Survey Report for
US Wind, Inc.

Title:
Marine Geophysical & Geotechnical Survey Report

Project:
Maryland Wind Energy Area

Survey Date:
June–July 2015

Project Number:
1751

Document Number:
1751-2

Report Status:
Rev. 1 / Final

EXECUTIVE SUMMARY

Alpine Ocean Seismic Survey, Inc. (Alpine) carried out a marine survey investigation on behalf of US Wind, Inc. (US Wind) to undertake high-resolution geophysical (HRG), geotechnical and environmental surveys on the Outer Continental Shelf (OCS), in the Maryland Wind Energy Area (WEA). The surveys were conducted to support development of renewable wind energy by providing necessary data for wind turbine construction and permitting and regulatory purposes.

The marine surveys covered a 251km^2 area between 20km and 30km offshore Ocean City, MD, located in Outer Continental Shelf Lease numbers OCS-A 0489 and OCS-A 0490. The 251km^2 survey location was within the two lease blocks, OCS-A 0489 and OCS-A 0490, and designated for construction and installation of wind turbine generators.

Survey operations were conducted in accordance with a Survey Plan developed to satisfy Bureau of Ocean Energy Management's (BOEM) "Guidelines for Providing Geological and Geophysical, Hazards, and Archaeological Information Pursuant to 30 CFR Part 585", dated 09-Nov-2012.

Geophysical data acquisition was carried out on board the RV *Shearwater*, which sailed to Ocean City, Maryland on 01-Jun-2015 with operations continuing until completed on 25-Jul-2015.

Bathymetric and geophysical data were collected by Alpine using a multibeam echosounder (MET tower area only), side-scan sonar, shallow penetration sub-bottom profiler and a marine magnetometer. A geotechnical borehole was advanced at the MET tower site and six other pre-determined locations. The geotechnical work also included combined drilling and CPT pushing with the acquisition of samples for physical description and laboratory testing. Grab samples and underwater video/photography were also performed in the MET tower area and in a baseline area approximately 1km north of the site. These combined data sets provided seafloor and sub-surface characterization needed to determine site suitability for wind turbine design and installation.

Alpine limited the bathymetry data collection to the MET tower area only (bathymetry outside the MET area was collected by during the 2013 survey). The collected bathymetry showed the seafloor to be characterized by limited relief, with water depths ranging between 26.3m to 27.1m.

Surface sediments in the survey area were categorized using two classifications. The first sediment classification was defined as moderately reflective sediments and interpreted to be composed of medium to coarse grained sand, with trace amounts of gravel. The second classification was characterized by variable reflectivity and was interpreted to be composed of two sediment types, alternating between fine-grained sand and medium to coarse-grained sand mixed with gravel. Small sand ripples are present throughout the survey area ranging in wavelength from 50cm to 160cm and ranging in wave height from 5cm to 17cm.

Sub-surface sediments are dominated by sands, with occasional interlayers of clay and gravel. A shallow reflector was observed throughout the survey area, occurring 0.5m to 7.3m below the seafloor and is interpreted to represent an erosional surface (ravinement surface) remnant from the last sea level transgression. This surface is interpreted as the boundary between late Pleistocene and early Holocene sediments.

Geotechnical data were compared to shallow penetration sub-bottom data collected during the current survey, and also with medium penetration sub-bottom data collected during the 2013 MEA survey. The geophysical and geotechnical data sets correlate well and three main sub-surface units were identified. Unit 1 represents recent Holocene sandy sediments ranging in thickness between 0m and 7.3m across the survey area. Unit 2 represents a channel complex directly underlying Unit 1. Unit 3 represents a thick sequence of sub-parallel layered sediments dominated by silt and clay. Geotechnical data and sample analyses for the other six boreholes across the survey area are not integrated into the scope of this geophysical report.

The data sets were reviewed for the presence of any natural or man-made hazards which could impact development of the site. A few significant hazards were identified within the survey boundary. The hazards included four known shipwrecks and two potential shipwrecks, some small areas of debris and buried paleo-channels. A total of 1,468 sonar contacts were observed and a total of 2,717 magnetic anomalies were detected. Only 52 of the magnetic anomalies could be associated with sonar targets. The large amplitude anomalies were mostly associated to known shipwrecks or unassociated anomalies that were considered to be possibly related to buried geology. The observed targets are not expected to impact construction of the wind turbine generators. The survey area is within a military training area so the possibility of shallow buried ordnance should be considered.

DOCUMENT SUMMARY

Compilation		
Interpretation	Surveying	M Kwasek
	Geophysics	J Bailey
Verification	Checked	M L Kosakowski
	Approved	R Mecarini

Reference

Project Number	Doc. Type	Doc. Date	Revision
1751	Survey Report	2015.12.23	Rev. 0 / Draft
1751	Survey Report	2016.03.01	Rev. 1 / Final

Distribution

US Wind, Inc.	PDF Copy
World Trade Center	FAO: Bill Follett
401 East Pratt Street	
Baltimore, MD	
21202	

SERVICE WARRANTY

USE OF THIS REPORT

This report has been prepared with due care and diligence and with the skill reasonably expected of a reputable contractor experienced in the types of work carried out under the contract and as such the findings in this report are based on an interpretation of data which is a matter of opinion on which professionals may differ and unless clearly stated is not a recommendation of any course of action.

Alpine has prepared this report for the client(s) identified on the front cover in fulfilment of its contractual obligations under the contract and the only liabilities Alpine accept are those contained therein.

Please be aware that further distribution of this report, in whole or part, or the use of the data for a purpose not expressly stated within the contractual work scope is at the client's sole risk and Alpine recommends that this disclaimer be included in any such distribution.

ALPINE OCEAN SEISMIC SURVEY, INC.
155 Hudson Avenue, Norwood, NJ 07648 USA
Telephone 1 201 768 8000 Fax 1 201 768 5750
www.alpineocean.com

TABLE OF CONTENTS

LIST OF DRAWINGS

NORTH-UP CHARTS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY OF ABBREVIATIONS

Abbreviation	Meaning	Typical Use in Documents
APE	Area of Potential Effect	
BH	Borehole	
BOEM	Bureau of Ocean Energy Management	
CHIRP	Compressed High Intensity Radar Pulse	
COP	Construction and Operations Plan	
CORS	Continuously Operating Reference Station	
CP&E	Coastal Planning & Engineering, Inc., a CB&I Company, 2014	
CPT	Cone Penetrometer Test	
DGPS	Differential Global Positioning System	
DPR	Daily Progress Report	
DTM	Digital Terrain Model	
GAMS	GPS Azimuth Measurement System	
GNSS	Global Navigation Satellite System	
HRG	High Resolution Geophysical	
Hz	Hertz	
IMU	Inertial Measurement Unit	
l	Wavelength	<5m l, l >5m
MAG	Magnetometer	
MBES	Multi-Beam Echo Sounder	
MEA	Maryland Energy Administration	
MET	Meteorological Tower	
MLLW	Mean Lower Low Water	
MV	Motor Vessel	
MW	Megawatt	
nT	Nano-Tesla	
NU	North Up	
NAD83	North American Datum of 1983	
OCS	Outer Continental Shelf	
PDOP	Position Dilution of Precision	
PPK	Post Processing Kinematic	
PPS	Pulse Per Second	
RTK	Real Time Kinematic	
QA/QC	Quality Assurance/Quality Control	
RV	Research Vessel	
SAP	Site Assessment Plan	
SBES	Single Beam Echo Sounder	
SBP	Sub-bottom Profiler	
SOW	Scope of Work	
SSS	Side-Scan Sonar	
SVP	Sound Velocity Profile	
USBL	Ultra-short Baseline	
USCG	United States Coast Guard	
USGS	United States Geological Survey	
UTM	Universal Transverse Mercator	
UXO	Unexploded Ordnance	
WD	Water Depth	WD 23m
WK	Wreck	WK Wreck name
WGS84	World Geodetic System 1984	
WEA	Wind Energy Area	
WTG	Wind Turbine Generator	
XTF	eXtended Triton Format	

DEFINITIONS

Terminology	Definition
Client	US Wind, Inc.
Survey Contractor	Alpine Ocean Seismic Survey, Inc.
Acoustic penetration	The ability of acoustic waves to travel through the subsurface.
Acoustic reflector	A subsurface that causes the velocity of seismic waves to change.
Bedding/Layering	A stratified or layered feature associated with sedimentary rocks and/or loose sediments.
Bedform	Any oscillatory topographic deviations from a flat bed produced by fluid movement including wave and current activity, generally in a sandy domain.
Bedrock	The solid rock lying beneath superficial material such as gravels or soils.
Boulder	A separated rock mass larger than a cobble, having a diameter greater than 200 mm. It is rounded in form or shaped by abrasion.
Chart Datum	A level so low that the tide will not frequently fall below it. NOAA interprets it as the approximate level of Mean Lower Low Water (MLLW)
Clay	A complex mineral assemblage with particle size <0.002 mm
Coarse sediment	Sediment composed mainly of sand and gravel.
Cohesive sediment	Sediments, typically clay and/or silt that resist separation due to nature of bonds between fine grained particles.
Continental shelf	A gently sloping, shallow-water platform extending from the coast to a point where there begins a comparatively sharp descent down the continental slope to the abyssal floor.
Debris	Sonar contacts attributed to human activity.
Fine sediment	Sediment composed mainly of silt and clay.
Gravel	An unconsolidated accumulation consisting of particles larger than sand (diameter 2 mm – 60mm).
MLLW	The average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch. This is the lowest level to which sea level can be predicted to fall under normal meteorological conditions. MLLW is not an extreme level, as meteorological conditions can cause a lower level: the level under these conditions is known as a storm surge or negative surge.
Loose sediment	Not cemented sediment, either cohesive or not.
Megaripples	Undulations produced by fluid movement (waves and currents) over sediments, generally with l of 0.5m to 25m.
Ridge	A long narrow raised portion of the seafloor, relatively to its surroundings.
Ripples	Undulations (<0.5m l) produced by fluid movement (waves and currents) over sediments.
Rock outcrop	Rock that is exposed at the seafloor.
Sand	A detrital particle larger than a silt grain and smaller than a gravel, having a diameter in the range of 0.062 mm to 2 mm.
Sandwave	Undulations produced by fluid movement (waves and currents) over sediments, generally with l > 60m.
Very coarse sediment	Sediment composed mainly of cobbles and boulders

1. INTRODUCTION

Alpine Ocean Seismic Survey, Inc. (Alpine) performed high-resolution geophysical (HRG), geotechnical and environmental surveys on behalf of US Wind, Inc. (US Wind) in the Maryland Wind Energy Area (WEA) located on the Outer Continental Shelf (OCS) (Figure 1.1). The surveys were performed to support development of an offshore wind farm, and were conducted in accordance with lease requirements (OCS-A 0489 and OCS-A 0490) as modified by the US Wind Survey Plan that was approved by the Bureau of Ocean Energy Management (BOEM) on 03-Jun-2015. This report covers the survey operations and data results for the US Wind construction area, as carried out by Alpine.

US Wind purchased the two leases described above for the development of an initial planned large scale 500 MW offshore wind farm. US Wind contracted Alpine Ocean Seismic Survey, Inc. to undertake the geophysical and geotechnical surveys for the offshore wind farm area.

The surveys were also in line with lease requirements and according to specifications described in BOEM's "Guidelines for Providing Geological and Geophysical, Hazards, and Archaeological Information Pursuant to 30 CFR Part 585", dated 09-Nov-2012, which were the latest guidelines available during project planning and survey data acquisition in June and July, 2015.

The surveys included protected species mitigation measures as detailed in the lease and described in the Marine Mammal Mitigation Plan submitted to BOEM prior to the onset of the survey. The surveys were conducted during 24-hr operations with continuous visual observations by qualified Protected Species Observers (PSO). In addition to visual monitoring, a Passive Acoustic Monitoring system (PAMS) was installed on the survey vessel with trained personnel operating the equipment at all times during survey operations, ramp ups and during shut downs. For more information on protected species mitigation, Appendix B includes a detailed PSO report for both the geophysical and geotechnical survey operations.

The RV *Shearwater* conducted the HRG and environmental surveys, and was mobilized in Ocean City, MD, during the period 2-Jun-2015 to 5-Jun-2015. The MV *Ocean Discovery* conducted geotechnical operations and was mobilized in Baltimore, Maryland during the period 16-Jun-2015 to 18-Jun-2015. Appendix A of this report includes details and results of the geotechnical surveys. The surveys focused on data and sample acquisition in the MET tower area to provide a framework for a Site Assessment Plan (SAP) and also covered the entire planned WTG array area to provide data for future wind farm planning and design, and for the eventual submission of a Construction & Operations Plan (COP).

While the RV *Shearwater* was docked in Ocean City, the vessel took on board survey and mitigation personnel (PSOs & PAMS operators) and undertook DGPS and gyrocompass verifications, as well as initial underwater equipment checks. The vessel commenced work on sailing from Ocean City at 11:15h local time, 05-Jun-2015 to conduct calibrations and perform a vessel and HRG equipment noise signature analysis test using the PAMS system to establish baseline sound levels generated by the vessel and survey equipment. The calibrations and tests were completed and the survey began on 06-Jun-2015 at 19:20h local time. HRG survey data was collected over the entire US Wind survey area during the period 06-Jun-2015 to 25-Jun-2015 while benthic grab samples and underwater camera work was completed on 25-Jul-2015. The drill ship conducted borehole drilling and CPT operations during the period 22-Jun-2015 to 07-Jul-2015.

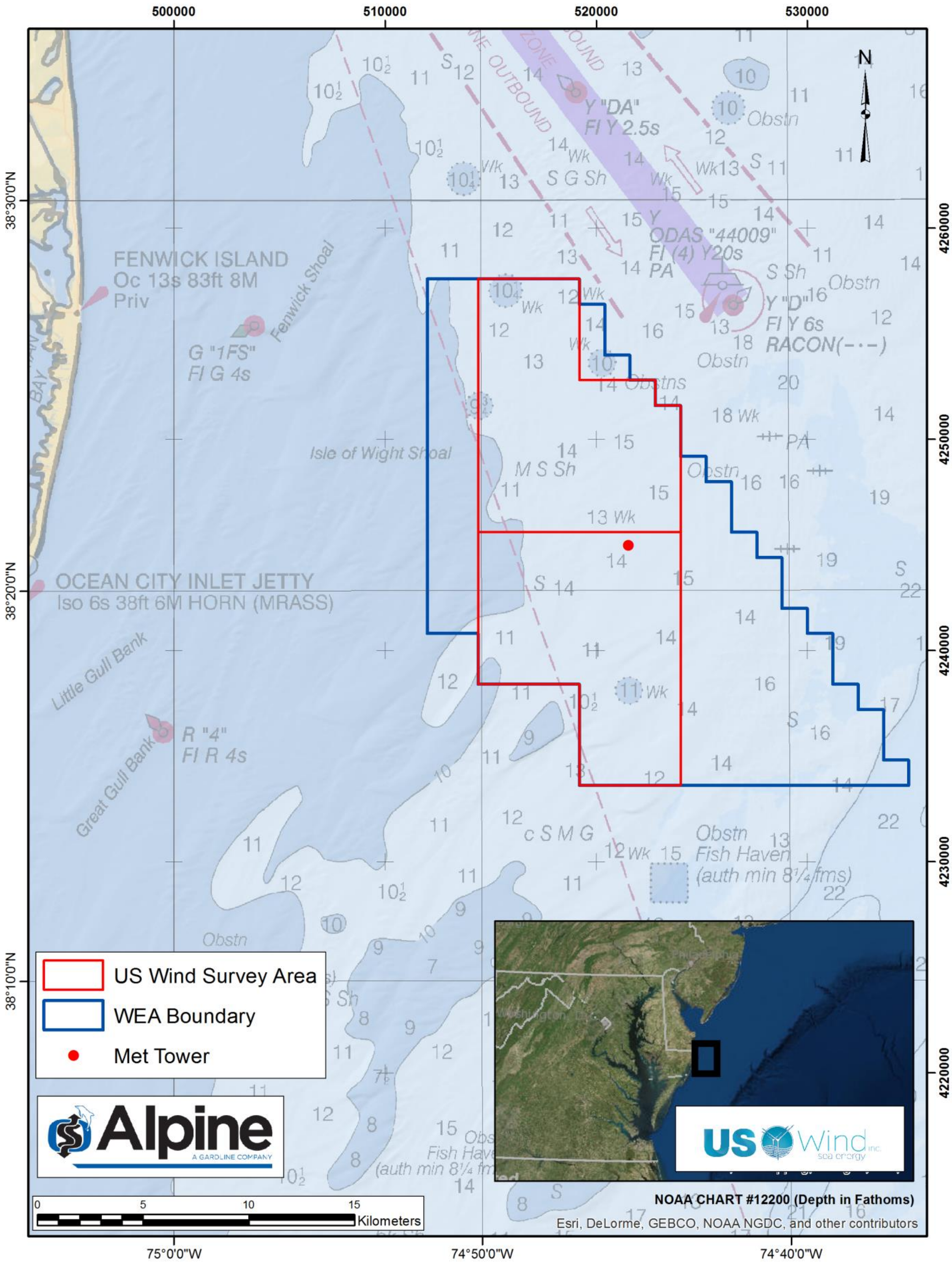

Figure 1.1 Survey Location Map

1.1 Field Work Summary

Program	Survey Vessel	Task	Dates
HRG & Environmental Surveys	RV *Shearwater*	Mobilization	02-Jun-2015 to 05-Jun-2015
		Calibrations and PAMS Noise Analysis Tests	05-Jun-2015 to 06-Jun-2015
		HRG and Environmental Survey Operations	06-Jun-2015 to 25-Jul-2015
Geotechnical Surveys	MV *Ocean Discovery*	Mobilization	16-Jun-2015 to 18-Jun-2015
		Drilling/CPT Operations	22-Jun-2015 to 07-Jul-2015

Table 1.1 Field Work Summary

1.2 Time Breakdown Summary

Activity	Project Hours	Percentage of Total
Operational Geophysical	753:48	58.48%
Transit	31:35	2.45%
Calibrations	5:55	0.46%
Standby (Weather)	189:09	14.67%
Standby (Port)	176:00	13.66%
Mobilization	61:00	4.73%
Survey Downtime	36:18	2.82%
PSO Mitigation	35:15	2.73%
Total	**1289:00**	**100%**

Table 1.2 Time Breakdown (HRG Survey)

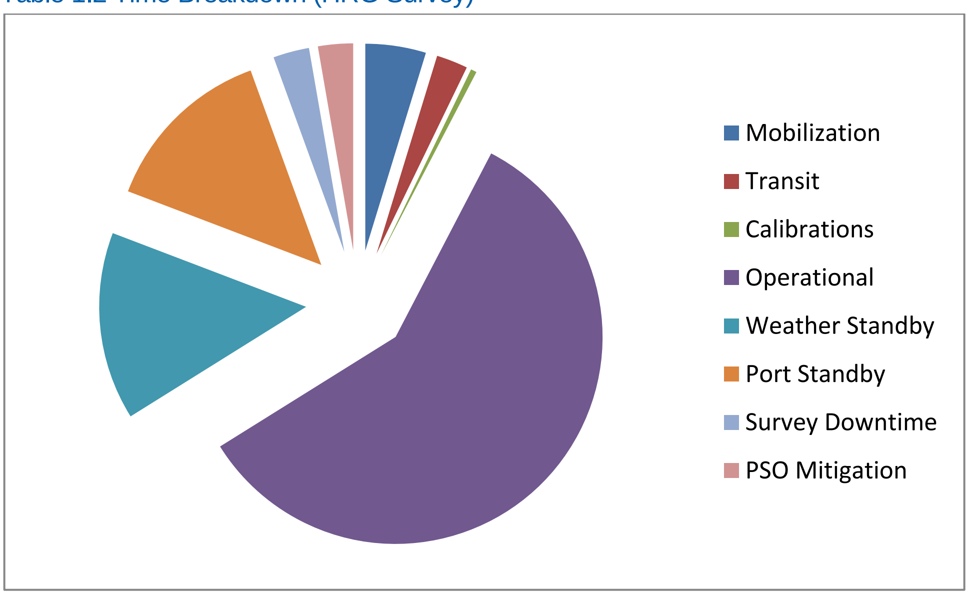

Figure 1.2 Time Breakdown

2. VESSEL SUMMARY

The RV *Shearwater* was used for the HRG and environmental survey work in the Wind Energy Area.

Brief Particulars	
Class	Multi-Role Survey
Flag	USA
Built	1981 (Reconfigured 2011)
Length OA	33.53m
Breadth OA	11.89m
Draft	2.74m
Gross Tonnage	198t
Endurance	21 days (nominal)
Main Engine	2 x 526 HP John Deere Model 6125AFM
Bow Thrust/Stern Thrust	Thrustmaster 100 HP / Hydraulically Driven "Z" Drives
Accommodation	20 Berths

Table 2.1 Vessel Specifications

Figure 2.1 RV *Shearwater*

3. SAFETY

Safety standards and procedures on board the RV *Shearwater* adhere to company policy which operates under the guidance of Alpine's Health and Safety Manual for Marine Geophysical Operations and is administered by the company's Health and Safety Officer. To maintain these standards every crew member is given a safety induction upon joining the vessel and regular safety drills are carried out during the cruise. Toolbox meetings are also conducted prior to equipment deployment, recovery and survey crew shift changes.

Prior to sailing a safety induction of all joining crew was carried out by the vessel safety officer.

During operations between 06-Jun-2015 and the completion of the surveys on 25-Jul-2015 a total of 103 toolbox meetings were completed.

3.1 Exposure Hours

The survey and marine crew totaled 18 persons from 06-Jun-2015 to 22-Jul-2015 and 13 persons from 22-Jul-2015 to 25-Jul-2015 during the survey. The total numbers of exposure hours from mobilization on 06-Jun-2015 to survey completion on 25-Jul-2015 were 22,771h during which there were no lost time incidents, no injurious incidents and no occurrences that resulted in damage to the environment.

4. CREW LIST

The following personnel were present on board the survey vessel.

Alpine / Gardline Personnel		Period	
Party Chief / Project Manager	Justin Bailey	03-Jun-2015	06-Jul-2015
Surveyor in Charge – 1st Rotation	Marcus Kwasek	02-Jun-2015	21-Jun-2015
Data Processor – 2nd Rotation	Marcus Kwasek	16-Jul-2015	25-Jul-2015
Surveyor in Charge	Chris Stillman	03-Jun-2015	19-Jun-2015
Surveyor – 1st Rotation	Kaios Ryan	03-Jun-2015	19-Jun-2015
Surveyor in Charge– 2nd Rotation	Kaios Ryan	19-Jun-2015	24-Jul-2015
Surveyor	Trevor Hoskins	02-Jun-2015	24-Jul-2015
Surveyor	Brett Young	19-Jun-2015	24-Jul-2015
Surveyor – 1st Rotation	Rob Vietri	06-Jul-2015	16-Jul-2015
Data Processor – 2nd Rotation	Rob Vietri	16-Jul-2015	25-Jul-2015
Surveyor in Charge – 1st Rotation	Cam Morrissette	21-Jun-2015	06-Jul-2015
Data Processor – 2nd Rotation	Cam Morrissette	06-Jul-2015	16-Jul-2015
Surveyor in charge	Farhan Arshad	16-Jul-2015	24-Jul-2015
Data Processor	Kelly Johns	03-Jun-2015	16-Jul-2015
Data Processor – 1st Rotation	Daniel Whitesell	02-Jun-2015	06-Jul-2015
Party Chief – 2nd Rotation	Daniel Whitesell	06-Jul-2015	25-Jul-2015
PSO/PAMS Operator	Sharon Doake	03-Jun-2015	24-Jul-2015
PSO/PAMS Operator	Randal Counihan	03-Jun-2015	06-Jul-2015
PSO/PAMS Operator	Teresa Martin	03-Jun-2015	24-Jul2015
PSO/PAMS Operator	Jack Allum	03-Jun-2015	06-Jul-2015
PSO/PAMS Operator	Sam Tufano	03-Jun-2015	24-Jul-2015
PSO/PAMS Operator	Lee Slater	06-Jul-2015	25-Jul-2015
PSO/PAMS Operator	Robert Lee	06-Jul-2015	25-Jul-2015
Captain	Wayne Porter	02-Jun-2015	25-Jul-2015
1st Mate – 1st Rotation	Michael Porter	02-Jun-2015	21-Jun-2015
1st Mate – 2nd Rotation	Michael Porter	06-Jul-2015	25-Jul-2015
Mate	Mike Masek	02-Jun-2015	06-Jul-2015
Mate	Jason Giery	21-Jun-2015	25-Jul-2015
Deckhand	Sydney Sanchez	02-Jun-2015	06-Jul-2015
Deckhand	Steve Miller	02-Jun-2015	21-Jun-2015
Cook	Larry Bennet	02-Jun-2015	06-Jul-2015
Deckhand	Ovidio Hernandez	21-Jun-2015	25-Jul-2015
Deckhand	Brandon Worley	06-Jul-2015	25-Jul-2015
Environmental Client-ESS	James Treacy	24-Jul-2015	25-Jul-2015
Environmental Scientist-Gardline	Laura Jamieson	24-Jul-2015	25-Jul-2015

Table 4.1 Field Personnel

5. SURVEY PROCEDURES

5.1 General

The US Wind WTG construction area survey comprised an investigation of the bathymetry, seabed features and shallow geology across the area US Wind has designated for MET tower and wind farm development, both for the SAP application and for future advancement of the project pursuant to submission of a Construction and Operations Plan (COP).

5.2 Project Survey Parameters

Datum & Projection Parameters		
Geodetic Datum	NAD83	
Ellipsoid	WGS84	
	Semi-Major Axis (a)	6 378 137.000 meters
	Inverse Flattening (1/f)	298.257 223 5634
	Eccentricity sq. (e^2)	0.006694379990
Projection	UTM Zone 18N	
	Origin Latitude	00°
	Origin Longitude	-075°
	Origin False Easting	500 000.00
	Origin False Northing	0.00
	Scale Factor	0.9996
	Grid Unit	meters

Table 5.1 Project Geodetics

5.3 Vertical Datum

The survey conducted for the MEA in 2013 included acquisition of MBES bathymetry across the Maryland WEA. This data was tide corrected and reduced to Mean Lower Low Water (MLLW) as described in the HRG resource survey report prepared for the MEA (Coastal Planning & Engineering, Inc., a CB&I Company, 2014).

MBES Bathymetry data was collected by Alpine in the MET tower APE, which encompasses a 300m radius circle around the planned installation location. This data was collected to supplant data acquired during the 2013 MEA geophysical survey, which did not attain 100% bottom coverage across the site. Bathymetry data were tide corrected and reduced to MLLW using the Post Processing Kinematic (PPK) method.

PPK techniques use a combination of the POS MV and POSPac Mobile Mapping Suite (MMS) systems. The POSPac MMS is the next generation software for direct geo-referencing of survey sensors using GNSS and inertial technology, specifically integrated with the POS MV for marine mapping applications. POSPac is a powerful post-survey software package that provides maximum accuracy and efficiency for georeferencing the MBES echosounder data. The suite incorporates the Applanix SmartBase™ module that automatically selects, downloads, and imports the best available network of continuously operating reference stations (CORS) surrounding the project area.

The raw POS MV position measurements are adjusted for the differential corrections from the network reference stations and simultaneously processed along with the inertial measurement unit (IMU) data using Applanix IN-Fusion™ technology to solve for GNSS ambiguities (i.e., outages, atmospheric delays) and final vessel position and orientation. Position accuracies are comparable with those achieved using an RTK system, and effectively eliminates the cost and time associated with establishing a local GPS reference station for the project.

CORS Station Used for Bathymetry Processing			
Station	Latitude	Longitude	Height
DEMI	(N)	(W)	(m)
Millsboro, DE	38° 36' 37.00549"	075° 12' 10.33286	-27.437

Table 5.3 CORS Station Parameters

It should be noted that multibeam bathymetry was only collected by Alpine within the MET tower survey area. Bathymetric contours for the full WEA are provided on **Chart 2** and an XYZ of the data is supplied in Appendix L. This data was collected during the earlier MEA survey in 2013 and not by Alpine.

Area	Depth Range (m)	Cell Size (m)
MET Tower APE	26.25 – 27.1	1

Table 5.4 MBES Gridding

5.4 Survey Design Summary

The survey design was based on the US Wind Survey Plan that was approved by BOEM prior to the beginning of survey operations. A previous survey was conducted in 2013 for the MEA, which acquired data on 150m spaced lines throughout the WEA and included MBES bathymetry, SSS imagery, medium penetration sub-bottom profiles, shallow penetration sub-bottom profiles and MAG data. These data were also collected on 900m spaced tie lines, in line with specifications under BOEMs “Guidelines for Providing Geological and Geophysical, Hazards, and Archaeological Information Pursuant to 30 CFR Part 585”, dated 09-November-2012. These guidelines detail this minimum line spacing for HRG surveys for hazard assessment and engineering purposes. These guidelines also call for a HRG survey for archaeological resource assessment with a primary line spacing not to exceed 30m throughout the project area, however, medium penetration sub-bottom data is not required on these additional lines.

Alpine collected side scan sonar, shallow penetration sub-bottom, and magnetometer data at a 30m line spacing to supplement the data collected in 2013 and complete data requirements as required by BOEM. MBES bathymetry was collected in the MET tower APE. Single beam echo sounder data were acquired while running the geophysical equipment across the entire surveyed area for quality control and data correlation/interpretation purposes, but were not intended for bathymetric data presentation.

The survey lines run in the previous survey in 2013 (150m spaced primary lines, 900m spaced tie lines) were not re-run during the 2015 survey campaign, but the data were merged with the more recent data for final data presentation. The SSS data were not merged, as the recent survey acquired greater than 200% bottom coverage with this swathe data set, and at a higher resolution, effectively replacing the older data set. Figure 5.1 illustrates the planned survey lines for the 2015 US Wind survey. **Chart 1**, provided with this report, presents a “Vessel Tracklines” map, which includes the line direction for the 2015 survey and also includes tracklines for the 2013 survey.

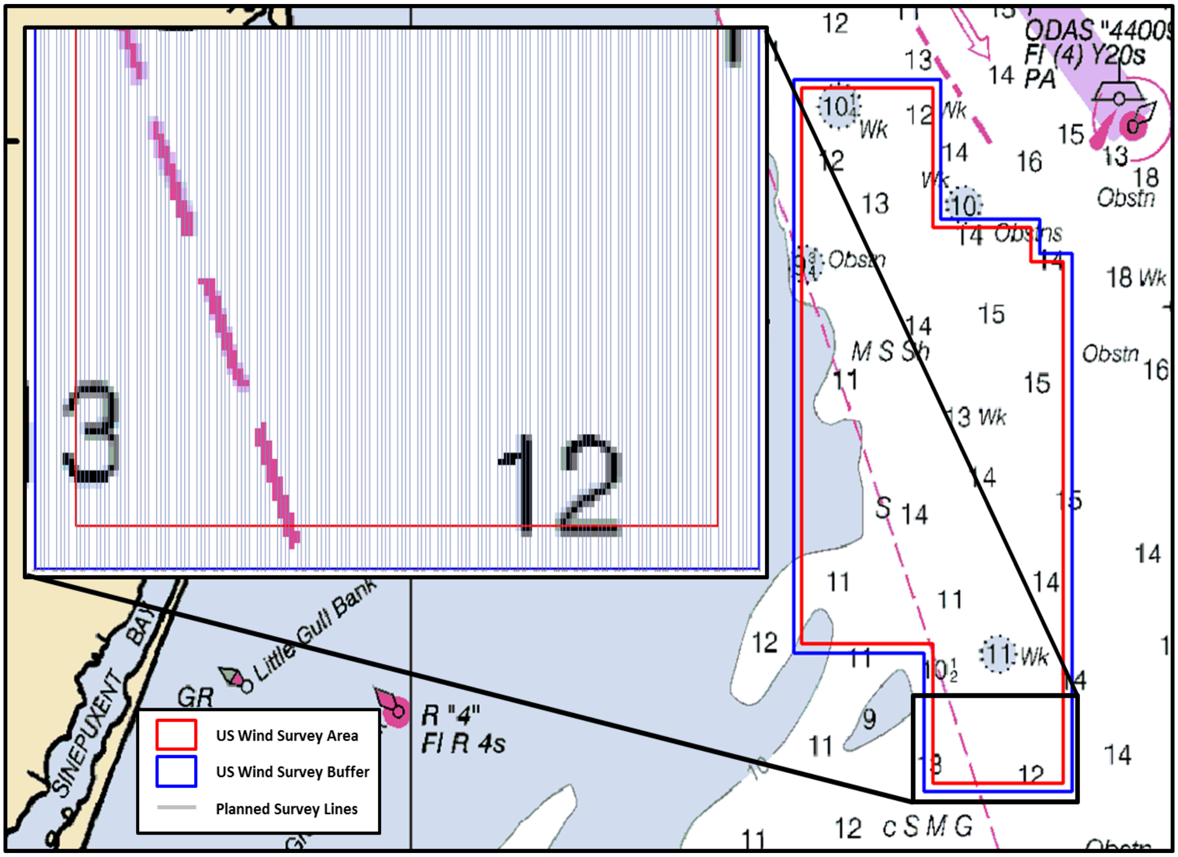

Figure 5.1 Planned Survey Line Plan Example

5.5 Geophysical Survey Equipment and Methods

5.5.1 Vessel Layout

The RV Shearwater provided the survey platform to conduct the bathymetric and geophysical investigation. The vessel provides a large aft deck, crane, hydraulic stern A-frame, fixed starboard A-frame, winches, laboratory and office space with on board processing capabilities. The SSS and MAG towfish were deployed from the stern A-frame using the vessel's main hydraulic winch equipped with 700m of armored cable. The CHIRP and USBL transducers were hull mounted in the starboard-side moon pool. For the MET tower survey, the MBES head was installed in the port-side moon pool.

5.5.2 Vessel and Equipment Navigation

The Applanix POS MV 320 was used for navigation control during the survey. Differential corrections were received from the USCG station in Annapolis, MD. This system, which includes a GPS aided Inertial Measurement Unit (IMU), provided precise real-time dynamic sub-meter positioning including heading, heave, pitch and roll.

Aboard the RV Shearwater the IMU was mounted on the main deck near the vessel's center of rotation/gravity. The GPS antennas were mounted above the upper deck and bridge, aligned normal to the longitudinal axis of the vessel. Offsets between the GPS antennas, IMU and all other fixed mounting points for the other geophysical sensors were precisely measured using a laser-ranging total station, with the services of a professional land surveyor (Fabre Engineering, Inc., Pensacola, Florida).

After the navigation system was installed and configured on the survey vessels, the following steps were taken to calibrate the POS MV:

1. The GPS Azimuth Measurement Subsystem (GAMS) Solution was calculated as follows:

    - GAMS calibration began when the number of satellites in view exceeded 5 and PDOP was less than 3.0.
    - The vessel was maneuvered through moderately aggressive turns (figure eights or S-turns) incorporating changes of speed and direction.
    - The operator then waited for the heading accuracy to be below the threshold value entered (0.5 degree) and for the GAMS Status to read Ready Offline.
    - Vessel motion was then stopped and the vessel held to a constant heading.
    - GAMS calibration was started.
    - Once GAMS calibration was complete the values were saved into the system, and were used for the remainder of the survey.

2. Summary of Navigation Data Accuracy

    - The result of the GAMS solution indicated that the azimuth or heading of the vessel was accurate to within 0.25 degrees. This result shows a very high degree of accuracy of the heading data being generated by the navigation system. In the same way, the accuracy of the navigation fix data was determined to be within one meter.

The positioning data from the POS MV was output to a computer equipped with QINSy navigational software, which transmitted continuous navigation data to all systems requiring geo-referencing.

Instruments receiving positioning from QINSy included the CHIRP sub-bottom acquisition system, the SSS system and the MAG. The POS MV system output was also directly interfaced to the MBES system using a PPS (pulse per second) device to avoid any latency delays. All offsets from the reference point for the navigation system to the various geophysical instruments were measured and recorded in QINSy. Data from the cable counter was input into QINSy as a backup layback system for the SSS and MAG systems, in the event that the USBL system could not be used. The QINSy navigation software converted the latitude and longitude data to UTM Zone 18 North (m), NAD83 datum, which was used for survey control.

Figure 5.2 Survey Instrumentation Diagram

Offset from Ref. Point ☒ meter ☐ feet	+ forward/ - backward	+ right/ - left	+ up/ - down
Primary GPS Antenna	-0.978	-1.591	5.043
Secondary GPS Antenna	-0.939	1.804	5.012
Internal Measurement Unit	0.000	0.000	0.000
Waterline			-3.624
MBES Transducer	-0.562	-3.972	-6.279
USBL Transducer	-0.780	4.206	-6.551
Single Beam Echo Sounder Transducer	-0.445	4.099	-6.316
Sub-Bottom Profiler Transducer	-0.628	3.825	-6.286
SSS Block Sheave	-16.810	0.005	-3.719

Table 5.5 RV Shearwater Survey Equipment Offsets

5.5.3 Ultra-Short Baseline Acoustic Positioning System

A Sonardyne Scout Pro USBL acoustic positioning system was used to calculate towfish position (SSS & MAG) in real-time on board the RV Shearwater. The system utilizes a hull mounted transceiver (installed on the starboard side moon pool next to the CHIRP transducer) and a transponder (beacon), which is fixed to the armored cable just above the SSS towfish. The USBL transceiver was tilted aft approximately 25 degrees in order to improve system range and performance. The USBL system was interfaced to the QINSy navigation software, which exported corrected sensor positions to the SSS and MAG logging computers.

The USBL system was calibrated using QINSy's calibration routine in approximately 25m water depth. The USBL system is interfaced with QINSy software and the Applanix POS MV which provides precise positioning, heave, pitch and roll values. Upon locating a site with a suitable water depth for calibration, a series of calibration lines were established. Parallel lines were spaced 50m apart (twice the ambient water depth). Due to a USBL transceiver malfunction during the HRG survey, a second calibration of the USBL was run after installation of the new transceiver. Both USBL calibration 1 and calibration 2 results are presented in Appendix E.

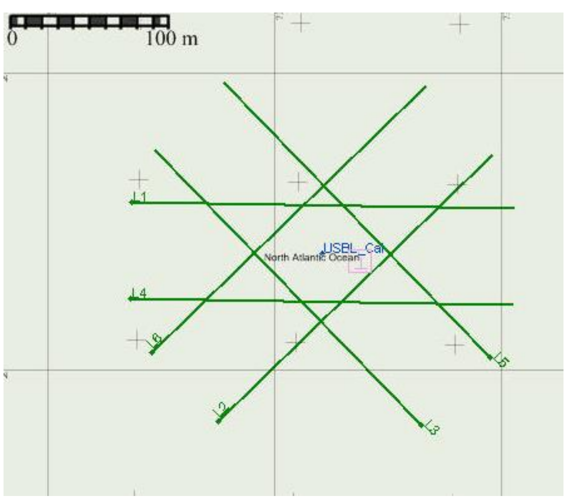

Figure 5.3 USBL Calibration Lines

5.5.4 Shallow Penetration Sub-Bottom Profiler (CHIRP)

A Teledyne Benthos CHIRP III Profiler system was used to generate the sub-bottom acoustic signal, which was transmitted through a set of four transducers mounted on the starboard-side moon pool of the vessel. The transducers were wired in parallel for maximum transmit power and optimum signal reception.

Each pulse consists of a swept frequency (2–7kHz) operated at a 15ms pulse length. The system was operated using a 125ms sweep length, providing for greater than 90m of recorded data. The signals were received and digitized using the CHIRP topside unit. The CHIRP system received positioning information from the QINSy software so that all the data were continuously geo-referenced. Real-time bottom tracking and display gains were applied to the data in the field using Chesapeake Technologies' SonarWiz software for quality control, and the data were recorded in SEGY format. SonarWiz also provides post-processing capability where the user can perform seafloor tracking, adjust gains and map and export sub-surface reflectors or features.

5.5.5 Side Scan Sonar System

A Klein 3900 dual-frequency (500/900kHz) SSS system was used to collect the side scan data during the survey. The system was interfaced with the QINSy navigation and all data were continuously geo-referenced. Sonar XTF files were recorded using Klein's SonarPro software platform. With SonarWiz the XTF files can be corrected for pitch, roll, slant range, gains and generation of a sonar mosaic at a user specified resolution. Sonar contacts can be picked, measured, saved and exported in a contact report.

Aboard the RV *Shearwater* the towfish height off seafloor was maintained at 10–20% of the sweep range using a deck mounted hydraulic winch and armored cable. The towfish position was calculated in real-time using the USBL system. A backup system was also used, utilizing a cable counter sheave to measure cable out from the stern of the vessel.

The sweep range was set to 50m per channel resulting in a 100m total swath. The system was operated and recorded using a frequency of 500kHz. All data were displayed in a waterfall format on a high definition LCD monitor during the survey work so that the operator could note any significant targets in the field.

After completing the USBL several SSS files were examined to verify correct positioning of the data. Lines in opposing directions were evaluated where discrete insonified features could be identified on adjacent lines. An extensive linear feature was observed on the seafloor and imaged with the SSS system (using the USBL for positioning), on adjacent lines that were run in opposite directions (see figure below). The alignment of the linear feature on adjacent lines verifies correct towfish positioning.

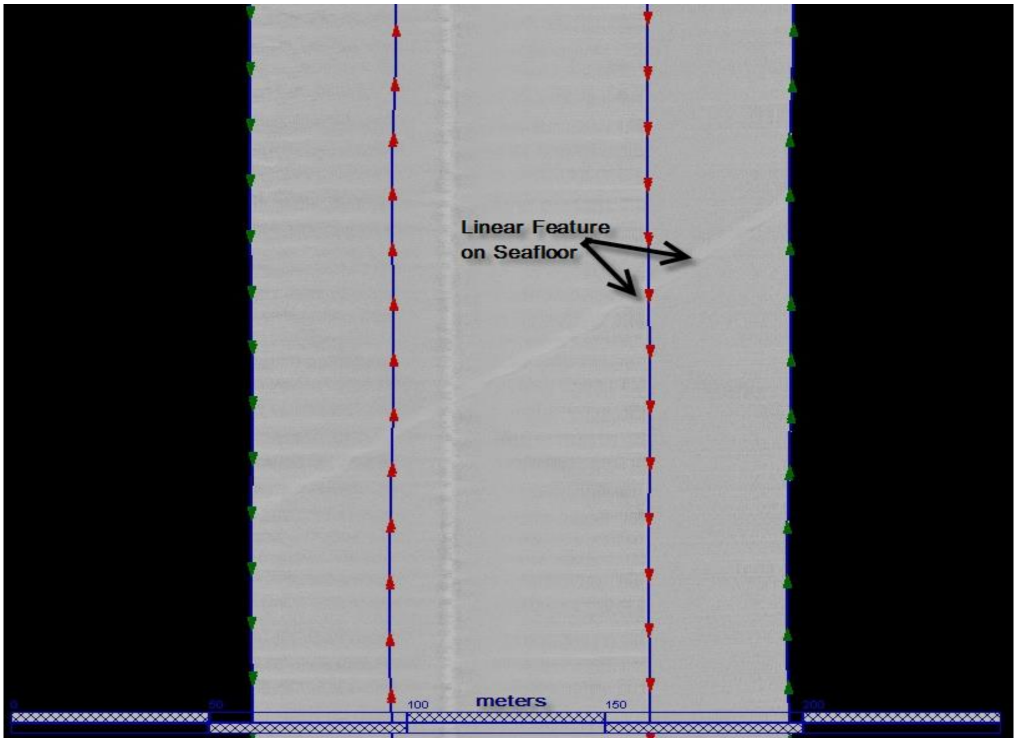

Figure 5.4 USBL Calibration Verification Lines

5.5.6 Marine Magnetometer System

A Geometrics 882 magnetometer was towed directly behind the SSS towfish using an umbilical cable. This towing configuration was optimal for controlling the altitude of the MAG, which was flown at the appropriate distance (less than six meters) from the seafloor. The MAG data was viewed in real time on board the survey vessel, and recorded in MagLog at 100ms intervals along all survey lines. The position of the towfish was determined using a fixed layback behind the USBL calculated position of the SSS towfish. The data was post-processed using Geometrics' MagPick software platform. MagPick has the capability to remove the regional background field and diurnal variation by using a built-in linear transformation tool, or alternatively by using locally recorded base station data.

5.5.7 Multi-Beam Echo Sounder

An R2Sonic 2024 MBES bathymetry system was used to collect the bathymetric data for SAP survey in the MET tower APE. On the RV *Shearwater* the transducer was mounted approximately amidships in the port-side moon pool. The moon pool included an extension pole to lower the transducer below the hull of the vessel, to eliminate hull interference. Once appropriate settings of power and gain were determined, the system was calibrated for pitch, roll, and yaw by running three parallel. This data was then run through a series of calibrations in a post-processing software package (CARIS) to determine the calculated calibration values for pitch, roll, and yaw. Calibration results for the MBES are included in Appendix G.

Data were collected using a signal transmitted at a frequency of 400kHz and variable settings were used for range/pulse-length and gain for optimal data quality. The speed of sound in water was determined using a Valeport 650 Sound Velocity Profiler (SVP). The SVP sensor data was used to generate a profile of the speed of sound, which was then applied in QINSy to correct for beam steering of the bathymetric data. Heading, heave, pitch and roll output from the Applanix POS MV system was recorded with the bathymetry data in the survey acquisition software (Qinsy), with final post-processing and DTM generation performed using CARIS. SVP casts were conducted at a minimum of every three hours during the SAP MBES survey.

5.5.8 Single Beam Echo Sounder

An ODOM Echotrac CVM 200kHz single beam bathymetry system was installed on the vessel to observe in real-time and collect data to QA/QC the geophysical instrumentation. Data was logged on all geophysical survey lines.

6. BACKGROUND GEOLOGY

6.1 Geologic Setting

The Maryland coast is part of a regional feature known as the Delmarva Peninsula. The Delmarva Peninsula is bounded to the north by the Delaware Bay, to the west by the Chesapeake Bay and to the east by the Atlantic Ocean. The Delmarva Peninsula and surrounding features are characterized by three geologic provinces, the Piedmont Plateau, the Coastal Plain, and the Atlantic Continental Shelf. The Piedmont Plateau and Coastal Plain provinces are separated by a “Fall Line”. The Fall Line separates the Coastal Plain on the east, from metamorphosed rocks of the Piedmont province to the west - the remnant core of the ancestral Appalachian Mountains. From the time the ancestral Appalachian Mountains were uplifted between 250–450 million years ago they began to erode. Rivers and streams flowing down from the mountain tops carried the eroded material to be spread out and deposited in deltas and outwash plains on the Coastal Plain. East of the Coastal Plain lies the Atlantic Continental Shelf, the submerged continuation of the Coastal Plain extending eastward another 75 miles where sediments exhibit a maximum thickness of 40,000 feet (Maryland Geological Survey, 2015).

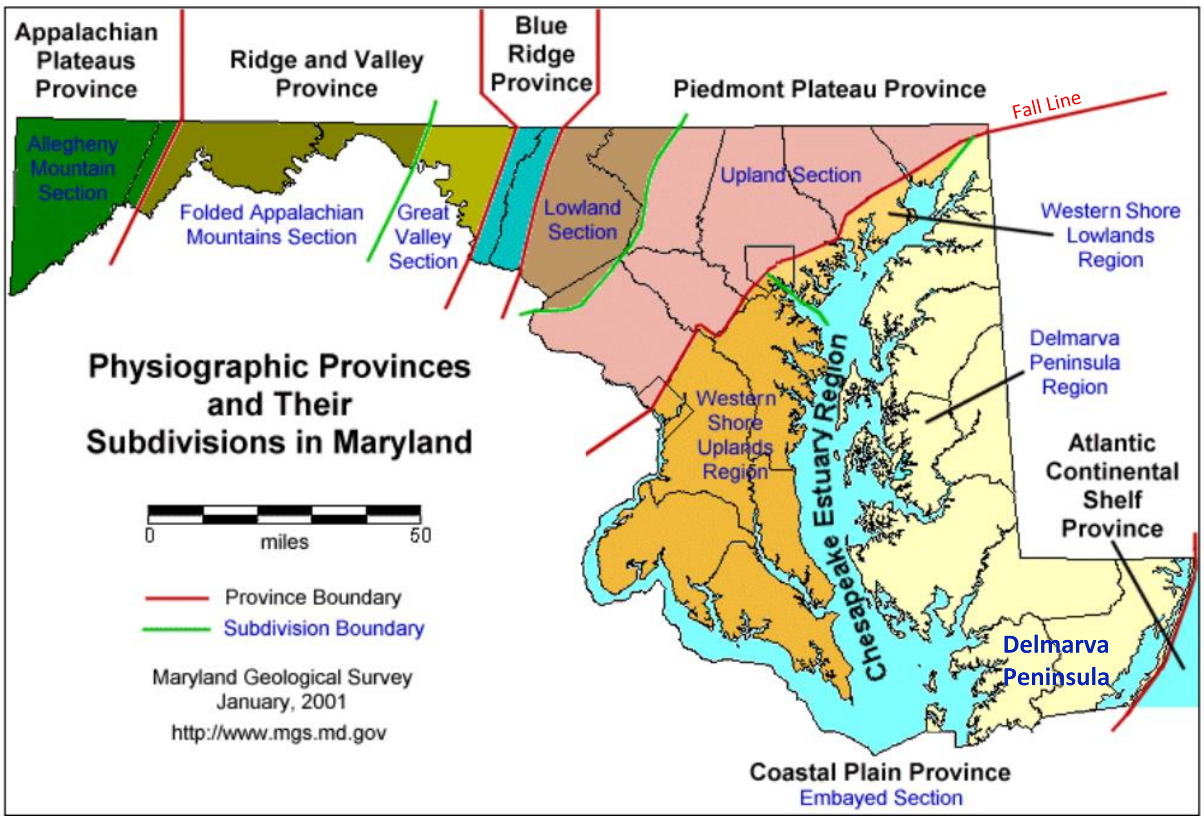

Figure 6.1 Maryland Physiographic Provinces (Modified from USGS)

6.2 Stratigraphy

The sediments of the Coastal Plain dip eastward at a low angle, generally less than one degree, thicken eastward and range in age from Triassic to Quaternary.

Linear shoals or sand ridges are among the largest, most pervasive, and enigmatic bedforms on the Delaware-Maryland continental shelf (Figure 8) (Conkwright, and Williams, 1996). Numerous scientists have investigated the seafloor geomorphology and the surficial stratigraphy of the Atlantic shelf to understand the origins and morphology of these linear shoals. Comprehensive reviews of these works have been published by Duane and others (1972), Field (1976, 1980), Toscano (1989), McBride and Moslow (1990), and Wells (1994). As a group, linear shoals share several common features. Duane and others (1972) characterized these features:

1. Linear shoal fields occur in clusters, or fields, from Long Island, New York to Florida.
2. Shoals exhibit relief up to 30ft, side slopes of a few degrees, and extend for tens of miles.
3. The long axes of linear shoals trend to the northeast and form an angle of less than 35° with the shoreline.
4. Shoals may be shoreface-attached, or detached. Shoreface-attached shoals may be associated with barrier island inlets.
5. Shoal sediments are markedly different from underlying sediments. Shoals are composed of sands and generally overlay fine, occasionally peaty, sediments.

With so many common characteristics, early researchers assumed a common origin for these features. Generally, it was assumed that linear ridges represented relict barriers or subaerial beaches, developed at a lower sea level stand, and preserved with sea level rise. (Veatch and Smith, 1939; Shepard, 1963; Emery, 1966; Kraft, 1971; and many others). Improvements in seismic data collection and reexamination of earlier data led to a new hypothesis of shoal evolution: linear shoals are post-transgressive expressions of modern shelf processes. In particular, Field's (1976, 1980) work on the Delmarva shelf could find no support for the theory of relict, submerged shorelines. Many investigators (including Field 1980; Swift and Field, 1981) concluded that ridge and swale topography developed by the interaction of storm-induced currents and sediments at the base of the shoreface. As the shoreface retreated during transgression, shoreface-attached shoals became detached, and isolated from their sand source. Once detached, the shoals continued to evolve within the modern hydraulic regime.

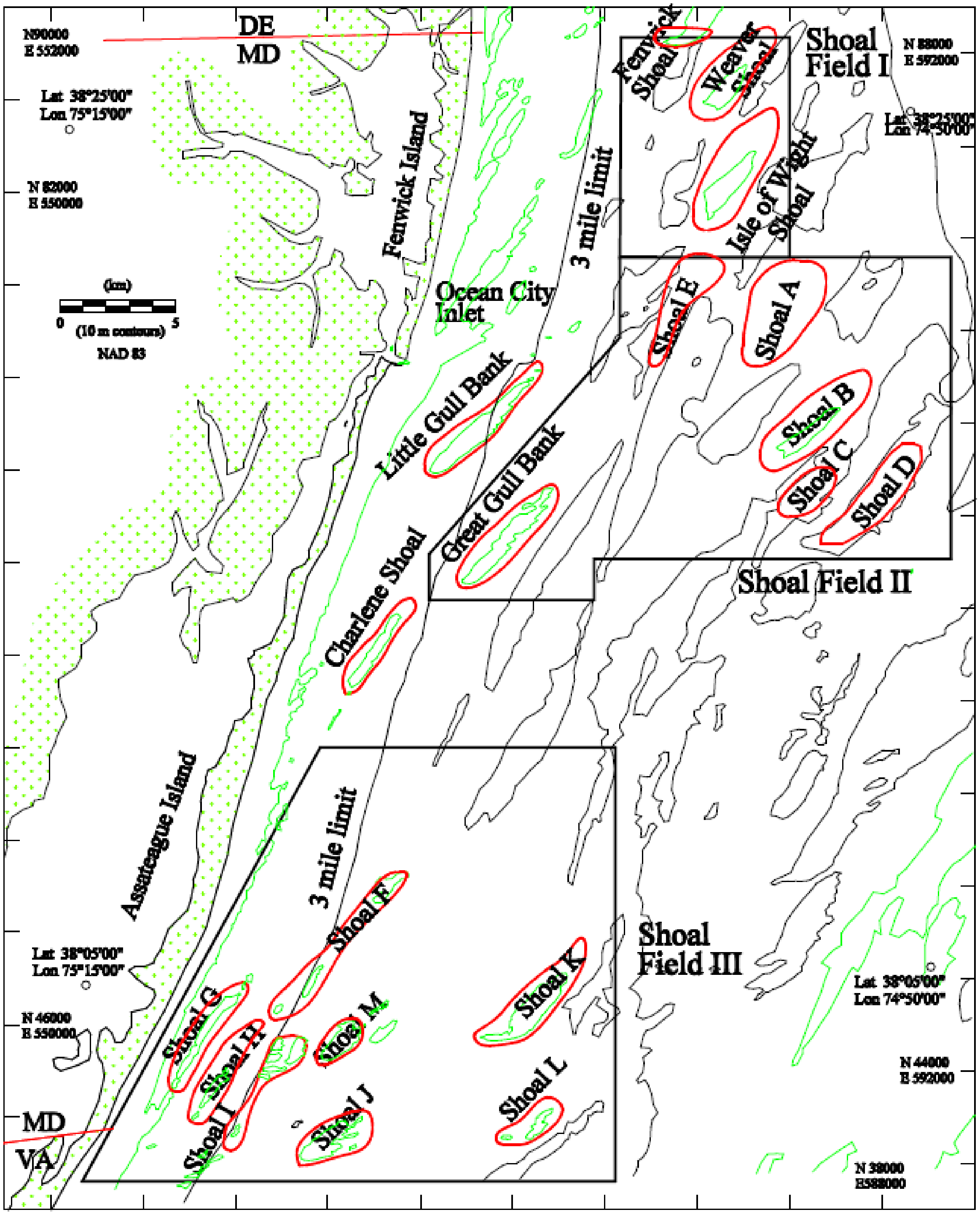

Figure 6.2 Index of Shoal Fields Offshore Maryland

Several shallow geophysical reflectors were mapped in the area in and around a series of sand shoals located offshore of Ocean City, MD. The reflectors described represent the Quaternary geologic sequence for the work area developed by the Maryland Geological Survey between 1987 and 1992 during work conducted as part of the Minerals Management Service Continental Margin Program.

Figure 6.3 illustrates the sedimentary sequence described by Wells (1994).

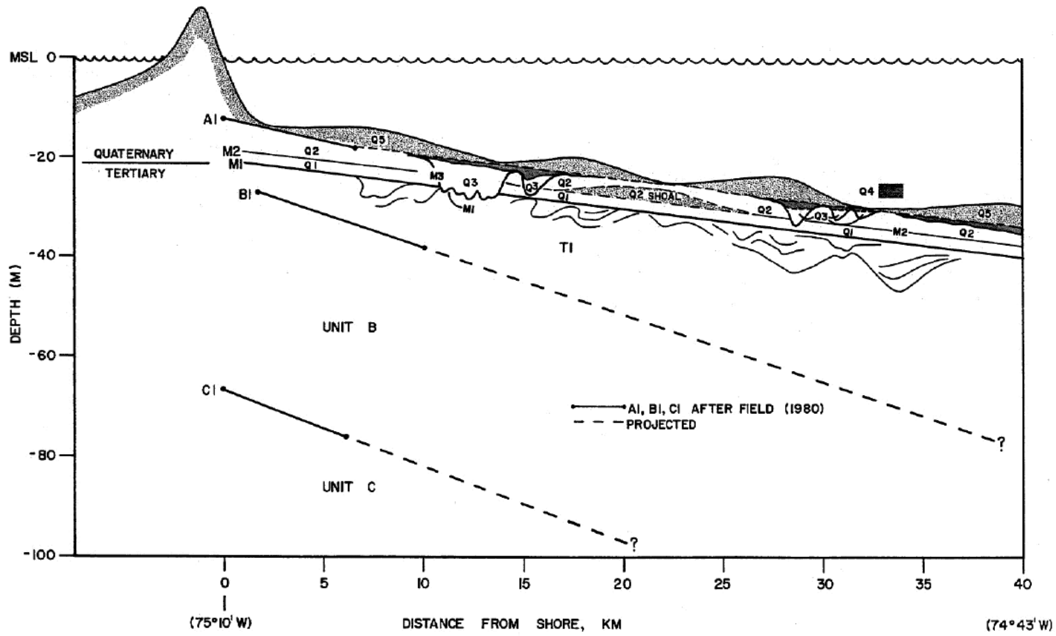

Figure 6.3 Maryland's Inner Continental Shelf Stratigraphy (from Toscano et al., 1989)

The reflectors and depositional units are described as follows (Wells, 1994):

The M1 reflector is correlated to the Tertiary-Quaternary unconformity and is generally present at a depth of 21 to 36m below MLLW within 10 miles of the shoreline.

The Q1/Q2 depositional unit immediately overlies the M1 reflector and is characterized by parallel to sub-parallel internal reflectors. A weak reflector, M2, separates the Q1 and Q2 sediments and is generally present at an elevation of 5-6m above M1. The Q1 sediments have been described as sands and gravelly sands containing shells where that unit was penetrated by Vibracore samples. The Q2 unit consists primarily of dewatered fossiliferous mud, with rare lenses of sand. This sequence was deposited during a 50,000 year long lower stand of the sea, correlated with an earlier portion of the Pleistocene.

During a low stand of sea level following deposition of the Q1 and Q2 sediments, a series of river channels were incised across the Maryland continental shelf and infilled with sediments. The most prominent of these is referred to as the St. Martin River paleo-channel, which extends to the southeast offshore of Ocean City, MD. Unit Q3 represents fluvial fill deposits of the ancestral St. Martin tributary system. Other shallower more recent channels are occasionally present on the geophysical data, but these are generally discontinuous due to post-depositional erosion.

The A1 reflector is usually planar and marks the base of the shoals. It represents the boundary between the ravinement surface formed by shoreface erosion and modern trailing edge shelf deposits.

Both the Q4 and Q5 depositional units are Holocene in age. The Q4 is interpreted to be transgressive leading-edge deposits (lagoonal/swamp deposits) and overlaps Q3 and Q2 depositional units. Unit Q5 represents modern shelf shoal deposits.

7. GEOPHYSICAL SURVEY RESULTS

7.1 Introduction

The following results describe the findings of the bathymetric and geophysical investigation during the SAP geophysical and geotechnical surveys conducted in June–July, 2015. Geotechnical results are presented in Appendix A of this report.

Near real-time data processing was conducted on board the RV *Shearwater* during survey operations. During the survey, preliminary charts were generated for each geotechnical borehole location, reviewed by the on-board geophysicists and geologists, and then submitted to the project archaeologist for review. Drilling operations began only after each location was reviewed and cleared of any potential hazards or cultural resources. All final data processing and analysis was completed at Alpine's office in Norwood, NJ.

7.2 Dockside Calibration

While the RV *Shearwater* was docked in Ocean City, MD a series of quay-side verifications were conducted. Prior to mobilizing the vessel, a local Maryland Professional Land Surveyor established two control points along, and parallel to, the USCG dock. The two points were installed in the center of a dolphin structure located near the bow and stern of the vessel. The distance from the vessel reference point to the closest control point was measured using a survey tape and compared to the calculated position using the vessel GNSS system and navigation software (QINSy). The two control points also established a baseline to compare against the survey vessel heading. It should be noted that currents run very strong where the vessel was docked near Ocean City Inlet, as a result the axis of the RV *Shearwater* was rarely aligned perfectly with the quay-side structure. Before conducting the SAP survey, a bar check was conducted to verify water depth measurements with the MBES system. A metal disc was lowered at a fixed and known depth along the side of the vessel near the installation point of the MBES transducer. Depths of the disc measured by the MBES system were compared against the physical depth it was lowered into the water. Results of these checks and verifications are presented in the tables below. Detailed MBES patch test and USBL calibration results are presented in Appendix G of this report.

Control Point	Published X	Published Y	Observed X	Observed Y	Delta	Tape Measure
Dolphin USCG Marina	492022.16	4242224.13	492010.14	4242215.72	14.68	15.03

Table 7.1 Vessel Positioning Verification

Control Point	Published Heading	Observed Heading	Delta
Baseline USCG Marina	205.114˚	204.089˚	1.025 ˚

Table 7.2 Vessel Heading Verification

MBES Water Depth	Bar Checked Depth	Delta
7.0m	6.93m	0.07m

Table 7.3 MBES Bar Check Results

7.3 Bathymetry

7.3.1 Data Processing & Analysis – SAP Area

The MBES data collected with the R2 Sonic system was processed using QINSy and CARIS HIPS software. Data were cleaned, tide and datum corrected and exported as a 1m binned ASCII XYZ sounding file. Electronic MBES bathymetry data are provided in Appendix L which includes an XYZ sounding file, a geo-referenced shaded relief image and backscatter data.

7.3.2 Data Discussion – SAP Area

The water depth (WD) across the SAP area varies less than 1m and ranged between 26.3m and 27.1m MLLW. In general, the seafloor is relatively flat and featureless, and displays down slope gradients of 0.5° or less. From the MET tower location, where the WD is 27.0m MLLW, the seafloor slopes gently upward to the northwest and southeast. No apparent surface obstructions or hazards were observed in the SAP area. A bathymetry map is presented on **Chart 2** included with this report. A 1m bin size DTM (XYZ file) of the MBES data is included on a USB drive included with this report Appendix L.

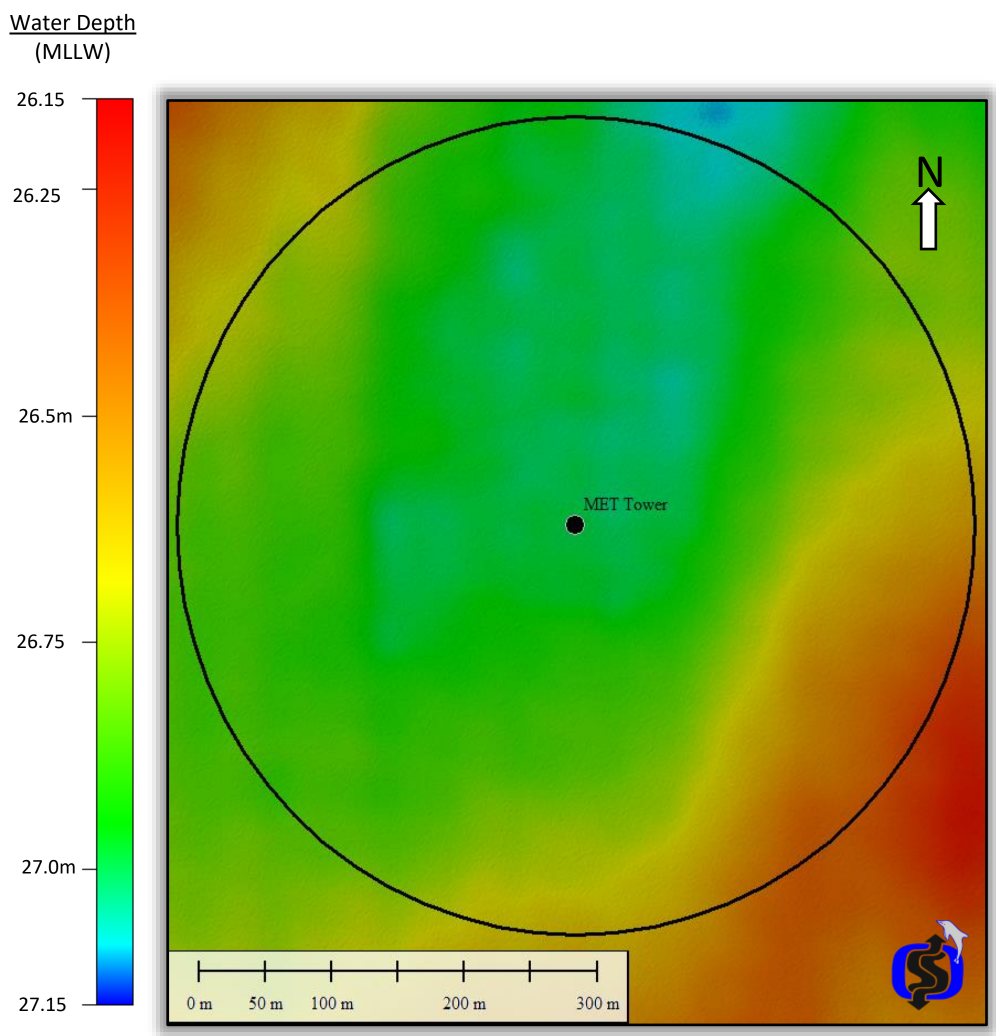

Figure 7.1 MBES Shaded Relief Bathymetry of SAP Area

7.3.3 Data Discussion – US Wind Construction Area (WEA)

Bathymetry data collected during the 2013 MEA survey was used to create a digital terrain model of the soundings from the US Wind survey area to further investigate seafloor morphology (Figure 7.2). Within the WTG survey area waters depths ranged from 15.7m at the shallowest to 33.9m at the deepest with an average depth of 24.2m. The data indicates the presence of sand ridge features and some small 1°- 3° slopes, which have 2-5 percent grade, in the western and southwestern region of the WTG area. The rest of the survey area appears predominantly flat or gently sloping as you move offshore. An XYZ of the multibeam data collected during the 2013 MEA survey was provided in Appendix L.

It is important to note that the bathymetry presented in this section was not collected by Alpine and was data acquired during the 2013 MEA survey.

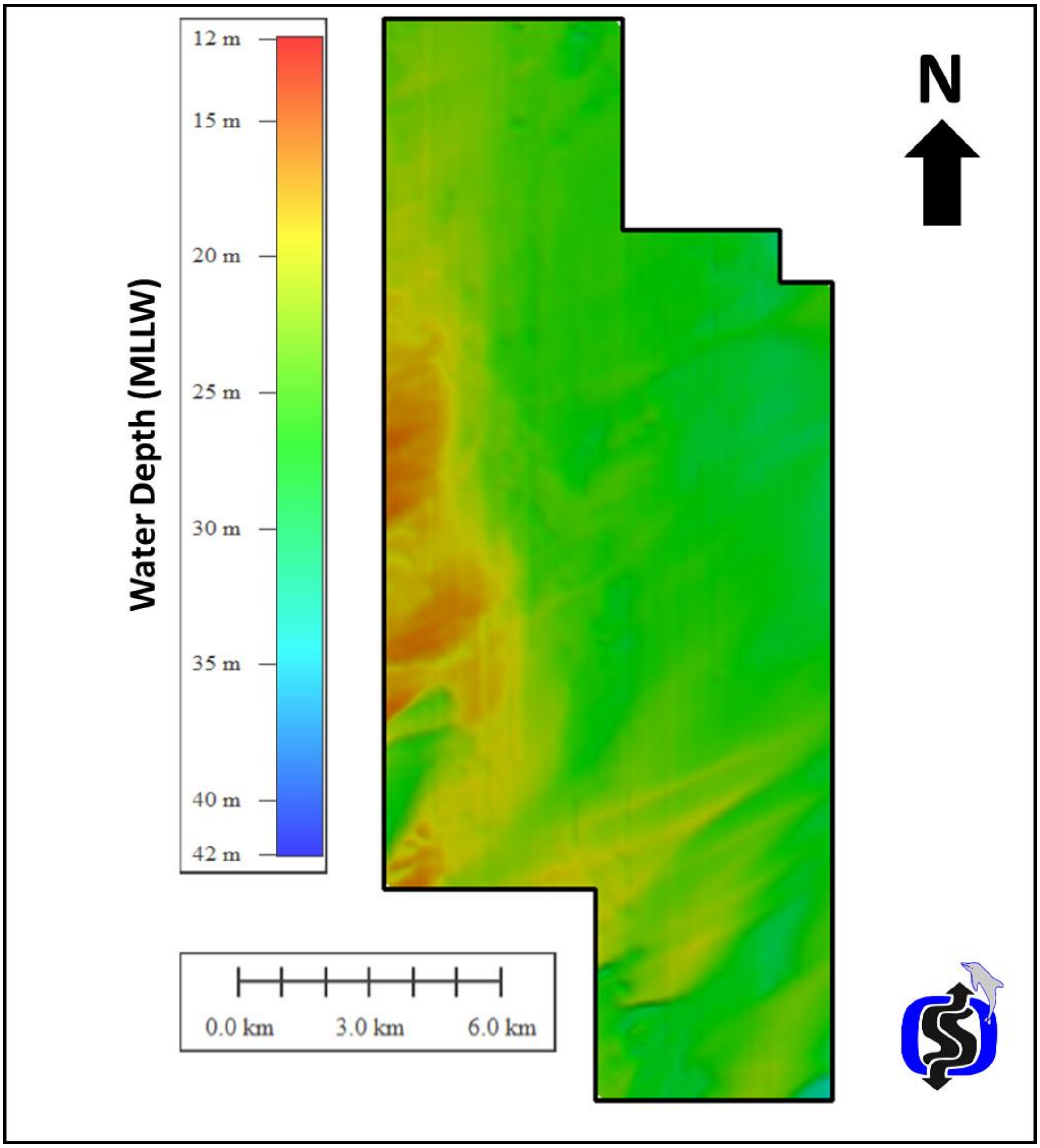

Figure 7.2 Survey Area Multi-Beam Bathymetry Grid (Collected during the 2013 MEA survey)

7.4 Side-Scan Sonar Data

7.4.1 Data Processing & Analysis

Side-scan sonar XTF data was collected using SonarPro and imported into Chesapeake's SonarWiz processing software. SonarWiz was used to apply navigation smoothing, seafloor tracking, gain adjustments and slant range correction. A mosaic was created for each survey line file, as well as a mosaic for the overall US Wind survey area. If identified, sonar contacts are chosen, mapped, measured and exported in a contact report. Electronic SSS deliverables are provided in Appendix L. Interpreted seafloor features are presented on Chart 3 included with this report. Chart 3 includes a bottom sediment type classification, location of mapped sand ridges, magnetic anomaly locations, side scan sonar targets as well as the environmental station locations which were investigated with grab samples and underwater camera photos and video.

7.4.2 Data Discussion

Side-scan sonar data were collected at a 50m range with 30m line spacing, providing greater than 100% overlapping bottom coverage. The overlap provides coverage within the nadir on adjacent survey lines and allows better target location. Some areas of the survey showed evidence of refraction in the outer portion of the sonar beam due to the thermocline. When the towfish could be flown below this layer, the overlap from adjacent lines provides the required coverage. The side scan towfish was flown at an altitude of 5–7m (10-15% of the range) above the seabed to maintain effective backscatter and accurate slant range corrections.

The side scan sonar mosaic of the survey area reveals two seafloor sediment types. The first sediment type is classified as variable reflectivity, alternating between fine-grained sand and medium to coarse-grained sand mixed with gravel (Figure 7.3). The second, more predominant sediment type is classified as moderate reflectivity, signifying medium to coarse-grained sand mixed with gravel (Figure 7.4). The survey area is characterized by regions of small bedforms, or sand ripples located throughout the survey location (Figure 7.3). The sand ripples range in wavelength from 50cm to 160cm and range in wave height from 5cm to 17cm. The axis of the sand ripples is aligned on a bearing ranging between 340˚ and 10˚. Larger scale sand ridge features were observed on the seafloor in the southern and western portions of the survey block. The locations of these sand ridges are identified by dashed lines surrounding the area containing the sand ridge features on Chart 3 and represent areas of potential bottom sediment transport.

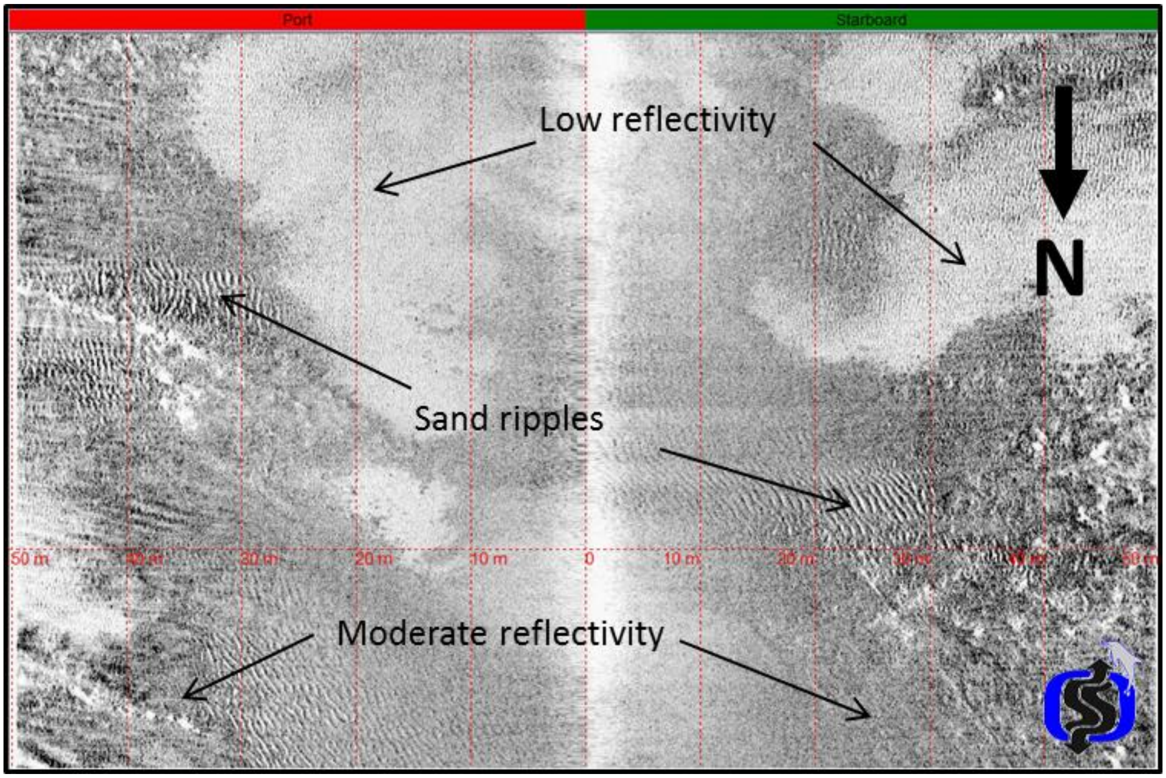

Figure 7.3 Side Scan Imagery Showing Variable Sediment Type and Sand Ripples

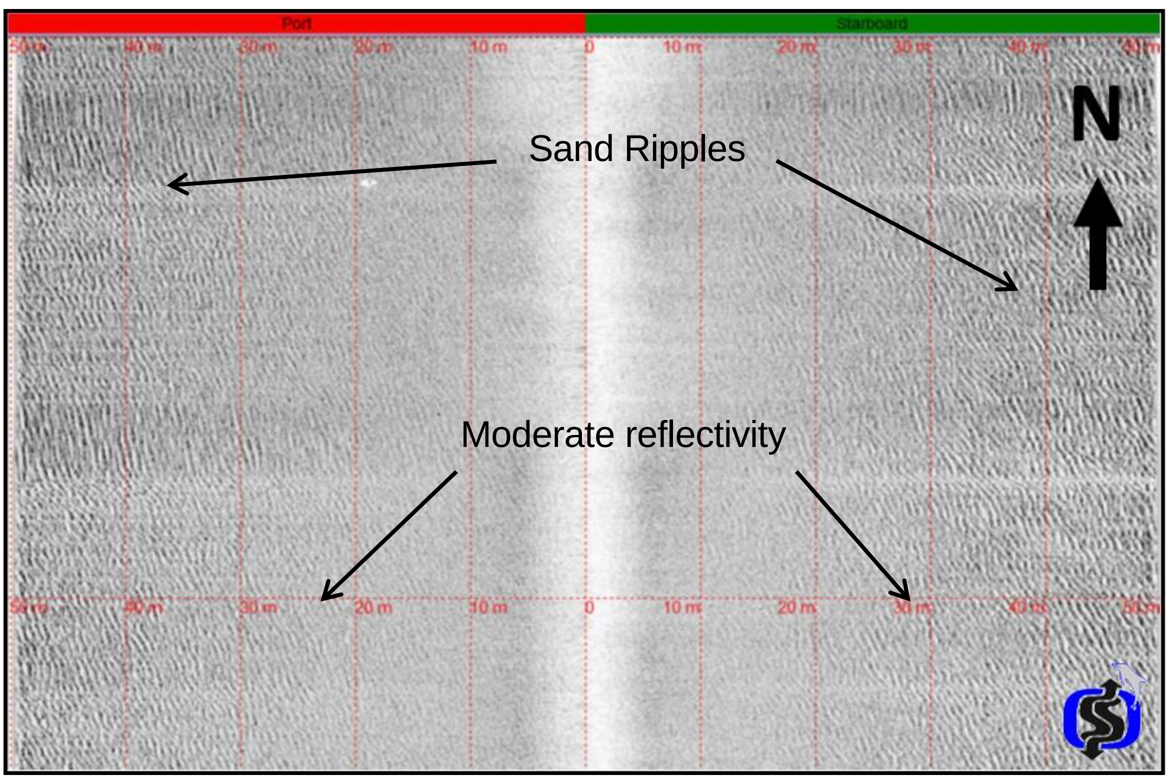

Figure 7.4 Side Scan Imagery Showing Moderate Reflective Sediment Type

The side scan imagery showed a total of 1,468 sonar targets located in the US Wind survey area. The heights above the seafloor of side scan sonar targets ranged from 0.1m to 2.6m. The majority of these targets were classified as small objects or debris with the exception of four known shipwrecks and two potential unknown wrecks. The four known shipwrecks are seen on nautical charts and the locations of these wrecks are marked on Chart 3. The first known shipwreck, labeled WK001, is located in the northwest region of the survey area (Figure 7.5). WK001 measured 32m in length, 13.5m in width and 2.6m in height. Another known shipwreck, labeled WK002, was located in northern region of the survey area (Figure 7.6). WK002 measured 13m in length, 4.4m in width and 0.5m in height. A third known shipwreck, labeled WK003, was observed in the middle of the survey area near line 161 (Figure 7.7). Wrk03 measured 43.5m in length, 13.1m in width and 1.4m in height. The fourth known shipwreck, labeled WK004, was located in the southeastern region of the survey area (Figure 7.8). WK004 measured 25.8m in length, 5.7m in width and 1.6m in height. Two other significant side scan targets were observed, which may be potential wrecks but are uncharted. Target 89 which is located in the northwestern region of the survey area approximately 300m west of WK001, appears to be a possible wreck but it could not be verified and has no associated mag targets (Figure 7.9). Target 752, located in the southeastern section of the survey area near WK004, is also a possible shipwreck (Figure 7.10). This potential wreck has a ship shape and shows relief but it could not be confirmed as a wreck and has no associated mag targets. All side scan sonar targets were compared to magnetometer targets for association within 10m of each other. There were a total of 52 magnetometer associations among the 1,468 side scan targets. The exact target associations can be seen in the side scan target table in Appendix D.

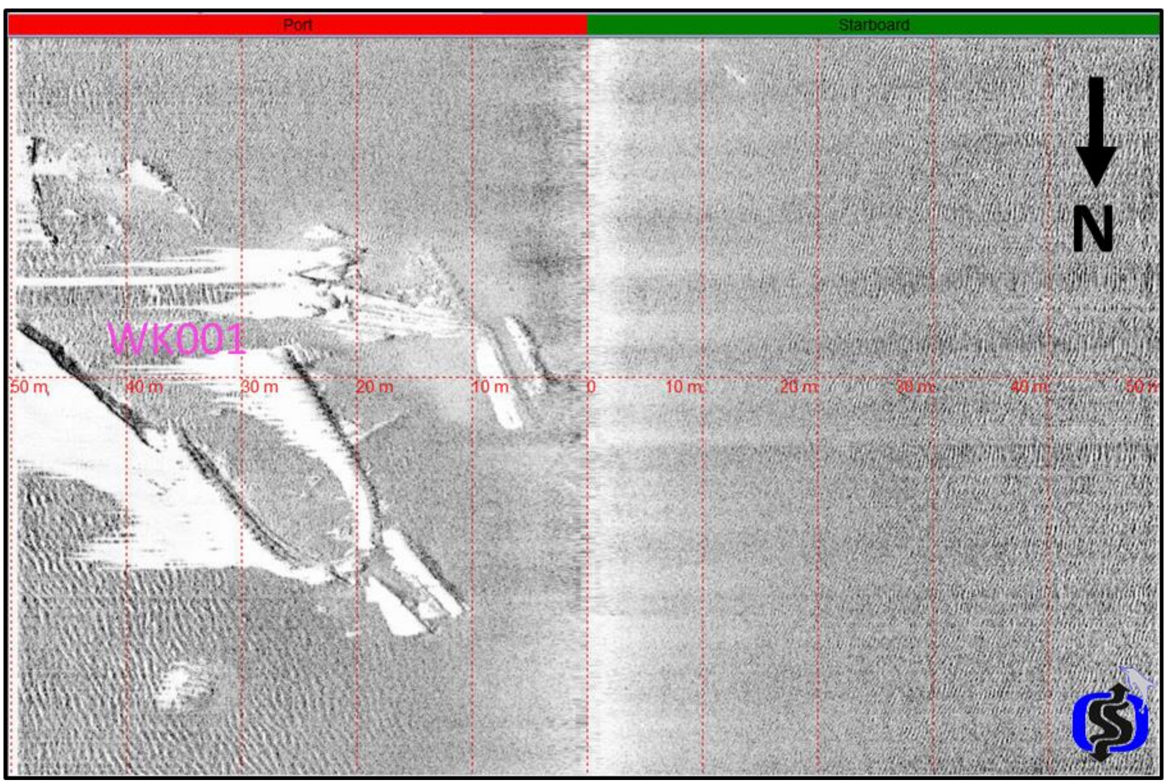

Figure 7.5 Known Wreck WK001 Observed in Side Scan Imagery

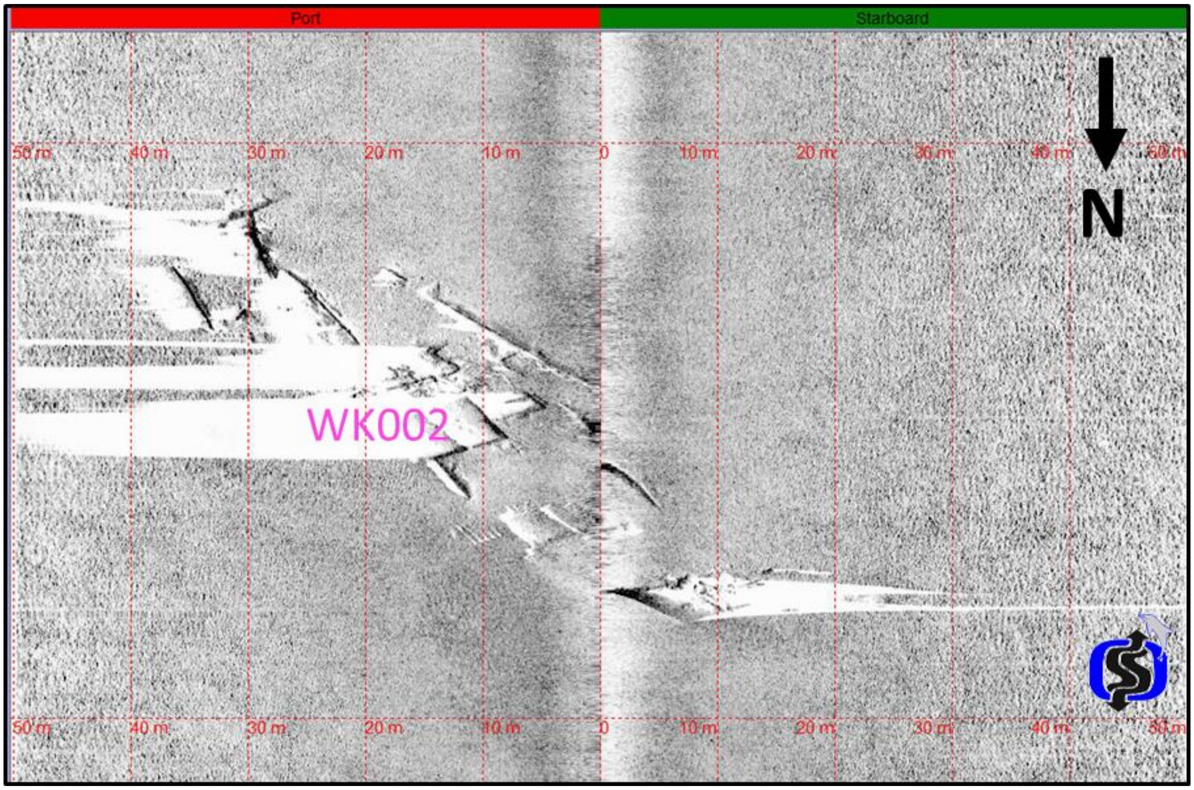

Figure 7.6 Known Wreck WK002 Observed in Side Scan Imagery

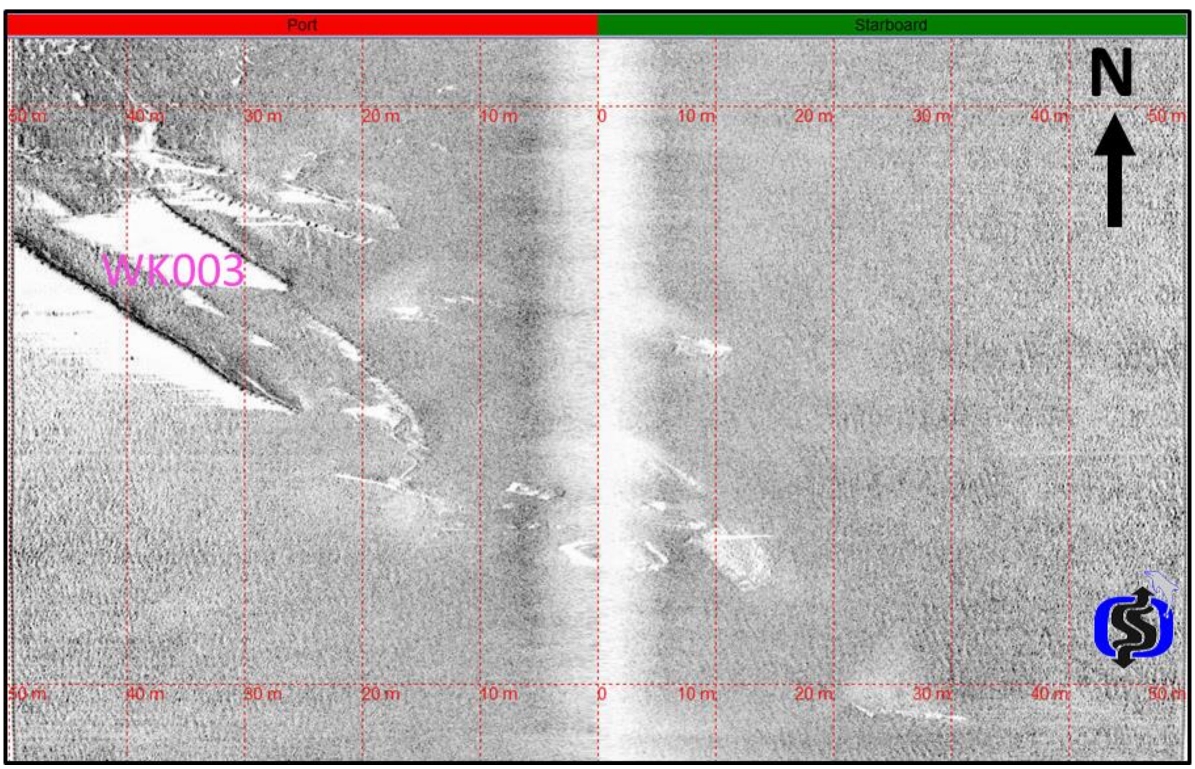

Figure 7.7 Known Wreck WK003 Observed in Side Scan Imagery

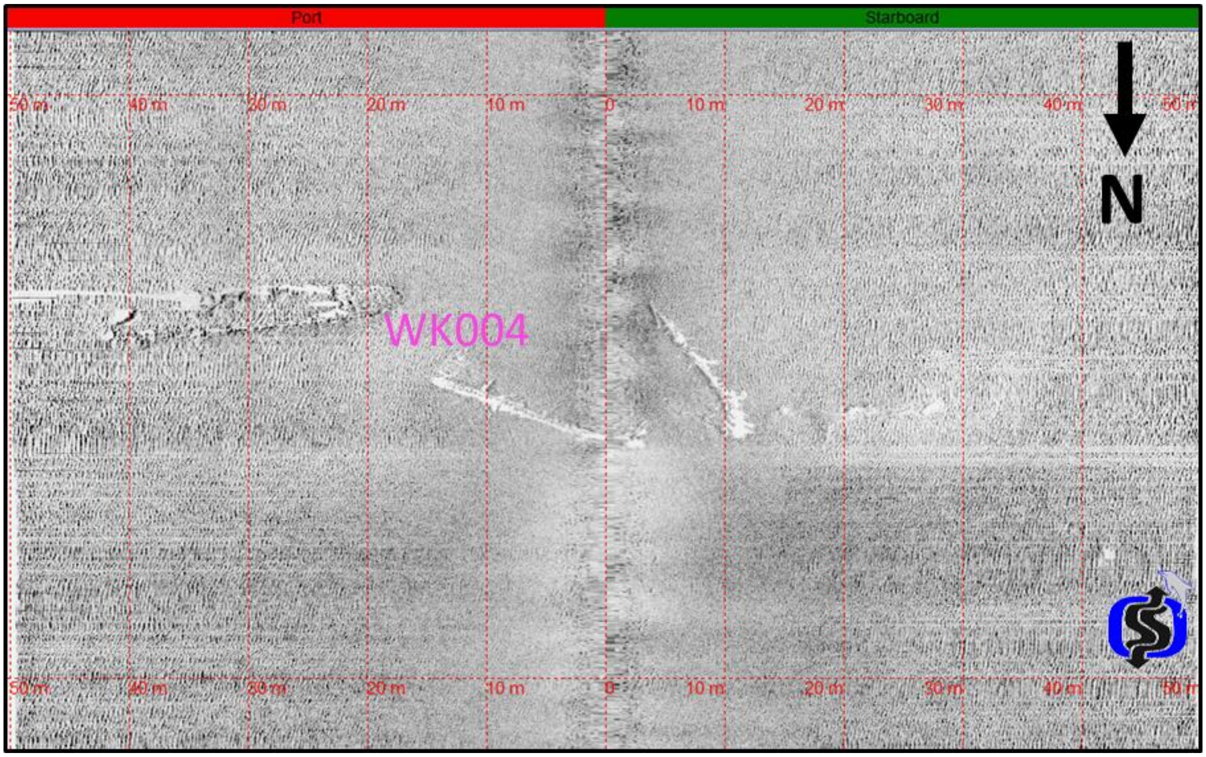

Figure 7.8 Known Wreck WK004 Observed in Side Scan Imagery

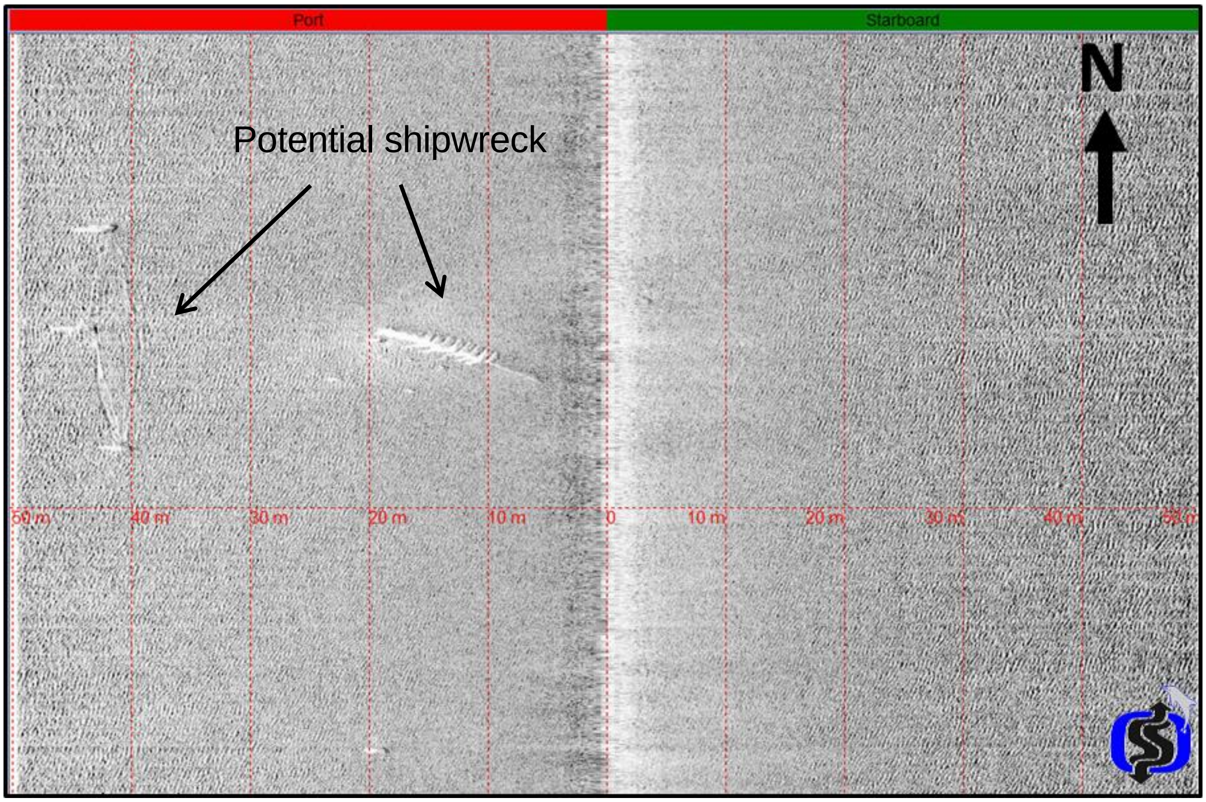

Figure 7.9 Potential Wreck Observed in Side Scan Imagery (Target 89).

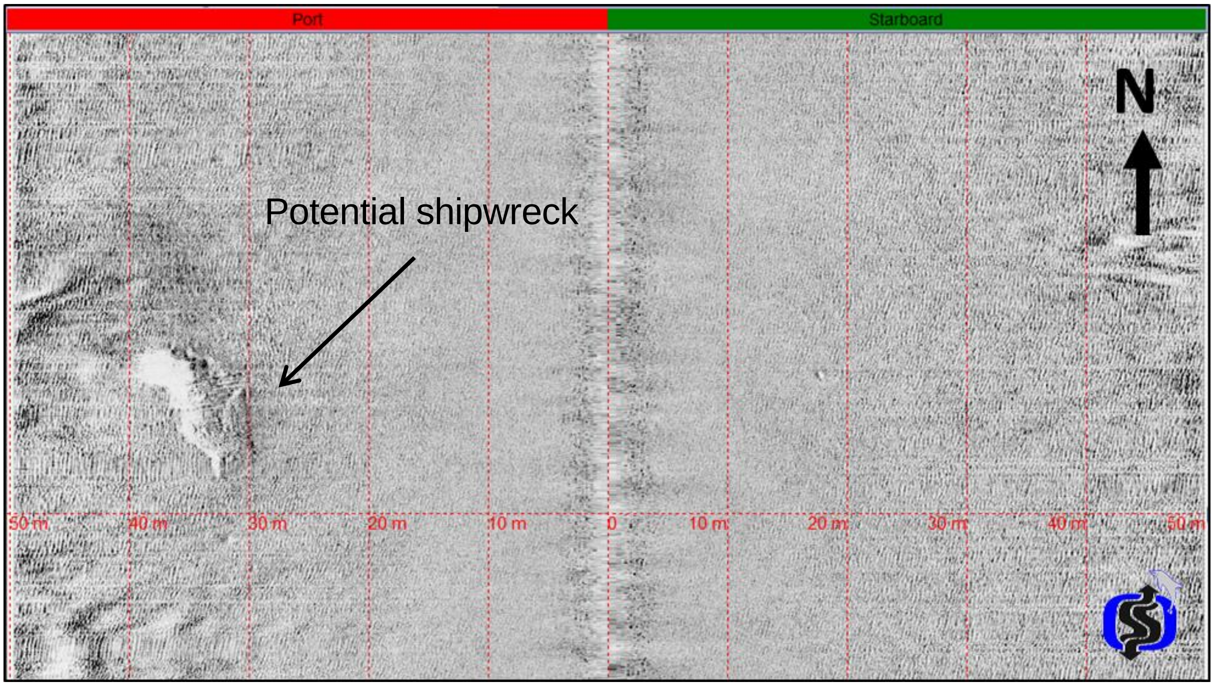

Figure 7.10 Potential Wreck Observed in Side Scan Imagery (Target 752).

7.5 Magnetometer Data

7.5.1 Data Processing & Analysis

Magnetometer data collected with Geometrics' MagLog software were post-processed using Geometrics' MagPick program. The data was edited for navigation fliers and data spikes before removing the regional background and diurnal variation. All data were corrected to a USGS magnetic base station located in Fredricksburg, VA to correct for diurnal drift. Good results were achieved by using MagPick's linear transformation to further remove the background magnetic field and diurnal variation. The linear transformation was performed on the MAG data collected in 2013 and the current data set.

Although most of the data could be smoothed, some data from the 2013 survey produced large anomalous spikes due to large, rapid altitude changes in the magnetometer towfish. These spikes caused by towfish altitude changes were not observed during the current survey and is attributed to the influence of the ship's hull on the magnetometer data. The 2013 survey was conducted on a large steel hull ship which can cause large magnitude magnetic flux changes when changing the distance of the magnetometer sensor from the ship's hull by raising/lowering the towfish. The current survey was conducted on an aluminum hull ship which did not affect the magnetometer data when raising/lowering the towfish sensor.

After removal of the background and diurnal variation the two data sets were merged. The resultant anomaly data was gridded at a 5m cell size and exported as 50nT contours, and as color shaded geo-referenced image. Magnetic anomalies were also picked and exported in a tabular format. Electronic MAG deliverables are provided in Appendix L.

7.5.2 Data Discussion

After reviewing the processed MAG data from the US Wind survey area, a total of 2,717 magnetic anomalies were identified. These anomalies ranged from 5nT to 32,150nT and were made up of dipoles, negative monopoles and positive monopoles. The MAG sensor was flown less than 6m above the bottom throughout the survey area.

Of the 2,717 detected magnetic anomalies, only 52 could be associated with observed side scan targets. The absence of sonar contacts near most of the magnetic anomalies suggests that these features may be buried in the shallow sub-surface. The sensor did locate the four known shipwrecks located in the survey area that were seen in side scan imagery. Two of these shipwrecks (WK001 and WK 002) can be seen in the magnetic contour map in the northwest region of the site (Figure 7.11). MAG anomalies with amplitudes between 5nT and 30nT were classified as small ferrous objects and anomalies with amplitudes between 30nT and 400nT were classified as medium-sized ferrous objects. Any anomalies above 400nT were related to known shipwrecks or considered possible underlying geology as most MAG anomalies did not associate with side scan targets.

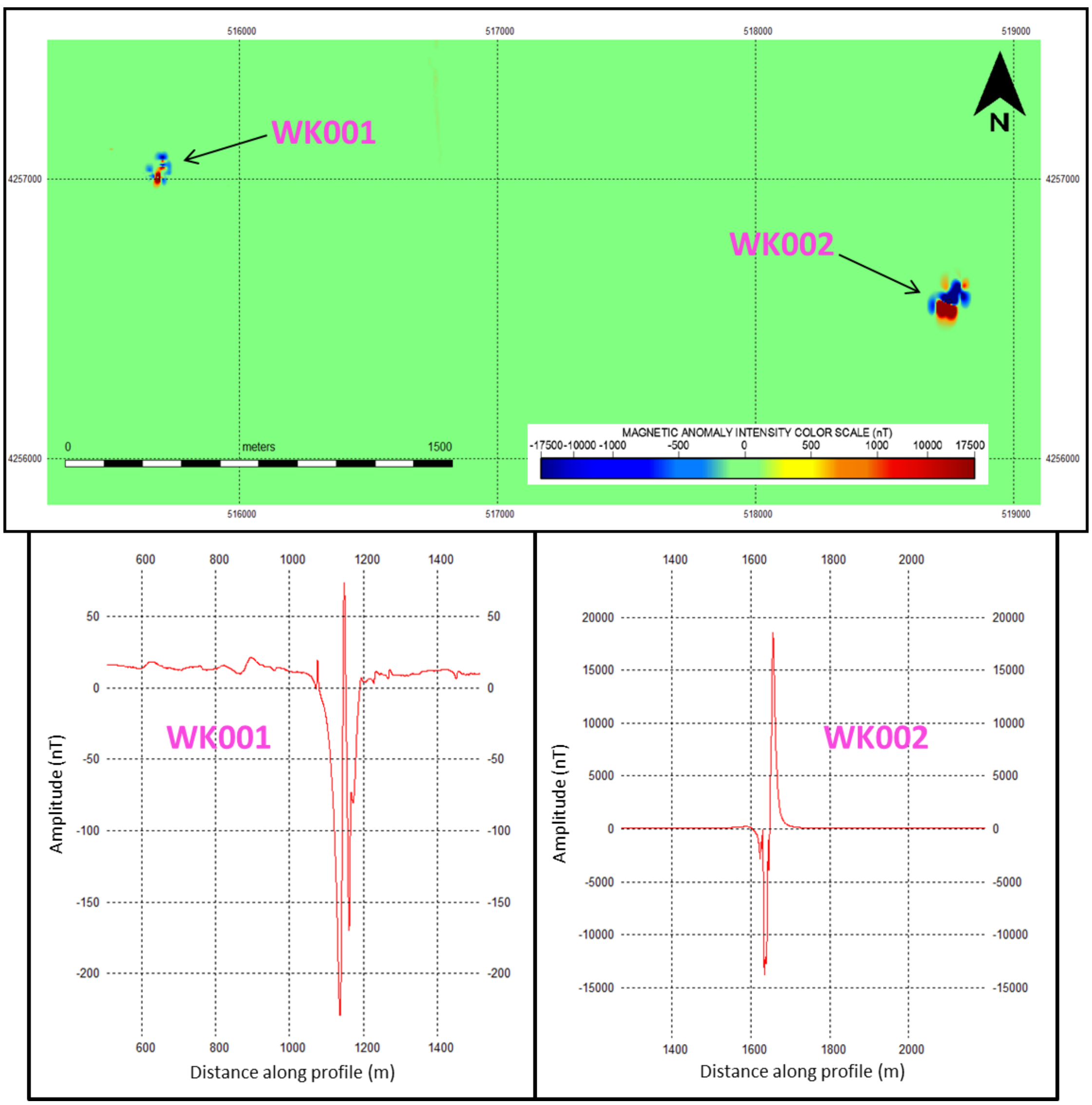

Figure 7.11 Wrecks WK001 and WK002 Magnetic Contour Maps and Amplitudes

All magnetic anomaly locations and supplemental data can be found in a table in Appendix C. The magnetic contour map of the entire US Wind survey area can be seen in **Chart 4**.

It should be noted that the coastal and OCS regional magnetic environment offshore Maryland is characterized by a strong geologic influence. The measured magnetic signal is very sensitive to sensor height off the bottom. Sea swell heights throughout the survey were commonly 1m or more, with heave motion experienced by the vessel being induced to the trailing towfish. These swell induced movements of +/-1m translated to approximately 5nT of flux in the readings. This phenomenon has been observed by Alpine on previous survey projects offshore Maryland. It was also observed in the 2013 survey data provided to the MEA. This effect is exaggerated during poorer weather conditions, and is less pronounced during fair weather and calm seas.

7.6 Shallow Penetration Sub-Bottom Profile Data

7.6.1 Data Processing & Analysis

Sub-bottom profile data collected with the CHIRP III system was processed in Chesapeake's SonarWiz software program. Each profile was bottom tracked and applied with a time varying gain. Any significant reflectors identified were mapped and exported as an ASCII XYZ thickness, or isopach file. This thickness file was merged with the data provided to Alpine from the MEA survey in 2013, and then contoured at a 0.5m interval. The contoured isopach data was then integrated with acquired multibeam bathymetry to produce a shallow structure map which was contoured at 1m and referenced to MLLW. The shallow isopach map can be seen in **Chart 5** and the shallow structure map can be seen in **Chart 6.** Electronic sub-bottom deliverables are provided in Appendix L.

7.6.2 Data Discussion

Sub-bottom penetration with the CHIRP system was restricted to approximately 6m to10m below the seafloor throughout the survey area however a wide-spread sub-parallel reflector was identified and mapped in the upper 0m to 7.3m of the seafloor. This reflector is interpreted as a ravinement surface representing an erosional boundary between late Pleistocene and early Holocene sediments, remnant from the last global sea level rise (Figure 7.12). The ravinement surface mapped with the CHIRP system correlates to the A1 reflector described in Section 6.0. The reflector is described as the boundary between the ravinement surface formed by shoreface erosion and modern shelf deposits (Wells, 1994). This surface also correlates to the base of Unit 1 as mapped by the 2013 MEA survey conducted by Coastal Planning & Engineering (CP&E).

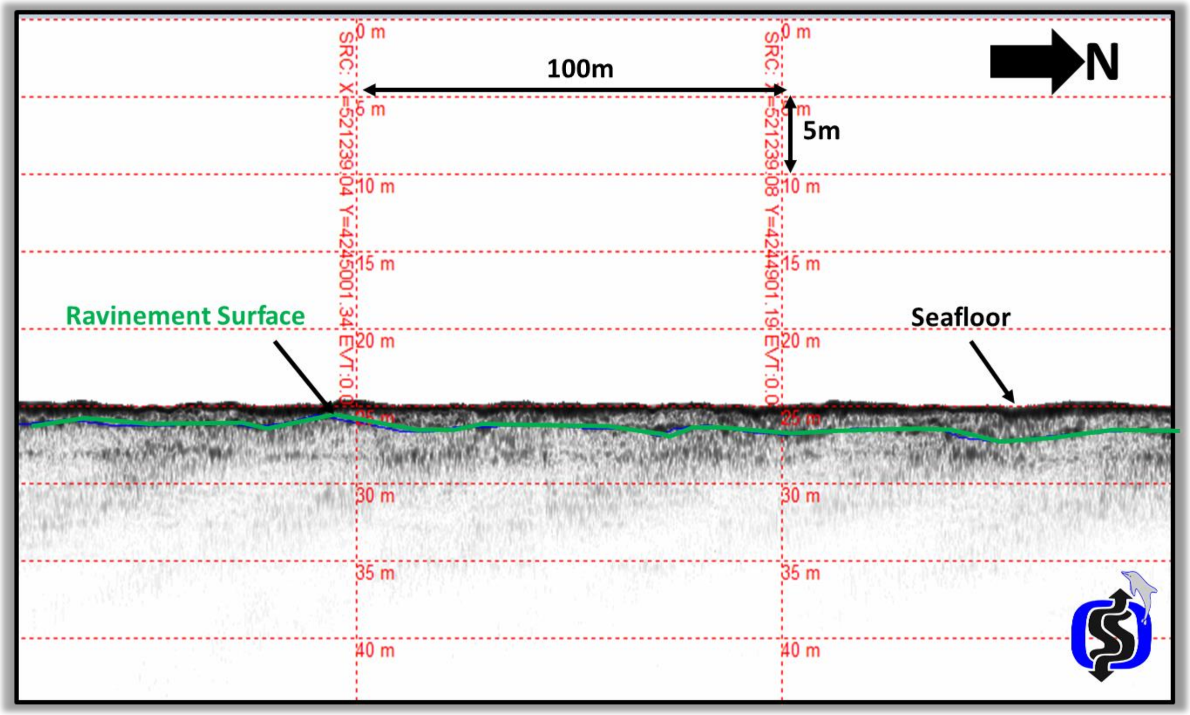

Figure 7.12 Sub-Bottom Profile Showing the Ravinement Surface

Similar to the survey conducted in 2013, CHIRP sub-bottom data collected by Alpine in the US Wind area detected two sub-surface units. Unit 1 is a thin surficial sheet of Holocene sandy marine sediments, ranging in thickness between 0m and 7.3m throughout the site. Areas with larger Unit 1 thicknesses were observed where sand ridge features have developed on the seafloor near the western and southwestern boundary of the survey area (Figure 7.13).

The CHIRP system was capable of penetrating only into the upper few meters of Unit 2, or channel complex as described during the previous survey. Throughout the survey, the CHIRP system identified many buried paleo-channel features in Unit 2. These channels are remnant features of inactive river or estuary channels that have been covered by newer sediment layers within the seafloor stratigraphy (Figure 7.14). The buried channel features were more prevalent on the western side of the survey area and are presented on Chart 7 (Hazards Map). Inshore sub-bottom data also revealed areas of horizontal strata with layering indicative of low energy sediment deposition (Figure 7.14), typically characterized by finer-grained sediments (silt-clay and fine sand).

All raw SEGY sub-bottom seismic files as well as XYZ files for the Holocene reflector thickness and for paleo-channel reflector thickness can be found in Appendix L.

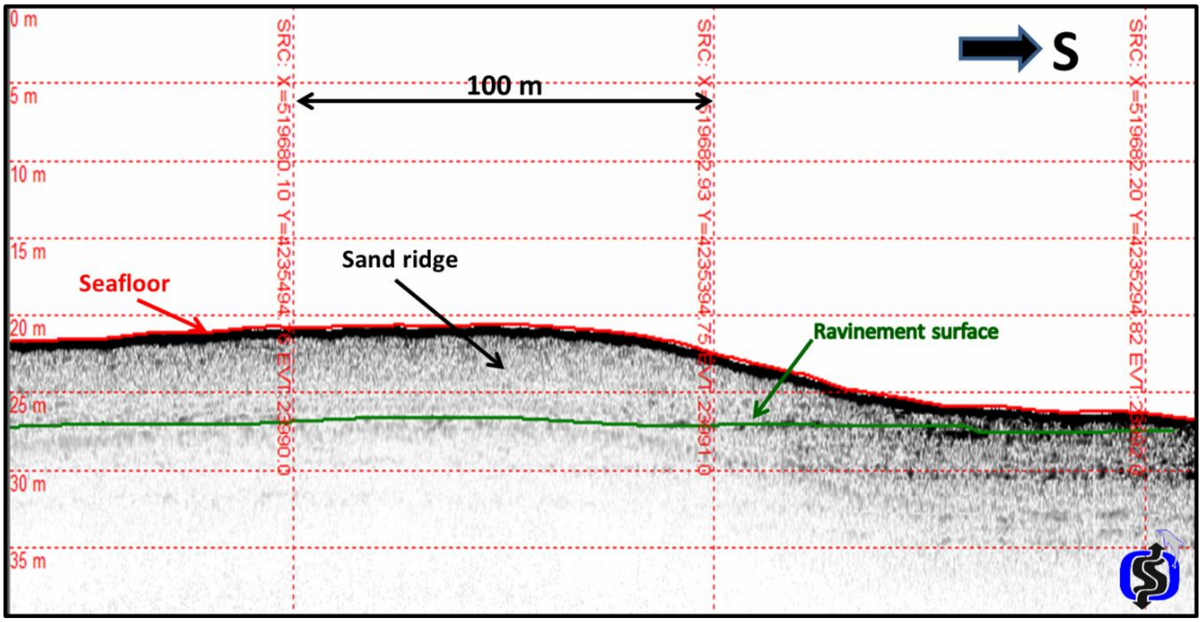

Figure 7.13 Sub-Bottom Profile Showing Unit 1 Thickness Changes due to Sand Ridges

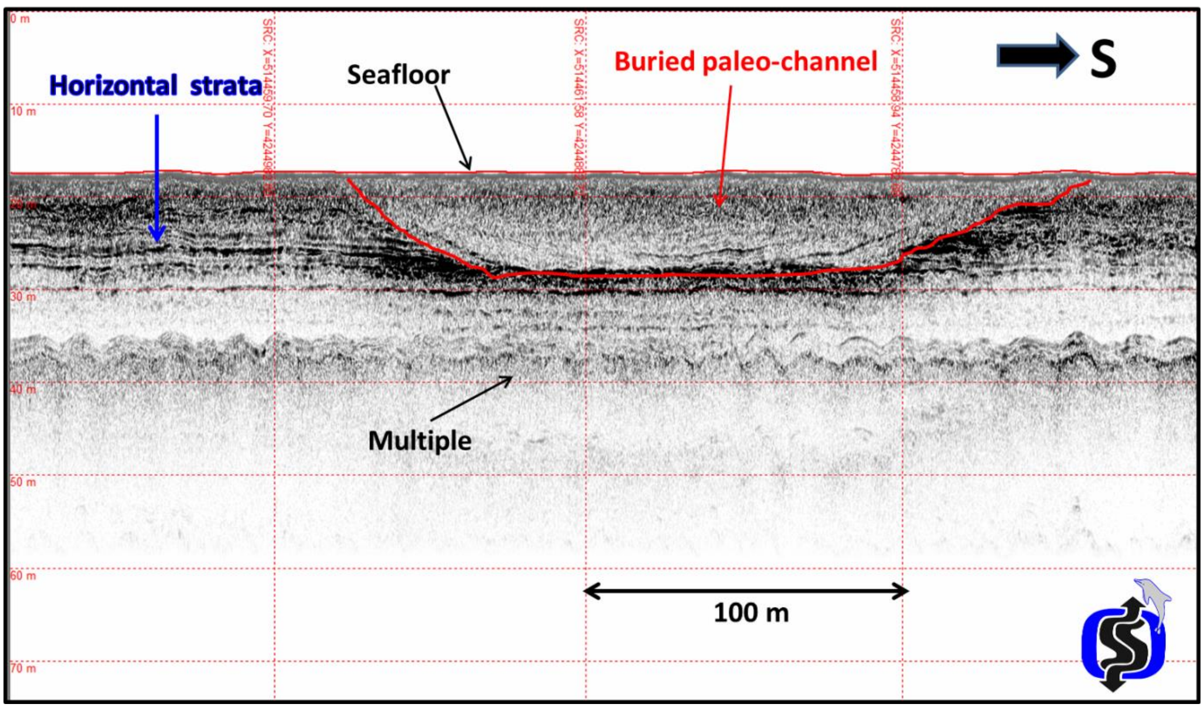

Figure 7.14 Sub-Bottom Profile Showing Paleochannel Feature in Unit 2 and Horizontal Strata

7.7 Borehole and CPT Data

During the survey of the US Wind planned WTG area, a composite geotechnical Borehole and CPT push was conducted at the MET tower location and six other pre-selected sites. A full geotechnical report including borehole logs and photographs for the MET tower location are presented in Appendix A of this report.

Near surface borehole information was compared to the CHIRP sub-bottom data collected over the MET tower location. The ravinement surface mapped in the sub-bottom data correlates well to a thin gravel layer overlying a clay lamina at approximately 1m below the seafloor. Geotechnical results correlate well to the medium penetration sub-bottom data collected near the MET tower location during the 2013 CP&E survey. Three units were identified in the geophysical data along Line 91, approximately 50m east of the MET tower location.

- Unit 1 – Recent Holocene sandy sediments
- Unit 2 – Pleistocene channel complex
- Unit 3 – Pre-Pleistocene sub-parallel sands and clays

A detailed comparison between geotechnical data at the MET tower and the medium penetration sub-bottom data collected by CP&E is presented in Appendix A.

Geotechnical data and sample analyses for the other six boreholes across the survey area are not integrated into the scope of this geophysical report.

8. HAZARDS SUMMARY

8.1 Seafloor Hazards

The geophysical and geotechnical data sets were reviewed and analyzed for potential seafloor hazards that may adversely impact installation and maintenance of the proposed wind farm. Following this review some small potential hazards were identified on the seafloor within the survey area including seafloor slopes and sand ripples. Table 7.1 below summarizes some of the common seafloor hazards and whether they were identified within the survey area.

Hazard	Identification/Description
Steep Seafloor Slopes	Small slopes of 2-5% grade, seen in western and southern region of the survey area.
Sediment Failure / Mass Movement	Not present
Bedforms / Sediment Transport	Present throughout the survey area in the form of sand ripples. Wavelengths and ripple heights are centimeter level in scale and likely do not pose a large risk to turbine installation or operation. Larger scale sand ridges also present in west and south part of survey area, which may pose a hazard with higher volumes of sediment transport.
Rock or Hard-bottom	Not present
Diapiric Structures	Not present
Faulting	Not present
Gas or Fluid Expulsion	Not present
Water Scour	Potential scour area identified in southwest area of survey, adjacent to sand ridges
Channels	Not present

Table 7.1 Seafloor Hazards

8.2 Sub-Surface Hazards

A review and analysis of the sub-bottom profiler and borehole data was also conducted to identify possible hazards in the sub-surface. The table below presents typical sub-surface hazards, and which were identified in the US Wind survey area.

Hazard	Identification/Description
Faults	Not present
Sediment Failure / Mass Movement	Not present
Shallow Rock	Not present
Diapiric Structures	Not present
Shallow Gas	Not present
Gas or Fluid Expulsion	Not present
Channels	Buried paleo-channels can be seen throughout the survey area.
Seismic Activity	Not present
Volcanic Activity	Not present

Table 7.2 Sub-Surface Hazards

8.2 Man-Made Hazards

All data sets were reviewed for potential anthropogenic, or “man-made” hazards. The table presented below lists typical man-made hazards in the marine environment and if they occur within the survey area.

The US Wind WTG area lies within the FACSFAC VACAPES Operating Area operated by the US Navy and accessible by the entire US military. The entire Maryland WEA is located in Warning Area 386 which is a special-use airspace. Military operations are known to occur within W-386 including flight testing, munitions deployment and general training exercises. While no obvious features were observed lying on the seafloor, there is a potential for shallow buried unexploded ordnance (UXO) in the area.

Hazard	Identification/Description
Shipwrecks	Four known shipwrecks and two potential wrecks were discovered within the survey area.
Debris	Many small areas of debris can be seen in SSS imagery throughout the survey area.
Cables	Not present
Pipelines	Not present
Ordnance	Possible throughout survey area due to active present and past military use in W-386 area. Many minor magnetic anomalies were identified with potential to be related to shallow buried UXO.
Cultural Resources	Four known shipwrecks and two potential unknown wrecks, to be confirmed by a Professional Archaeologist

Table 8.1 Man-Made Hazards

9. REFERENCES

Coastal Planning & Engineering, Inc., a CB&I Company, 2014, Maryland Energy Administration High Resolution Geophysical Resource Survey (Project Number DEXR240005) Final Report of Investigations. Boca Raton, Florida: Coastal Planning & Engineering, Inc., a CB&I Company, 109p. (Prepared for the Maryland Energy Administration).

Conkwright, R. D., and Williams, C. P., 1996, Offshore Sand Resources in Central Maryland Shoal Fields: Department of Natural Resource, Maryland Geological Survey, Coastal and Estuarine Geology, File Report No. 96-3

Duane, D.B., Field, M.E., Meisburger, E.P., Swift, D.J., and Williams, S.J., 1972, Linear shoals on the Atlantic inner continental shelf, Florida to Long Island; in, D.J. Swift, D.B. Duane, and O.H. Pilkey, eds., Shelf Sediment Transport: Process and Pattern: Dowden, Hutchinson, and Ross, Stroudsburg, Pa, p. 447-498.

Emery, K.O., 1966, Atlantic continental shelf and slope of the United States, a geologic background: U.S. Geological Survey Prof. Paper 529-A, p. 1-23.

Field, M.E., 1976, Quaternary evolution and sedimentary record of a coastal plain shelf: Central Delmarva Peninsula, Mid-Atlantic Bight, U.S.A.: Ph.D. Dissertation, Dept. Geology, George Washington Univ., Washington, D.C., 200 pp.

Field, M.E., 1980, Sand bodies on Coastal Plain shelves; Holocene record of the U.S. Atlantic inner shelf of Maryland: Jour. Sed. Petrology, vol. 50, p. 505-528.

Kraft, J.C., 1971, Sedimentary facies patterns and geologic history of a Holocene marine transgression: Geol. Soc. Am. Bull., v.82, p. 2131-2158.

Maryland Geological Survey, Maryland Geology, 2015, http://www.mgs.md.gov/geology/index.html

McBride, R.A., and Moslow, T.F., 1991, Origin, evolution, and distribution of shoreface sand ridges, Atlantic inner shelf, U.S.A.: Marine Geology, vol. 97, p. 57-85.

Swift, D.J. and Field, M.E., 1981, Evolution of a classic sand ridge field: Maryland sector, North American inner shelf: Sedimentology, vol. 28, p. 461-482.

Shepard, F.P., 1963, Submarine Geology, Harper and Row, New York, NY., 2nd ed., 557 pp.

Toscano, M. A., Kerhin, R. T., York, L. L., Cronin, T. M., and Williams, S. J., 1989, Quaternary stratigraphy of the inner continental shelf of Maryland: Maryland Geological Survey, Report of Investigations No. 50, 116 p.

Veach, A.C., and P.A. Smith, 1939, Atlantic submarine valleys of the United States and the Congo submarine valley: Gol. Soc. Am. Spec. Paper 7, 101 pp.

Wells, D.V., 1994, Non-energy resources and shallow geologic framework of the inner continental margin off Ocean City, Maryland: Maryland Geological Survey Open File Report No. 16, Baltimore, MD.

APPENDICES

APPENDIX A GEOTECHNICAL REPORT

APPENDIX B PROTECTED SPECIES OBSERVER REPORTS

APPENDIX C MAGNETIC ANOMALY TABLES

APPENDIX D SIDE SCAN SONAR TARGET TABLES

APPENDIX E SIDE SCAN SONAR TARGET REPORT

APPENDIX F EQUIPMENT SPECIFICATION SHEETS

APPENDIX G EQUIPMENT CALIBRATIONS

APPENDIX H SURVEY LOGSHEET

APPENDIX I WEATHER SUMMARY

APPENDIX J DAILY PROGRESS REPORTS

APPENDIX K SOUND VELOCITY PROFILES