compass

The KVH AutoComp 1000 fluxgate compass was used to measure magnetic compass headings along survey tracklines. The AutoComp 1000 incorporates next generation electronic fluxgate technology to provide 0.5-degree accuracy and an automatic compensation system that automatically corrects for compass deviation on the vessel, without a compass adjuster. The system automatically calibrates itself after installation by steering the survey vessel in a circle so the microprocessor-controlled unit can measure, process, and compensate for the magnetic field. The unit corrects for B, C, D, and E coefficient errors, while standard NMEA 0183 output provides easy interfacing with other equipment. The digital data are logged on the HYPACK navigation computer.

Reson SeaBat 8125 Digital Multibeam Echo Sounder

Precision swath water depth measurements are obtained by using a Reson SeaBat 8125 digital multibeam echosounder capable of recording high-resolution water depths up to 150 meters. The 455 kilohertz frequency system utilizes 240 dynamically focused receive beams to measure a 120° swath across the seafloor, detect the bottom, and deliver measured ranges at a depth resolution of approximately 6 millimeters. The system employs signal beam widths of 0.5° and 1° in the across track and along track directions, respectively. Operated as the sole survey instrument on a vessel, the system can collect data at speeds upwards of 10 knots while still maintaining 100% coverage of the bottom. Digital data can be output through any of its RS-232 serial ports and displayed on a high-resolution color VGA monitor. The SeaBat 8125 incorporates tide and draft corrections plus a calibration capability for local water mass sound speed. A Sea-Bird CTD profiler mounted at the head provides real-time surficial water quality measurements and velocity profiles obtained from casts, which are input to correct for speed of sound variations in the water column.

Due to the deeper water present in many survey areas, sound velocity measurements are collected using a Sea-Bird CTD (conductivity, density, temperature) profiler. An average sound velocity for the entire water column can be calculated from the CTD measurements for input to the single or multibeam depth sounders in use on the project. More precise post-survey velocity adjustments may be performed if CTD data reveal unique site conditions affecting the depth data, such as freshwater influx or seasonal stratification of the water column.

Sea-Bird Model SBE19 SeaCat CTD Profiler

Salinity, temperature, and depth data were collected using a Sea-Bird Electronics, Inc. Model SBE19 SeaCat CTD Profiler. The SeaCat Profiler is a self-powered, self-contained micro processing unit capable of collecting temperature, conductivity (salinity), and depth measurements at a rate of four scans per second. The manufacturer states an 0.005 accuracy and the unit has 8 megabytes of internal memory. The SBE19 has a fast sampling and pump controlled TC-ducted flow configuration, significantly reducing salinity spiking caused by ship heave. Data are internally processed, corrected, and recorded in solid-state memory and can later be downloaded via RS-232 direct serial connection cable to a computer where the operator can view the data and archive it for final processing.

Operationally, the SeaCat Profiler was lowered over the side of the survey vessel into the water where it was allowed for 30 seconds to come to equilibrium at the surface. To perform a cast the instrument was lowered down through the water column at a drop rate of approximately 2 feet per second until the instrument reached the bottom. Once on the bottom the profiler was held there for another 15-30 second period then raised to the surface at the same rate.

Klein 3000 Dual Frequency Side Scan Sonar System

Side scan sonar images of the bottom were collected using a Klein 3000 dual-frequency, high-resolution sonar system operating at frequencies of 100 and 500 kilohertz. The system consists of a topside computer, VGA monitor, keyboard, mouse, an EPC1086 dual-channel thermal graphic recorder, tow cable, and sonar towfish. All system components are interfaced via a local network hub and cable connections. The system contains an integrated navigational plotter, which accepts standard NMEA 0183 input from a GPS system. This allows vessel position to be displayed on the monitor and speed information to be used for controlling sonar ping rate. Sonar sweep can also be plotted in the navigation window for monitoring bottom coverage in the survey area.

The hardware listed above is interfaced to the Klein SonarPro data acquisition and playback software package, which runs on the topside computer. All sonar images are stored digitally and can be enhanced real-time or post-survey by numerous mathematical filters available in the program software. Imagery is displayed in a waterfall window in either normal or ground range (water column removed) formats. Other software functions that are available during data acquisition include; changing range scale and delay, display color, automatic or manual TVG (time variable gain), speed over bottom, multiple enlargement zoom, target length, height, and area measurements, logging and saving of target images, and annotation frequency and content. The power of this system is its real-time processing capability for determining precise dimensions of targets and areas on the bottom.

As with many other marine geophysical instruments, the side scan sonar derives its information from reflected acoustic energy. A set of transducers mounted in a compact towfish generates the short duration acoustic pulses required for extremely high resolution. The pulses are emitted in a thin, fan-shaped pattern that spreads downward to either side of the fish in a plane perpendicular to its path. As the fish progresses along the trackline this acoustic beam sequentially scans the bottom from a point directly beneath the fish outward to each side of the survey trackline.

Acoustic energy reflected from any bottom discontinuities is received by the set of transducers in the towfish, amplified and transmitted to the survey vessel via the tow cable where it is further amplified, processed, and converted to a graphic record by the side scan recorder. The sequence of reflections from the series of pulses is displayed on a video monitor and/or dual-channel graphic recorder on which paper is incrementally advanced prior to printing each acoustic pulse. The resulting output is essentially analogous to a high angle oblique "photograph" providing detailed representation of bottom features and characteristics. This system allows display of positive relief (features extending above the bottom) and negative relief (such as depressions) in either light or dark opposing contrast modes on the video monitor. Examination of the images thus allows a determination of significant features and objects present on the bottom within the survey area.

Hulcher Digital Sediment Profile Camera

The sediment profile camera system consisted of a digital camera enclosed in a pressure-resistant housing, a 45º prism, and a mirror that reflects an image of the sediment through the camera lens. A strobe was mounted inside the prism and was used to illuminate the sediment. The camera/prism system was mounted in a cradle secured to a larger frame ensuring that the prism penetrated the sediment at a 90° angle. An electric winch was used to gently lower the entire assembly to the seafloor. When the system was on the seafloor, a hydraulic piston controlled the penetration rate of the camera/prism assembly into the sediment. More detail on sediment profile camera operation can be found in Rhoads and Cande (1971).

At each station, a digital Hulcher sediment profile camera was deployed three times. The digital profile camera captured a 5.2-megapixel image using a Minolta Dimage-7i camera. The camera was set to ISO 200, white balance to flash color temperature, contrast to normal, saturation to normal, maximum image size of 2560 X 1920 pixels, and saved using super-fine jpg compression. Images were stored in the camera on a 1-gigabyte IBM microdrive. The video output of the Dimage-7i was also used to monitor prism penetration during sampling. The video feeds from the surface and profile cameras were sent to the surface vessel to allow monitoring of the Hulcher camera operation and image capture in real-time. Between replicates, the frame was raised to the surface and the Plexiglas window of the prism was cleaned. Station and time of each camera penetration were recorded by hand in a field log. The location of each replicate was marked as an event by OSI personnel using Differential Global Positioning System (DGPS) interfaced to a laptop computer running HYPACK hydrographic survey software.

The camera was triggered from the surface on contact with the sediment with a series of images taken at about an interval of 1.5-sec until the prism stopped penetrating the sediment. No penetration stops were used and the prism was allowed to penetrate until stopped by the sediment.

APPENDIX 2

DATA PROCESSING AND ANALYSIS METHODS

- Navigation and Hydrographic Data
- Side Scan Sonar Imagery
- Sediment Profile Images

Navigation and Hydrographic Data

Upon completion of the fieldwork, the digital files of vessel position and hydrographic data were processed to apply field calibrations and datum adjustment. The raw multibeam data were processed employing the HYPACK software. Using a Multibeam editor, unprocessed field data files consisting of multibeam range and beam information, water level, vessel position, and attitude information, are processed to eliminate erroneous data using automated and manual editing tools. After the multibeam data are processed, and referenced to the project datum, the corrected sounding data points are used to create a Triangulated Irregular Network (TIN). The TIN data are then contoured and presented in plan view.

Side Scan Sonar Imagery

The sonar images were used to develop a mosaic of the seafloor to show the variations in bottom reflectivity related to surficial sediments and any large objects that might be present. Files collected with the Klein 3000 SonarPro software package were processed and placed into a mosaic using Triton Isis Delph Map software. A geospatially corrected TIFF file is exported out of Delph Map and brought into AutoCAD for presentation. The individual track images can then be overlaid to provide the best possible acoustic overview.

During interpretation of the side scan sonar records, areas on the seafloor exhibiting different acoustical properties were identified. The variation in acoustical characteristics on the bottom represents changes in surficial lithology and/or the presence of benthic communities and foreign material.

Sediment Profile Camera Images

All sediment profile images were evaluated visually with data of all features recorded in a pre-formatted spreadsheet file. Images selected for analysis were digitally processed to enhance contrast and color using a Red-Green-Blue (RGB) color space. Each image was histogram equalized and trimmed from 0.2 to 2.0% using the image program Adobe PhotoShop®. Steps in the computer analysis of each image were standardized and data sequentially saved to a spreadsheet file for later analysis. Details of how these data were obtained can be found in Diaz and Schaffner (1988) and Rhoads and Germano (1986). A description of each parameter measured and evaluated follows.

Prism Penetration - This parameter provided a geotechnical estimate of sediment compaction with the profile camera prism acting as a dead weight penetrometer. The further the prism entered into the sediment, the softer the sediments, and likely the higher the water content. Penetration was measured as the distance the sediment moved up the 23-cm length of the faceplate.

Surface Relief - Surface relief or boundary roughness was measured as the difference between the maximum and minimum distance the prism penetrated. This parameter also estimated small-scale bed roughness, on the order of the prism faceplate width (16.5 cm), which is an important parameter for predicting sediment transport and in determining processes that dominate surface sediments.

Apparent Color Redox Potential Discontinuity (RPD) Layer - This parameter is an important estimator of benthic habitat conditions, which relates directly to the quality of the habitat (Rhoads and Germano 1986, Diaz and Schaffner 1988, Nilsson and Rosenberg 2000). RPD provides an estimate of the depth to which sediments appear to be oxidized. The term "apparent" is used in describing this parameter because no actual measurement was made of the redox potential. It is assumed that given the complexities of iron and sulfate reduction-oxidation chemistry the reddish-brown sediment color tones (Diaz and Schaffner 1988) indicate sediments are in an oxidative geochemical state, or at least are not intensely reducing. This is in accordance with the classical concept of RPD layer depth, which associates it with sediment color (Fenchel 1969). The apparent color RPD has been very useful in assessing the quality of a habitat for epifaunal and infaunal organisms from both physical and biological points of view. The depth of the RPD layer from sediment profile images was found to be directly correlated to the quality of the benthic habitat (Rhoads and Germano 1986, Nilsson and Rosenberg 2000).

Sediment Grain Size - Grain size is an important parameter for determining the nature of the physical forces acting on a habitat and is a major factor in determining benthic community composition (Rhoads 1974). The sediment type descriptors used for image analysis follow the Wentworth classification as described in Folk (1974) and represent the major modal class for each image. The following is provided as a means of comparing Phi scale sizes corresponding to sediment descriptors derived from SPI images, even though fine-sand-silt-clay and fine sand/silt were the only sediment type identified in this study:

Phi Scale	Upper Limit Size (mm)	Grains Per cm of Image	SPI Descriptor	Sediment Size Class & Subclass
-6 to –8	256.0	<<1	CB	Cobble
-2 to –6	64.0	<1	PB	Pebble
-1 to –2	4.0	2.5	GR	Gravel
1 to –1	2.0	5	CS	Coarse Sand
2 to 1	0.5	20	MS	Medium Sand
4 to 2	0.25	40	FS	Fine Sand
4 to 3	0.12	80	VFS	Very Fine Sand
5 to 4	0.06	160	FSSI	Fine Sandy Silt
5.5 to 4.5	0.06	160	FSSICL	Fine Sandy Silt/Clay
6 to 5	0.0039	>320	SIFS	Silty Fine Sand
8 to 6	<0.0039	>320	SICL	Silty Clay
>8 to 7	<0.0039	>320	CLSI	Clay/Silt
>8	<0.0005	>2560	CL	Clay

Subsurface Features - Subsurface features included a wide variety of features (such as infaunal organisms, burrows, water filled voids, gas voids, or sediment layering) that reveal a great deal about physical and biological processes influencing the bottom. For example, habitats with grain-size layers or homogeneous color layers are generally dominated by physical processes while habitats with burrows, infaunal feeding voids, and/or visible infaunal organisms are generally dominated by biological processes (Rhoads and Germano 1986, Diaz and Schaffner 1988, Nilsson and Rosenberg 2000). Subsurface features were visually evaluated from each image and compiled by type and frequency of occurrence.

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APPENDIX 3

AREA 1-NORTH

- Figure A3-1: Multibeam Image – Winter 2009
- Figure A3-2: Seabed Change – Winter 2009 versus Fall 2007
- Figure A3-3: Seabed Change – Winter 2009 versus Summer 2008
- Figure A3-4: Side Scan Sonar Image – Winter 2009
- Figure A3-5: SPI Camera Locations – Winter 2009
- Summary of SPI Results Area 1-North – Winter 2009

APPENDIX 4

AREA 1-SOUTH

APPENDIX 5

AREA 2

- Figure A5-1: Multibeam Image – Winter 2009
- Figure A5-2: Seabed Change – Winter 2009 versus Fall 2007
- Figure A5-3: Seabed Change – Winter 2009 versus Summer 2008
- Figure A5-4: Side Scan Sonar Image – Winter 2009
- Figure A5-5: SPI Camera Locations – Winter 2009
- Summary of SPI Results Area 2 – Winter 2009

APPENDIX 6

AREA 3

- Figure A6-1: Multibeam Image – Winter 2009
- Figure A6-2: Seabed Change – Winter 2009 versus Fall 2007
- Figure A6-3: Seabed Change – Winter 2009 versus Summer 2008
- Figure A6-4: Side Scan Sonar Image – Winter 2009

APPENDIX 7

AREA 4

- Figure A7-1: Multibeam Image – Winter 2009
- Figure A7-2: Seabed Change – Winter 2009 versus Fall 2007
- Figure A7-3: Seabed Change – Winter 2009 versus Summer 2008

APPENDIX 8

DATA CD