Appendix II-A1

Integrated Site Characterization Report

www.essgroup.com

McNeilan & Associates

converting challenges into opportunities

INITIAL, INTEGRATED GEOPHYSICAL & GEOTECHNICAL (G&G) SITE CHARATERIZATION REPORT

US WIND OFFSHORE WIND PROJECT

MARYLAND OCS

Prepared for:
US WIND INC.
Baltimore, MD

Document No. 19-03-07
Issue Date: August 24, 2020

McNeilan & Associates, LLC
Norfolk, Virginia

this page intentionally blank

INITIAL G&G SITE CHARACTERIZATION REPORT
US WIND OFFSHORE WIND PROJECT, MARYLAND OCS

TABLE OF CONTENTS

1.0 INTRODUCTION, ADMINISTRATIVE DETAILS, AND CONCLUSIONS 1
1.1 US Wind Offshore Wind Project 1
1.2 Purpose of Report 1
Initial G&G Site Characterization Report Purpose 1
Development of an Integrated G&G Site Characterization 2
Future Updates to Integrated G&G Site Characterization Report 2
1.3 Report Authorization 3
1.4 Report Organization 3
1.5 Definitions and Terminology 4
1.6 Conclusions 5
2.0 PROJECT DESCRIPTION 6
2.1 Lease and Site Description 6
2.2 Proposed Wind Farm Development 6
2.3 Lease Infrastructure 6
2.4 Export Cable 7
3.0 PREVIOUS G&G PROGRAMS 7
3.1 Geophysical Surveys 7
CB&I – Preliminary Lease Survey (2013) 8
Alpine – (Partial) Lease Survey (2015) 9
Alpine – Export Cable Route Survey (2016) 10
HRG Systems Used During Previous Surveys 10
Limitations of Previous Survey Data Sets 11
3.2 Geotechnical Exploration Programs 12
Gardline – Preliminary Geotechnical Exploration Lease Program (2015) 12
Alpine – Export Cable Route Sampling Program (2016) 13
3.3 Supplemental Data Processing & Evaluations 13
Oceaneering – CB&I Seismic Reflection Data Set Reprocessing (2020) 13
Fugro Pile Driving Assessments (2015 and 2020) 14
4.0 SITE AND SEAFLOOR CONDITIONS 14
4.1 Regional Conditions 14

Regional Physiography 14
Common Physiographic Features 15
4.2 Water Depth & Bathymetry 16
Water Depth 16
Seafloor Slope 17
4.3 Seafloor Morphology and Seafloor Features 18
4.4 Seafloor Sediments 19
5.0 GEOLOGIC CONSIDERATIONS 19
5.1 Geologic Setting 19
5.2 Geologic Processes During the Quaternary 20
Drainages and Paleo-Channels 21
Shoreline Retreat 21
Stratigraphic Complexity 22
Current Conditions 23
5.3 Late Pleistocene – Holocene Sea Level Transgression 23
5.4 Pre-Quaternary Geology 23
6.0 SUBSURFACE CONDITIONS 24
6.1 HRG Data and Interpretations 24
Data Synopsis 24
Interpretation Overview 24
CB&I (2013) Interpretation 25
Oceaneering Reinterpretation 25
Discussion 26
6.2 Geologic Horizon and Stratigraphic Units 27
Geologic Horizon 27
Continuity of Mapped Horizon 28
Strata Description 29
6.3 Geophysical – Geotechnical Correlation 31
Gardline (2015) Interpretation 31
Comparison of Gardline Interpretation with Reprocessed Seismic Records 32
6.4 Subsurface Features 32
Surficial Sediments (Stratum 1a) 32
Presence of Channeling (with Strata 1b and 2a) 32
7.0 INITIAL GEOHAZARDS EVALUATION 33
7.1 Sediment Transport and Scour 33

7.2 Subsurface Conditions and Variability 35
7.3 Seafloor Conditions and Variability 36
7.4 Boulders 36
7.5 Shallow Gas 36
7.6 Seismic Hazards 36
Earthquake Ground Motions and Ground Shaking 36
Fault Rupture Hazard 37
7.7 Slope Instability 37
7.8 Tsunami Risk 37
7.9 Volcanism 37
8.0 INITIAL GROUND MODEL 38
8.1 Ground Modeling Process 38
8.2 Geophysical Horizon Mapping 39
Overview of Mapping Stages 39
Pre-COP-Phase HRG Interpretation & Mapping 39
Upcoming COP-Phase HRG Subsurface Interpretation 39
Site Zonation 39
8.3 Sediment Lithology and Seismic Stratigrahy Correlation 40
Initial, Global Interpretation 40
Future, 2nd Pre-COP, Preliminary Evaluation 40
8.4 Definition of Soil Properties 41
Initial, Global Interpretation 41
2nd COP-Phase Evaluation 42
9.0 CONCEPTUAL PILE DESIGN & INSTALLATION EVALUATION 42
9.1 Conceptual Pile Capacity Evaluation 42
Definition of Representative Soil Stratigraphy 42
Pile Capacity and Soil Stiffness 43
9.2 Pile Drivability 44
10.0 FUTURE G&G PROGRAMS 44
10.1 COP-Phase High-Resolution Geophysical (HRG) Survey 44
Survey Intent and Overview 44
Applicable BOEM Guidelines 45
Objectives of Bathymetry, Side Scan Sonar, and Gradiometer Data Acquisition 45
Objectives of Subsurface Geophysical Data Acquisition 45
Survey Corridors and Grid 46

10.2 Design-Phase Geotechnical Exploration Program 47
Lease Area 47
Export Cable Route 48
11.0 REFERENCES 48
11.1 Site- and Project-Specific References 48
11.2 Regulatory and Related Guidelines and Standards 49
11.3 General References 49

TABLES

Table 3-1 Geophysical Systems Used During Previous Surveys 11
Table 4-1 Correlation of Boring Locations and Mapped Seafloor Sediment Conditions 19
Table 6-1 Definition of Stratigraphic Units and Horizon 27
Table 6-2 Structural Horizon Elevations 29
Table 6-3 Correlation between Seismic Units and Geotechnical Strata 31
Table 6-4 Presence of Channeling at Boring Locations 33
Table 9-1 Lower and Upper Bound Soil Profile Formulation 43

FIGURES

Figure 1-1 Project Location
Figure 1-2 Lease & Site Location
Figure 1-3 Lease OCS-A-0490
Figure 2-1 Conceptual Turbine Grid Layout
Figure 2-2 Conceptual Turbine Grid Geometry
Figure 2-3 Export Cable Route Options
Figure 3-1 Previous Geophysical Survey and Geotechnical Exploration
Figure 3-2 Representative CB&I North-South Seismic Record
Figure 3-3 Representative CB&I East-West Seismic Records
Figure 3-4 CB&I (2014) Stratigraphic Interpretation
Figure 3-5 Gardline (2016) Stratigraphic Interpretation
Figure 3-6 Reprocessed C&I 2013 m-c Seismic Reflection Lines
Figure 3-7 Representative, Reprocessed CB&I Seismic Records
Figure 4-1 Regional Physiography
Figure 4-2 Regional Bathymetry
Figure 4-3 Lease Bathymetry
Figure 4-4a Lease Bathymetry at 2-meter Contour Intervals

Figure 4-4b Lease Bathymetry, at 0.5-m-Contour Intervals
Figure 4-5 Water Depth at 86 Hypothetical Turbine Locations
Figure 4-6 Seafloor Slope
Figure 4-7 Seafloor Morphology
Figure 4-8 Seafloor Sediment
Figure 5-1 Regional Stratigraphic Charts
Figure 5-2 Mid-Shelf Geologic Evolution
Figure 5-3 Channel Incision & Burial Schematic
Figure 5-4 Barrier Island and Tidal Estuary Schematics
Figure 5-5 Landward Migration of Barrier Islands
Figure 5-6 Schematic Mid-Shelf Geologic Profile
Figure 5-7 Late Pleistocene – Holocene Sea Level Rise Curve
Figure 6-1 Locations of Illustrated Seismic Reflection Records
Figure 6-2 Structural Contours on CB&I's Base Surface Sediments
Figure 6-3 Isopach (Thickness) of CB&I's Surface Holocene Sediments
Figure 6-4 Structural Contours on Oceaneering Horizon A
Figure 6-5 Structural Contours on Oceaneering Channel Base Horizon
Figure 6-6 Structural Contours on Oceaneering Horizon B
Figure 6-7 Structural Contours on Oceaneering Horizon C
Figure 6-8 East-West, Mid-Penetration Seismic Reflection Records
Figure 6-9 North-South, Mid-Penetration Seismic Reflection Records
Figure 6-10 Organized and Poorly-Organized Paleochannel and Tidal Sequences
Figure 7-1 Regional Sediment Mobility Hazard
Figure 8-1 Formulation of Lower- & Upper-Bound Strata Depths & Thicknesses
Figure 8-2 Interpreted Submerged Unit Weight Profiles
Figure 8-3 Interpreted Undrained Shear Strength Profiles
Figure 8-4 Interpreted Effective Angle of Internal Friction Profiles
Figure 9-1 Upper-Bound Stratigraphy Formulation
Figure 9-2 Lower-Bound Stratigraphy Formulation
Figure 9-3 Ultimate Axial Pile Capacity – Unit Skin Friction
Figure 9-4 Ultimate Axial Pile Capacity – Unit End Bearing
Figure 9-5 Ultimate Axial Pile Capacity – Global Upper-Bound Conditions
Figure 9-6 Ultimate Axial Pile Capacity – Global Lower-Bound Conditions
Figure 9-7 Comparison of Global Lower- & -Bound Axial Pile Capacity
Figure 10-1 COP-Phase HRG Survey Tartan Survey Corridors
Figure 10-2 COP-Phase HRG Survey Tartan Survey Corridor Detail
Figure 10-3 COP-Phase HRG Survey Seismic Reflection Data Collection Detail

this page intentionally blank

INITIAL GEOPHYSICAL & GEOTECHNICAL (G&G) SITE CHARACTERIZATION REPORT US WIND OFFSHORE WIND PROJECT, MARYLAND OCS

1.0 INTRODUCTION, ADMINISTRATIVE DETAILS, AND CONCLUSIONS

1.1 US WIND OFFSHORE WIND PROJECT

US Wind is proposing an offshore wind project of up to 1.5 gigawatts to be developed within its lease area off the coast of Maryland in the Maryland Wind Energy Area (WEA). The proposed project will include up to 125 Wind Turbine Generators (WTG) and up to four (4) Offshore Transformer Modules (OTM). The project will be interconnected into the existing Indian River substation near Millsboro, Delaware on the Delmarva Peninsula.

Figure 1-1 shows the location of US Wind's lease (the Bureau of Offshore Energy Management's [BOEM]'s designated Maryland offshore wind energy lease OCS-A-0490) on the Maryland Outer Continental Shelf (OCS). As shown on Figures 1-2 and 1-3, the lease is approximately 19.5 to 43 kilometers (12.1 statute or 10.7 nautical miles to 26.7 statute or 23.5 nautical miles) offshore from Ocean City, Maryland. The trapezoidal-shaped lease includes nine (9) full OCS Lease Blocks and portions of eleven (11) other OCS Lease Blocks (Figure 1-3)

1.2 PURPOSE OF REPORT

Initial G&G Site Characterization Report Purpose

This document is intended to provide an Initial, Integrated Geophysical & Geotechnical (G&G) Site Characterization Report (hereafter Initial Site Characterization Report or Initial Site Characterization) for US Wind's Offshore Wind Project on the Maryland Outer Continental Shelf (OCS).

This Initial, Site Characterization is based on the integrated interpretation of available geophysical survey and geotechnical exploration data and is intended to support two specific components of US Wind's project development. Those components are:

- The Project's Construction Operations Plan (COP), which was submitted on August 7, 2020, and
- The Project's Geotechnical Departure Request (GDR), which is to be filed concurrent with the COP filing.

The second (GDR) component is the primary purpose for the preparation of this report. To review the GDR, BOEM has indicated that the application should include (or refer to) US Wind's understanding and evaluation of the site and subsurface conditions. Thus, this report is intended to fulfill that requirement.

A future Preliminary, Site Characterization Report will include the results of planned high-resolution geophysical (HRG) survey. The Preliminary, Site Characterization Report will be prepared and submitted as part of the supplemental studies that are to be provided during the initial COP review period.

The preparation of this Initial, Site Characterization Report, and the subsequent updates of this Report (see subsequent discussion) have been (and will be) guided by the ground definition process (also referred to as Ground Model development process) provided in BOEM Publication No. 2018-054: *Data Gathering Process: Geotechnical Departures for Offshore Wind Energy,* which describes (and advocates for) how a Phased Approach can be adopted to develop the understanding of the seafloor and subsurface conditions for offshore wind project development.

Development of an Integrated G&G Site Characterization

BOEM Publication No. 2018-054 provides two technical criteria for judging the adequacy of the Project Ground Model for COP submittal analyses (and by inference a GDR). Those criteria are:

- Criteria 1 – Is there sufficient resolution and confidence in the ground model to:
  - a) Define the baseline geological conditions of the area directly impacted by the project described in the COP. The area should include the seabed surface, validation of the depth of the geologic units to the maximum depth and lateral extent affected by the project?
  - b) Define the baseline geological conditions of any area indirectly affected by the project described in the COP. The description should include the seabed surface sediments and may be based on available information at the time of submission?
  - c) Define any geological units that may contain surface or buried features of archaeological potential?
- Criteria 2 – Are the geotechnical characteristics of the pertinent geological units adequately characterized to:
  - a) Demonstrate that the maximum environmental actions of the proposed project have been established?
  - b) Demonstrate the technical feasibility of the proposed project and any project alternatives, as described in the COP, to ensure the project does not pose an unacceptable risk to health, safety and the environment?

We believe that the G&G data and evaluation, as described in this Initial Site Characterization Report are adequate for: 1) demonstrating the technical feasibility and environmental consequences of the Project development, and 2) showing that the project will not create unacceptable risk to health, safety and the environment.

Future Updates to Integrated G&G Site Characterization Report

Updates to this Initial Site Characterization Report will be provided as the results of future, Project G&G programs (and related evaluations) are conducted. The two most significant updates and their timing is anticipated to be:

- The Preliminary, (Integrated G&G) Site Characterization Report will be prepared following completion of the planned geophysical survey program, as described in the Project Survey Plan, submitted April 9, 2020 (and the pending revision of that plan to be submitted based on the modified schedule for the HRG survey). US Wind plans to submit the Preliminary Site Characterization Report together with other Supplemental Studies prior to the end of the initial COP review period.
- The Final, (Integrated G&G) Site Characterization Report will be prepared following completion of the design-phase geotechnical exploration program. This report will be included with the Project's FIR/FDR submittal.

1.3 REPORT AUTHORIZATION

Preparation of this Initial, Integrated, Site Characterization Report, was authorized by US Wind's signed acceptance (November 21, 2019) of McNeilan & Associates' proposal 19-03-03, dated November 15, 2019.

1.4 REPORT ORGANIZATION

This report includes:

- Section 1: Introduction, Administrative Details, and Conclusions
- Section 2: Project Description
- Section 3: Previous G&G Programs and Evaluations
- Section 4: Seafloor Conditions
- Section 5: Geological Considerations
- Section 6: Subsurface Conditions
- Section 7: Initial Geo-hazard Assessment
- Section 8: Initial Ground Model Formulation
- Section 9: Conceptual Pile Foundations Evaluation
- Section 10: Future G&G Program
- Section 11: Report References

Graphics that support the different report sections are provided after the report text. These supporting graphics are numbered with the section number and sequence number of the figure: i.e., Figure 1-1, Figure 3-11, etc.

The references (Section 11) are divided into three groups, which include:

- Project Reports, which provide the citations for various, previous project- and/or site-specific documents that provide factual G&G data, evaluate that data, or otherwise are relevant to this Initial, Site Characterization Report. These listed documents are incorporated by reference as part of this Initial Site Characterization Report.

- Regulatory and Industry Standards, which include the citations for the applicable BOEM Guidelines and documents as well as other industry standards that are applicable to the evaluations contained herein.
- General References, which include the citations for other (generally geologically-focused) documents that are cited in this report.

1.5 DEFINITIONS AND TERMINOLOGY

The following definitions and terminology have been adopted and used within this document:

- BOEM – Bureau of Ocean Energy Management.
- BOEM *Guidelines* – refers to various BOEM guidelines that are relevant to geophysical surveys, geotechnical exploration, geo-focused evaluations, and related activities. These guidelines include:
  - *Guidelines for Providing Geophysical. Geotechnical, and Geohazard Information Pursuant to 30 CFR Part 585* (May 2020) – referred to as *Geo Guidelines,*
  - *Guidelines for Providing Archaeological and Historical Property Information Pursuant to 30 CFR Part 585* (May 2020) – referred to as *Arch Guidelines*,
  - *Guidelines for Submission of Spatial Data for Atlantic Offshore Renewable Energy Development Site Characterization Surveys* (February 2013) referred to as *Spatial Data Guidelines*, and
  - *Guidelines for Information Requirements for a Renewable Energy Construction Operations Plan (COP), Version 4.0* (May 2020) referred to as *COP Submittal Guidelines*.
- US Wind Project (or Project) – US Wind's proposed offshore wind development and associated structures and cables.
- Project Lease – is defined as the designated BOEM lease OCS-A-0490.
- Project Area – corresponds to the Maryland WEA/US Wind Lease plus the project's export cable route.
- Project Components:
  - WTGs – Wind Turbine Generators (or wind turbines), aligned in a parallelogram grid that includes:
    - (Primary) Turbine Rows – nominal north-south turbine Rows A through R.
    - Turbine Cross-Rows – nominal east-west turbine Rows 1 through 13.
  - OTMs – Offshore Transformer Modules.
  - Inter-Array Cables – within the lease that connect between adjacent WTGs and OTMs.

  - Export Cables – The export cable route for the Project is proposed to run along the northern edge of the lease area in a generally northwest–southeast direction to a shore landing location proposed on the Delaware Seashore.
- US Wind Project Permit Submittals:
  - Construction and Operations Plan (COP) – US Wind's COP.
  - COP Administrative Review Period – The period following COP submittal, used by BOEM for determining the COP submittal's completeness prior to initiating the preparation of the project's Environmental Impact Statement (EIS).
  - Geotechnical Departure Request (GDR) – US Wind's revised GDR (to be submitted concurrently with the COP) for waiver of certain Rule Requirements for timing of completion of the project's various G&G surveys, programs and studies.
  - Final Design and Installation Report (FDIR) – US Wind's future submittal that documents the project's: design basis, design, fabrication, installation and other elements of the project development, and which is used to obtain the final permits to construct and operate the project.
- Geophysical Surveys, Geotechnical Exploration Programs, and Related Geo-Evaluations (G&G Studies), including:
  - Previous, Preliminary G&G Studies, as described herein, that are the basis for the interpretations and evaluations presented in this Initial, Site Characterization, which precedes the COP Submittal.
  - COP-Phase G&G Studies that are ongoing or planned for completion during the COP administrative review period. These studies will be used to update the Initial Site Characterization and complete the project's Preliminary, (Integrated G&G) Site Characterization. A description of these studies and their timing is described in the Data Deferral Request, submitted with the COP, which will be updated to reflect the new timing for the survey.
  - Future, Design-Phase G&G Studies that will be conducted to support the project's design. These studies will be used as the basis to prepare the project's Final, Integrated G&G Site Characterization, which will be provided as part of the project's future FDIR submittal.
- Initial, Integrated Geophysical and Geotechnical Site Characterization Report – this document, inclusive of figures, tables, appendices, and references.

1.6 CONCLUSIONS

As described in Section 3 various site-specific, geophysical and geotechnical data, as well as subsequent re-processing, interpretation, and analyses efforts form the basis for the interpretations presented in this Initial Ste Characterization Report. While the previous G&G surveys and exploration are acknowledged to include certain limitations, we believe that they provide a viable basis for: a) detailing the requirements for future G&G surveys and explorations, b) defining the general geologic, seafloor and subsurface conditions that underlie the site, c) anticipating subsurface layering and its variability, d) defining the types of geohazards that will be most relevant to project development, e) initiating the ground model development effort that will advanced during the different phases of project development, and f) conducting initial pile design and installation evaluations.

The available data indicate that the seafloor and subsurface conditions beneath the Lease are consistent with the types of deposits and variability of conditions that are to be expected for a site on the Mid-Atlantic Shelf of the OCS. We conclude that the available data and subsequent evaluations are adequate, based on the criteria proposed in BOEM Publication No. 2018-054, for:

1) Demonstrating the technical feasibility and environmental consequences of the Project development, and
2) Showing that the project will not create unacceptable risk to health, safety and the environment.

2.0 PROJECT DESCRIPTION

2.1 LEASE AND SITE DESCRIPTION

US Wind's lease (BOEM's designated Maryland offshore wind energy lease OCS-A-0490) on the Maryland OCS (Figure 1-2) is approximately 19.5 to 43 kilometers (12.1 statute or 10.7 nautical miles to 26.7 statute or 23.5 nautical miles) offshore from Ocean City, Maryland.

As shown on Figures 1-2 and 1-3, the Project Lease is four & 3/4^{ths} (4.75), 3-mile by 3-mile OCS Lease Blocks wide (east-west) by five (5) OCS Lease Blocks tall (north-south). The trapezoidal-shaped lease includes nine (9) full OCS Lease Blocks and portions of eleven (11) other OCS Lease Blocks. The partial lease blocks include a total of 80 aliquots (each aliquot being equal to 1/16th of a lease block), equivalent to the size of 5 standard OCS Lease Blocks. Hence, the 79,707-acre OCS-A-0490 lease is equal to 14 OCS Blocks.

The Project Lease measures a maximum 22.93 kilometers (14.25 statute or 12.54 nautical miles) east-to-west by a maximum 24.14 kilometers (15 statute or 13.2 nautical miles) north-to-south. The northeastern boundary of the lease is defined by the Delaware Canyon and the navigational, traffic-separation lanes inbound to and outbound from Delaware Bay.

2.2 PROPOSED WIND FARM DEVELOPMENT

US Wind proposes to build and operate an offshore wind farm with up to 1.5 GW (nameplate) capacity. The Project COP is based on an envelope approach that assumes the use of the entre lease and an export cable, as described in the following sections of this report.

2.3 LEASE INFRASTRUCTURE

The wind farm could include up to 125 wind turbine generators (WTGs) positioned at the intersection points of a parallelogram-shaped grid (Figure 2-1). The WTG grid includes 18 north-south turbine rows and 13 east-west turbine cross-rows. As shown on Figure 2-1, the north-south rows have an alphabetical designation from row A (at the west of the lease) to row R (at the east) and the east-west cross-rows are numbered from row 1 (at the north) to row 13 (at the south).

As shown on Figure 2-2, the WTG locations along the (nominal) north-south rows are positioned at about 1,886-meter-intervals along reciprocal 7º 3' 40.8" – 187º 3' 40.8" azimuths. Similarly, the WTG locations along the (nominal) east-west cross-rows are located at about 1,425-meter-intervals along reciprocal 89º 59' 35.9" – 269º 59' 35.9" azimuths. Calculated distances (rounded to 0.1 meters) and azimuths (rounded to 0.1 second) within a typical grid cell are shown on Figure 2-2.

The project will include up to four offshore transmission module (OTMs) platforms that will be located within the turbine array. Inter-array cables will connect the different turbines to the OTM structures. The OTMs are planned to be located about 140 meters to the northeast of the adjacent WTG.

Inter-array cabling will primarily extend along the north-south turbine rows. However, at some locations the inter-array cabling will extend along the east-west turbine cross-rows or diagonally across adjacent turbine rows.

2.4 EXPORT CABLE

Export cables will extend from each OTM to a common export cable route corridor (ExCRC) that extends along the lease boundary (or several boundaries) to near the northern border or northwest corner of the Lease. That ExCRC will then extend northwesterly (Figure 2-3) across the OCS to the State Lands – Federal 3 nautical mile (nm) boundary. From the 3-nm State/Federal boundary, the ExCRC will extend to a preferred landing (subject to future negotiations with DNREC) in the Delaware Seashore State Park at 3R's beach. The cable will then be routed through Indian River Bay to the point of interconnection at the existing Indian River substation. one of several potential landing points/shore crossings.

3.0 PREVIOUS G&G PROGRAMS

Project- and/or site-specific surveys, exploration programs, and related efforts that are the basis for the interpretations and evaluations in this Initial, Site Characterization Report are described below. Full citations for each of these studies, which are included as part of this report by reference, are provided in Section 11.1 of this document. We generally reference these efforts by the year in which the field work occurred – in several instances the reports were issued (and dated) during the following year.

3.1 GEOPHYSICAL SURVEYS

There have been three prior high resolution geophysical (HRG) surveys in the lease area. The areas covered by those prior, HRG surveys are shown on Figure 3-1. The three surveys are:

- Coastal Planning & Engineering (a CB&I Company) conducted a *High-Resolution Geophysical Resource Survey* for the Maryland Energy Agency (MEA) in 2013. The survey extended across the entirety of the Maryland OCS WEA. The survey included N-S-oriented primary survey lines at 150-meters-spacing and E-W tie-lines at 900-meter-sacing.

- Alpine Ocean Seismic Survey (then a Gardline Company) conducted a *Geophysical Survey of the "Core Zone" of Lease* (that includes about 2/3rds of the Lease for US Wind in 2015. This survey was used to infill between the prior CB&I primary survey lines within the core zone.
- Alpine Ocean Seismic Survey also conducted a second, *High-Resolution Geophysical Survey of the Proposed Export Cable Route* in 2016. This survey extended from the project development area to the proposed shore-landing location for the export cable.

Additional detail relative to the three surveys, which were conducted in general compliance with the applicable BOEM Guidelines at the time of their execution, are described below.

The previous HRG surveys and the data collected provide valuable insight relative to the seafloor and subsurface conditions. As noted in the following discussion, additional data collection and evaluations are required in support of the COP process.

Despite certain deficiencies and limitations, we believe that the combined results of the previous studies are adequate for: a) the evaluations summarized herein and b) BOEM's review and acceptance of the Project's GDR.

As described in Section 10, the planned COP-phase HRG survey is designed and will be executed to upgrade and update the previous HRG data.

CB&I – Preliminary Lease Survey (2013)

CB&I's 2013 HRG survey for the Maryland Energy Agency (MEA) extended across the entire Wind Energy Area (i.e., the Lease) plus a 1,000-meter buffer beyond the lease boundaries (Figure 3-1). About 2,800 line-km of data were collected along:

- 158, N-S-oriented primary survey lines at 150-meters-spacing and
- 46, E-W-oriented tie-lines at 900-meter-spacing.

The types of data collected along all survey lines included:

- multi-beam echo-sounder (MBES),
- side scan sonar,
- magnetometer,
- Chirp sub-bottom profiler, and
- seismic reflection data collected using a sparker source and a 24-channel hydrophone array.

Additional bathymetry data were collected between the primary survey lines.

The CB&I data and report generally provide a viable basis for preliminary, regional interpretation of the seafloor and subsurface conditions (as was intended by the scope of work executed). Our perspectives and conclusions related to the various data that we consider relevant to this Initial, Site Characterization include the following:

- The multibeam bathymetry data have the following limitations:
  - The data were not intended to and do not provide full coverage of the lease.
  - The data include miss-ties (probably due to tidal correction deficiencies) between the corrected water depths at some crossing locations of primary and tie-lines.
- The side scan sonar and multibeam bathymetry data document variable topography across the lease.
- The sub-bottom, Chirp data are judged to be of fair to good quality, although in some areas (most notably where sand ridges are present on the seafloor) the penetration is limited.
- The mid-penetration, seismic reflection data document the complexity of the subsurface stratigraphy. These data are judged to be of fair to good quality, although the level of data processing was limited.

CB&I's May 2014 report:

- Provides a limited number of data examples (including the seismic reflection data examples reproduced on Figure 3-2 and 3-3),
- Defines three representative seafloor conditions,
- Divides the subsurface into three stratigraphic (sic., seismic) units (Figure 3-4),
- Maps the seafloor, upper sand isopach, and seafloor/near seafloor (say shallower than about 20 meters) features, and
- Does not map and provides only minimal discussion of the deeper conditions.

Alpine – (Partial) Lease Survey (2015)

Alpine's 2015 survey in the central portion of the lease (Figure 3-1) included 30-m-spaced, north-south track-lines that "filled-in" between the 150-m-spaced CB&I survey lines. The Alpine (partial) lease survey did not include collection of additional tie-line data. Rather, Alpine's scope work merged their survey data with the previously collected CBI data to provide a more detailed analysis of the central area of the lease. Alpine's products, evaluation and report for the central portion of the Lease were then based on the merged data set.

The types of data collected along all survey lines included:

- single-beam echo-sounder (SBES),
- side scan sonar,
- magnetometer, and
- Chirp sub-bottom profiler,

The Alpine survey also included collection of MBES data at the planned meteorological tower location (Figure 3-1). The Alpine survey did not include collection of additional mid-penetration, seismic reflection data.

The combined CB&I and Alpine survey data provides greater detail and improved imaging, than was provided by the prior CB&I report, in the central area of the project lease. Perspectives and conclusions (related to the various data and report relevant to the Initial, Site Characterization) include the following:

- The Alpine survey did not collect additional multibeam bathymetry data (except at the proposed met tower location) to add to the data collected during the prior CB&I report.
- The side scan sonar data confirm the significant complexity in seafloor conditions.
- The sub-bottom, Chirp data are judged to be of fair quality. In some areas (most notably where sand ridges are present on the seafloor), the Alpine Chirp data achieved limited penetration.
- No additional mid-penetration, seismic reflection data were collected to add to the data previously collected by CB&I.
- Only a limited number of data examples are provided.
- Alpine report supplements and adds details to the prior interpretations by CB&I.
- Provides no additional data, interpretation nor insight relative to the deeper subsurface conditions.

Alpine – Export Cable Route Survey (2016)

Alpine Ocean Seismic Survey conducted a *High-Resolution Geophysical Survey of the proposed Export Cable Route* (Figures 2-3 and 3-1) in 2016. This survey extended from the project development area to the proposed shore-landing location for the export cable. The survey included collection of data along the corridor centerline and 5 wing lines to either side at 30-m-spacing to provide a 300-m wide corridor of data in the OCS. Within State Lands the survey line were spaced at 15m, and in some areas the survey corridor was widened. Tie-lines data across the survey corridor were collected at 500-m-intervals.

The types of data collected along all survey lines included:

- multi-beam echo-sounder (MBES),
- side scan sonar,
- magnetometer, and
- Chirp sub-bottom profiler,

The Alpine survey and report are considered generally adequate for the Initial, Site Characterization of the initial export cable route.

HRG Systems Used During Previous Surveys

The different systems used during the three surveys are summarized in the following table.

Table 3-1: Geophysical Systems Used During Previous Surveys

	CB&I (2013)	Alpine (2015)	Alpine (2016)
MBES	Reason 7125	---	Reason 7125
SSS	EdgeTech 4200 (300/600kHz)	Klein 3900 (455/900 kHz)	Klein 3900 (455/900 kHz)
Magnetometer	Geometrics G882 (Cesium)	Geometrics G882 (Cesium)	Geometrics G882 (Cesium)
Sub-Bottom Profiler	EdgeTech 3200 profiler with 512i towfish [1]	side-mounted, Teledyne Benthos Chirp III [2]	side-mounted, Teledyne Benthos Chirp III [2]
Seismic Reflection	Geo-Source 200 multi-tip Sparker with 24 channel GeoEel [3]	---	---
1	swept frequency of 1 – 10 kHz, 5 ms pulse length, a ping rate of 7 Hz, and 60% pulse power level		
2	swept frequency of 2 – 7 kHz, 15 ms pulse length, and 125 ms sweep length		
3	1,000 joules source and 24 channels @ 3.125-meter group interval hydrophone array		

Limitations of Previous Survey Data Sets

The three previous geophysical data sets have the following limitations (relative to the project permitting and design requirements):

- MBES Bathymetry Data – Available MBES data in the Lease do not provide full-coverage of the seafloor (nor was the CB&I survey intended to provide such data coverage) in the project area. Full-coverage MBES data will be acquired within all future survey areas.
- Side Scan Sonar Data:
  - The merged side scan sonar data from the CB&I (2013) and Alpine (2015) surveys provide full-coverage of the portion of the lease covered by the Alpine 2015 survey (Figure 3-1). The data were obtained using two different SSS systems operating at different frequencies.
  - Elsewhere in the lease, the SSS data from the CB&I (2013) survey provide SSS data at 150-meter-intervals, and do not provide full-coverage of all areas where the seafloor will be disturbed by project development.
  - Additional data collection will be required at 30-m-line spacing to meet BOEM requirements before conducting seafloor disturbing activities (including subsurface exploration).
- Magnetometer Data – The combined CB&I (2013) and Alpine (2015) magnetometer data provide data at 30-meter-line spacing in the area surveyed by Alpine. Additional

data collection will be required using a Gradiometer at 30-m-line spacing to meet BOEM requirements before conducting seafloor disturbing activities (including subsurface exploration).

- Sub-Bottom Profiler Data – The sub-bottom systems used during the past surveys provided limited imaging depths in some areas of the lease. Additional data will be acquired during future HRG surveys to provide greater clarity for identifying and mapping the paleo-horizon (required for marine archeological/cultural interpretation) across the entirety of the lease.
- Mid-Penetration, Seismic Reflection Data – The CB&I, multi-channel, sparker data set provides a basis for interpretation of the regional geologic and stratigraphic conditions. To enhance the value of these data, US Wind retained Oceaneering International Inc, to reprocess the data, as discussed subsequently. The results of the reprocessing will be used to define system requirement for multichannel data collection during future HRG surveys.

The previous survey data were collected in 2013, 2015, and 2016. While these data have limitations, they provide valuable data that will be used together with the planned additional HRG survey data acquisition (Section 10). These older data will prove to be valuable (when compared to newly acquired data) to identify and define changes in the seafloor conditions over the past five to seven years.

3.2 GEOTECHNICAL EXPLORATION PROGRAMS

Gardline – Preliminary Geotechnical Exploration Lease Program (2015)

In 2015, Gardline advanced, sampled, and tested seven (7) borings to about 70+/- -meters-penetration below the seafloor. The borings alternated sample and downhole CPT data collection. Downhole suspension (P & S-wave velocity) logging data were collected in four of the 7 borings.

Locations of the 7 reconnaissance borings are shown on Figure 3-1. As shown, the seven borings were advanced in the central portion of the proposed wind turbine development area. Gardline divided the soil layering, as encountered in the borings, into seven (7) geotechnical, lithographic units. Many of those lithographic units were further subdivided in some of the borings.

Gardline's results include an initial correlation of the subsurface stratigraphy encountered by the borings and the seismic reflectors imaged by the prior CB&I mid-penetration, sparker, seismic reflection survey lines that pass through (or nearby) the boring locations. The 3rd volume of the Gardline report provides two N-S subsurface profiles (one of which is reproduced on Figure 3-5) that combine subsurface stratigraphy as imaged by the sparker data and soil lithologies as defined by the borings.

Gardline states that:

> *Geotechnical and geophysical datasets were combined to build a three-dimensional ground model. The geophysical and geotechnical results correlate relatively well at the different borehole locations.*

> *The CB&I report identifies three main geophysical units ... (that) … seem to match reasonably well with the geotechnical records (soil layering). The geotechnical records depict further detail of the sedimentary sequence and allowed the identification of additional soil units …*

The Gardline report further notes that some (but not all) of the soil layer boundaries could be matched to local reflectors in the seismic records.

The Gardline study included an extensive amount of laboratory testing on the recovered samples. The results of the testing, as well as Gardline's interpretation of representative soil property profiles for each boring, are included in the Gardline report. The Gardline report includes limited correlation between the different soil properties data or comparison of soil properties and their variations among the 7 boring locations.

The seven preliminary soil borings encountered a variety of subsurface stratigraphy and soil conditions and illustrate much of the possible variation of conditions that may be encountered in the Lease. Gardline's results include an initial correlation of the subsurface stratigraphy encountered by the borings and the seismic reflectors imaged by the prior CB&I mid-penetration, sparker, seismic reflection survey lines that pass through (or nearby) the boring locations.

Examination of the site-specific soil conditions at the seven boring locations and the variation of the geologic and seismic stratigraphy across the site suggest that the borings are likely to be generally representative of most of the conditions that may be present beneath the lease. Therefore, they are believed to provide a reasonable basis for estimating the soil conditions beneath the project development area.

Alpine – Export Cable Route Sampling Program (2016)

Alpines 2016 HRG survey of the initial export cable route included vibracore sampling at 34 locations in the Atlantic Ocean (plus additional locations in the Inshore Indian River Inlet). Of the 34 vibracores, eight are located within the area immediate to the north and northeast of the lease, shown on Figure 3-1. .

Penetrations ranged from about 3 to more than 4.7 meters below the seafloor. With only a few exceptions, the recovered seafloor sediments consisted of fine or medium sand.

3.3 SUPPLEMENTAL DATA PROCESSING & EVALUATIONS

Oceaneering – CB&I Seismic Reflection Data Set Reprocessing (2020)

In 2020, US Wind contracted Oceaneering International, Inc. (Oceaneering) to:

- Review the existing 2013, multi-channel, seismic reflection data collected by CB&I,
- Reprocess the multi-channel seismic reflection data files (to the extent possible, as discussed below),
- Re-interpret key structural horizons (seismic reflectors), including – but limited to – those previously identified by CB&I, and
- Map those horizons (as both structural elevation contours and as depth below seafloor isopach) across the Lease..

Oceaneering used the (partially) processed 2D seismic data volume in SEG-Y format, that had been provided to US Wind by the Maryland Energy Administration (MEA). The data set provided by MEA did not include the raw data files, but rather included partially processed,2D data at a 0.125-millisecond sample interval in a 32-bit IEEE floating point format.

Oceaneering's reprocessing improved the resolution and imaging of the data set. However, it was not possible to optimize the re-processing because of the lack of documentation of the prior (partial) processing, and the construction of the data files, as provided by MEA. Most importantly, it was not feasible to deconstruct the prior processing to remove or mute the first two water bottom multiples, as they are likely the result of initial processing steps and/or data collection configuration. Thus, the presence of those multiples continues to obscure subsurface imaging within the depths and elevations of those multiples.

The 2D seismic reprocessing and reinterpretation was completed on: a) every fourth, 150-m-spaced, N-S, primary survey line and b) all 900-m-spaced E-W, tie-lines. This results in a 600-m by 900-m grid of data across the entire Lease (Figure 3-6). In addition, all N-S primary survey lines that pass through or nearest to the seven, 2015 Gardline borings were reprocessed and interpreted. Oceaneering's report includes a catalogue of images (at common horizontal and depth scales and vertical exaggeration) of those 46, N-S, primary-direction and 27, E-W, secondary-direction records. Two annotated examples of the reprocessed records are shown on Figures 3-7.

After re-processing, the seismic records provide adequate resolution for interpretation down to elevation -250 meters. Oceaneering then used the 2D seismic data to map five seismic horizon (reflectors) that are present across the (or majority of the) Lease. In addition to mapping structural contours of the 5 horizons, Oceaneering also mapped the total thickness of sediment above each mapped horizon (equal to the depth below seafloor of each mapped horizon).

Additional discussion of US Wind's use of the Oceaneering's reprocessed data and mapped horizon is included in Section 6.

Fugro Pile Driving Assessments (2015 and 2020)

Fugro have previously (2015) conducted design analyses, inclusive of pile drivability calculations for conventional-sized offshore foundation piles at the proposed meteorological tower location (Figure 3-1). Additional pile drivability analyses were conducted by Fugro (2020) for a large diameter, monopile at that same location. These analyses document expectations that piles for either a pile-supported jacket or monopiles can be driven at the site.

4.0 SITE AND SEAFLOOR CONDITIONS

4.1 REGIONAL CONDITIONS

Regional Physiography

The lease is located on the inner mid-Atlantic continental shelf, which is the submerged extension of the Coastal Plain (Figure 4-1). The continental shelf has a very gentle regional slope of about 0.1 degree from the Maryland coastline to the shelf break, about 135 kilometers to the east.. The edge of the continental shelf is demarcated by the shelf break at about the 200-meter isobath, where the slope of the seafloor steepens to about 3 to 6 degrees down the continental slope. A number of prominent canyons are incised into the continental shelf (Figure 4-1).

The depositional environments along the present Mid-Atlantic shoreline are dominated by barrier-island systems and estuaries. Both barrier-island and estuarine systems have a well-defined organization with transitions between sub-environments occurring in predictable locations in relation to the distance from the shoreline dominated by marine processes Classification of both barrier island systems and estuaries are based on the relative influence of storm, wave and/or tidal action

The Mid-Atlantic Shelf is currently characterized as a storm-dominated shelf where the regional sediment transport is alongshore in a southwesterly direction. The present configuration of the Mid-Atlantic coast of the United States can be divided into distinct sections (such as New Jersey; the Delmarva Peninsula; and Virginia-North Carolina) that correspond to a repeating pattern of barrier-fronted coastal compartments separated by estuaries each defined by unique landscape elements (Fisher, 1967; Oertel and Kraft, 1994).

The four sections that comprise each Mid-Atlantic coastal compartment, listed from north to south, are:

- A cuspate spit located along the southern tip of each estuary's mouth,
- An eroding headland,
- Barrier spits and long linear barrier islands, and
- Short tide-dominated barrier islands with numerous inlets occurring north of the estuary which defines the start of another coastal compartment.

Each of these sections and the adjacent offshore continental shelf share similarities with respect to geomorphology, sediment transport, and sediment accumulation.

The Maryland Wind Energy Area lies approximately 40 km southeast of the entrance to Delaware Bay, one of several large estuaries along the Mid-Atlantic coastline. Estuaries, which are the seaward portion of a drowned valley system are influenced by tidal, wave and fluvial processes. They typically contain both fluvial and marine sediments. Such shelf-valley complexes traverse the Mid-Atlantic OCS and are believed to represent large estuarine systems that infilled former river valleys. These landforms migrated landward as sea level rose during the Late Pleistocene/Holocene transgression Swift et al., 1980).

Common Physiographic Features

Predominant features on the continental shelf include paleo-shorelines, shoals, filled channels and valleys, and shoal retreat massifs. Some of these types of features are present in the lease and along the proposed export cable route to shore.

Shoals (Sand Ridges and Dunes) The inner and mid--shelf off the mid-Atlantic coastline (Figure 4-2) is comprised of prominent ridges and swales that have a northeasterly trend The sand ridges commonly exhibit 10 to 12+ meters relief, are 1 to 2-km-wide, and may extend 10 to 15 km. The ridges are postulated to be shoreface deposits abandoned as the shoreline transgressed during the last rise in sea level (Swift et al., 1973). The western one-third of the lease lies within a linear shoal field.

Filled Channels Multiple, filled channels traverse the shelf. These channels connect the various bays and drainage along the coast to the canyon observable at the shelf break (Figure 4-1). These features may have seafloor expressions that appear as surface channels or valleys (Swift et al., 1980; Duane and Stubblefield, 1988). These shelf valley complexes are considered to represent a retreat path of an estuary-mouth scour channel or a river valley modified by estuarine processes during transgression (Swift et al., 1980). At the estuarine mouth, tidal scour processes incise a channel (shelf valley) as it retreats up the estuary axis during transgression. The shelf valley expression does not always coincide with the buried river valley location.

The Delaware Valley is one of the major cross shelf topographic channels within the mid-Atlantic region (Figure 4-2). It is a well-defined, broad valley, that is immediately to the northeast of the Lease. Various tributary valleys that reflect the former drainage system that fed the major valley are associated with each of the major valleys. The former, but now buried, drainage systems may be quite extensive, and may produce complex subsurface stratigraphy beneath the shelf.

Shoal-Retreat Massifs. Shoal-retreat massifs are broad areas with topographic relief related to former positions of estuary mouths. Near the estuary mouth, littoral drift converges on one or both sides of the estuary to create levee-like highs. This process occurs as the estuary retreats during transgression and creates the massifs (Swift 1973; Swift et al., 1980). A shoal-retreat massif region, formed as the former Delaware River retreated during the last sea level rise, is present to the east of the Lease (figure 4-2).

Paleo-shorelines. Paleo-shorelines were created during sea level low-stands that occurred during periods of glaciation. During the Quaternary period (within the last 1.6 million years), the repeated cycles of glacial advance and retreat caused the sea level to fluctuate or regress (shoreline retreat) and transgress (shoreline advance). Several prominent paleo-shorelines that appear as shore-parallel, terraces or scarps in the bathymetry have formed during sea level stillstands.

4.2 WATER DEPTH & BATHYMETRY

Water Depth

The water depth in the Maryland OCS (Figure 4-2) regionally slopes from west to east. The most prominent bathymetric feature is the Delaware Valley that borders the northeast perimeter of US Wind's Project Lease.

In addition, the seafloor to the southwest and west of the lease includes numerous south-southwest- to north-northeast-trending ridges and swales. The northeastern ends of those landforms extend into the lease area (Figure 4-2). Farther to the north and east, the seafloor bathymetry becomes less variable.

Topographic variations, or seafloor morphology, are due to: 1) the presence of relict geologic features associated with the glacial sea level low stands, 2) subsequent post-glacial period sea level transgression, and 3) active erosion and deposition due to tidal and/or storm currents.

Figure 4-3 reproduces the bathymetry map from the CB&I, 2014 report. In addition, Figures 4-4a and 4-4b shows CB&I's 2013 MBES bathymetry data rendered using a blue pallet of colors with 2-m contours (Figure 4-4a) and 0.2-contours (Figure 4-4b).

As shown on Figures 4-2 through 4-4, the water depth typically increases from northwest to southeast. The flatter Delaware Shelf Valley crosses the area from the middle of the northern border to the southeast corner of the area, while the seafloor elevation farther to the west and south is dominated.by the SSW – NNE-trending ridges and swales. As shown, the lease includes significant local topography – such local topography being more prevalent in the western half of the Lease.

The minimum water depth in the Lease is about 15.5 meters (re: MLLW datum) and the maximum water depth is about 41.5 meters. The water depth, however, is typically between about 18 and 32 meters in most of the Lease. Shallower water depths are generally limited to the locations of the taller sand ridges (dunes) and deeper water depths are generally restricted to the southeastern corner of the Lease.

A statistical evaluation of the water depths at 86 hypothetical structure locations (we note that those locations are based on a superseded turbine grid, but they never-the-less illustrate the variability) in the western, central, and eastern portions of the site are shown on Figure 4-5.. Globally, the median water depth at the 86 locations is 25.8 meters, while the water depth at the shallowest one-fourth of the locations is less than 23 meters and the water depth is deeper than 27.4 meters at the deepest one-fourth of the locations.

Seafloor Slope

Regionally, the seafloor across the lease-area slopes to the west to the east at a gentle gradient of less than 1 percent. However, a field of prominent seafloor ridges or dunes are superimposed on the regional slope, as shown in Figure 4-6. As shown, the dune field a series of prominent shoals with an axis oriented southwest-to-northeast to west-southwest-to-east-northeast. This series of trending ridges (or dune fields) extends several kilometers into the southwestern corner of the lease. .

The ridges or dunes are elongated, 3 to 4-kilometer-wide features. To the west and southwest of the lease (and in the southwestern corner of the lease), these ridges (or dunes) are taller than 10 meters.

As shown on Figure 4-6, the slope of the flanks of these ridges, within the lease, are generally no more than 4 degrees. The one exception to that generality is the slope of Shoal C, which extends into OCS Block 6773 and the northwest corner of Block 6774. Within, the corner of the lease, that shoal includes side slope that are locally as steep as 6 to 8 degrees.

4.3 SEAFLOOR MORPHOLOGY AND SEAFLOOR FEATURES

Interpretation by CB&I suggests that, outside of the Delaware Shelf Valley, the seafloor in the lease area includes at least three scales of bedforms that are inferred to reflect bottom current flows of different duration, intensity, and direction.

Figure 4-7 (modified from CB&I) shows the distribution of different seafloor landforms and features in the lease. As shown on Figure 4-2, the large sand ridges that extend into the site from the south-southwest are the most prominent seafloor features in the Lease. Regionally, these are the northeastern limits of broad, south-southwest- to north-northeast-trending ridges, which are flanked by adjacent swales. To the southwest and west of the lease, the largest of these features extend 10 to 15 kilometers, are 1- to 2-kilometers wide, and may include 10 to 12+ meters of elevation difference between the top of a ridge and trough of the adjacent swales (Figure 4-3). However, the elevation difference between crest of ridge and trough of swale within the lease is typically less than 8 meters.

To the east of the prominent sand ridges, the seafloor in the lease is flatter and more undulating. Lesser sizes and scale of seafloor bedforms including smaller sand bedforms (sand dunes, sand waves, and sand ripples) are present on the ridges, their flanks, and elsewhere. These bedforms are inferred to reflect both geologic processes and sediment mobility. They include smaller, sand ridges or dunes with an SW-NE to WSW-ENE orientation across much of the site.

CB&I interpreted and mapped the presence of three interpreted seafloor sediment types/features within the lease area. That mapping (reproduced on Figure 4-7) included: 1) sand ridges, 2) unconsolidated (sand) sediments, and 3) mud/clay. CB&I's descriptions of these features, which were differentiated based on differences in the side scan sonar backscatter reflectivity, are as follows:

- Sand ridges are positive topographic features of various sizes, that stand proud (above) the surrounding seafloor,
- Areas of "unconsolidated sediments" which were inferred to be areas where the seafloor sediments may include coarse deposits of sand with gravel or lag gravel deposits, and
- Areas of fine-grain sediments (i.e., mud or clay).

The locations of the seven Gardline borings with respect to CB&I's mapping of the seafloor sediment/conditions is provided below

Table 4-1: Correlation of Boring Locations to Mapped Seafloor Sediment Conditions

CB&I's Mapped Condition	Gardline Boring Designation						
	G7	H10	MT	K16	D14	G17	I21
Sand Ridge	no	no	no	no	no	no	no
Sand with Gravel	no	yes	no	no	yes	fringe	fringe
Mud or Clay	no	fringe	no	fringe	no	no	no

None of the 7 Gardline borings were located on a sand ridge. While CB&I does not specify the expected seafloor conditions in the unmapped areas, the character of the geophysical data and samples collected in the borings suggest that those areas are generally underlain by sand. We note that the mapped presence of unconsolidated sediments (sand with gravel) and mud/clay may (in some areas) be attributable to the lack of precision of CB&I's mapping.

As shown by the previous table, two borings are located on the fringes of CB&I's mapped area of fine-grain (mud/clay) seafloor. However, sand was recovered in the first sample of both borings. Also, two borings were located within and two additional borings were located on the fringes of areas mapped as possible unconsolidated (sand with gravel). Some minor quantity (described as trace) of gravel was included in the upper samples from two of those four borings.

4.4 SEAFLOOR SEDIMENTS

A compilation of the various, available sediment samples, and their classifications (USGS, 2005) is provided on Figure 4-8. The grain size of the seafloor sediments from the Gardline borings and Alpine vibracores have been added to the data compiled by the USGS.

The site-specific exploration data suggest that sandy sediments, which sometimes include a small (typically trace quantity) of gravel fraction, predominate. Neither the complied USGS nor site-specific exploration data substantiate CB&I interpretation of broad swales of mud/clay being present in the bathymetric troughs that cross the Lease.

Therefore, we anticipate that the seafloor is composed of well-sorted (poorly-graded) fine, fine-medium or medium sand beneath the majority of the lease. Some lesser fraction of gravel may be locally (or more widely) present in the seafloor sands. Fine-grained silt, clay or mud may be locally present within the bathymetric lows, but the percent of the seafloor composed of such fine-grained sediments is anticipated to be much smaller than inferred by CB&I (and their map seafloor morphology map, reproduced as Figure 4-7).

5.0 GEOLOGIC CONSIDERATIONS

5.1 GEOLOGIC SETTING

The lease lies near the western rim, or the hinge-line, of the Baltimore Canyon Trough, a northeast-southwest-trending rift basin structure that formed due to extensional tectonics during the Jurassic and Triassic periods (Grow et al, 1988). Following the basin formation, sedimentation and erosional processes related to fluctuating sea levels primarily controlled the geologic development of the inner and mid shelf..

The Baltimore Canyon Trough consists of a wedge of sedimentary sediments that thickens to the east. The wedge of sedimentary units overlying the crystalline basement is approximately 3,000 feet thick beneath the inner and mid continental shelf. During the basin formation and infilling, minor structural deformation is attributed to:

1) Sediment loading and thermal subsidence eastward of the hinge-line (from zero westward of the hinge-line up to 0.015 mm/yr. east of the hinge-line.

2) Differential crustal movement from isostatic adjustment to the north of the "glacial-isostatic hinge zone" following retreat of the Late Wisconsin ice sheet.

3) Local uplift from movement of salt intrusions near the seaward edge of the shelf.

This region is currently considered to be a tectonically quiet, passive margin.

5.2 GEOLOGIC PROCESSES DURING THE QUATERNARY

The Mid-Atlantic Continental Shelf extends from Long Island on the north to Cape Hatteras on the south. The northern margin is approximately coincident with the southern extent of Late Wisconsin Glaciation. The islands of Long Island, Martha's Vineyard, and Nantucket are the terminal moraines or southern glacial limit. Glacial outwash plains extend southward through the gaps between the different portions of the terminal moraine. Glacial processes to the north produced paleo-landforms (e.g. moraines, glacially carved valleys, and outwash plains) that are significantly different from non- glaciated areas to the south.

Although Quaternary glaciers did not advance across the site, the subsurface geologic conditions have been extensively influenced by the glacial-interglacial cycles during the Pleistocene. Sea-level fluctuations produced by the glacial-interglacial cycles caused the shoreline to regress and transgress across the shelf multiple times. The geologic processes during the Quaternary are primarily responsible for shaping the geology that will influence the siting, type selection, engineering design, and installation of wind farm structures.

The same fluvial, tidal and marine processes that have shaped the present Mid-Atlantic coastline also were responsible for creating and modifying sedimentary environments that are currently buried below the Atlantic seafloor. The position of the various paleo-landforms (e.g., barrier islands, incised valleys, etc.) preserved beneath the Continental Shelf record a geologic history of multiple glacial-interglacial cycles with associated sea-level adjustments that have come to characterize the Quaternary Period. Identification of these landforms is important for reconstructing past geological events, defining stratigraphic relationships, and evaluating the engineering characteristics of the sediment sequence.

These processes have produced a complex, highly variable subsurface. During the various cycles of glacial advances and retreats, the geologic processes eroded, transported, and redeposited the sediments. Two regional stratigraphic charts that illustrate the potential subsurface layering that may be present at a specific site are shown on Figure 5-1.

Drainages and Paleo-Channels

The cycles of glaciation and the corresponding repeated cycle of sea level retreat and rise are particularly important. During these cycles, drainages are cut across the exposed shelf, as sea level falls, and then infilled and buried as sea level rises. This geologic process of channel incision and burial is illustrated on Figures 5-2 and 5-3, which show map view sketches and block diagrams, respectively, of the processes. Each figure relates the geologic process at various stages of sea level and correlates those stages to time periods during the latest Late Pleistocene glacial advance and the following Late Pleistocene - Holocene sea level rise. Since these figures represent the process on the mid-shelf, the time intervals for when the inner shelf (and the lease-area) was submerged is later than shown on the figures.

During sea level low-stands, paleo-drainages developed on the shelf, deltas formed at river mouths, and estuary-lagoon-barrier complexes formed near inlets. During the peak of the last Glacial Maximum (Wisconsin glacial period, approximately 25 to 15.7 thousand years ago [kya]), the sea level was approximately at the 120-meter isobath. During this time, drainages formed across and carved channels into what is now the shelf (Figure 5-2, panel B and Figure 5-3, panel A).

As the sea level rose, the shoreline transgressed and retreated westward, and the channels began to flood, transition into estuaries, and were infilled with sediments (Figure 5-2, panel C and Figure 5-3 panel B). The channels typically are infilled with a fining-upward sequence of sediments. That sequence can include coarse basal lag deposits overlain by sands and then silts or clays. The infill sediments may be dissimilar to the sediments outside the incised channel or they may be composed of similar, but younger, materials.

Shoreline Retreat

As sea level rose, following the last glacial advance (and other prior glacial maxima), the coastal estuary-lagoon-barrier depositional system transitioned westward across the shelf. Such systems typically include the mouths of coastal estuaries flanked by barrier island as illustrated at the top of Figure 5-4. As shown on that figure, the landforms and geomorphology at the land – sea transition include many features and significant complexity. Also illustrated at the bottom of Figure 5-4 is additional detail of that complexity at the mouth of a tidal-dominated estuary.

At the mouths of estuaries, tidal channels allow the exchange of water and sediment between the marine environment and lagoon systems. During those fluctuations, sediment is transported landward during flood tides and then seaward during receding ebb tides.

In wave-dominated barrier systems, ebb-tidal deltas are generally small or non-existent while flood-tidal deltas are typically large (Davis, 1994). Wave-dominated estuaries are composed of barrier, washover, tidal inlet and tidal delta deposits. There is a net landward movement of sediment in that type of estuary.

In mixed-energy systems, barrier island systems are influenced significantly by both waves and tides. The formation of seaward protruding ebb-tidal deltas causes wave refraction and the reversal of longshore current direction down drift of the ebb delta causing sediment trapping along this portion of the ebb-tidal delta (Davis, 1994).

The evolution of these features, as sea level rises also depend on the relative rate of the sea level rise, the sources and quantity of available sediment, and other factors. Figure 5-5 illustrates the differences between the seaward retreat of a barrier island during a period of slowly rising sea level (at the top of the figure) and the in-place drowning (burial) of a barrier island due to rapid sea level rise (at the bottom of the figure).

Shoal retreat massifs form at the estuary mouths as the shoreline transgress across the shelf (Swift et al., 1977). Today, relict shoal retreat massifs can be observed on the seafloor and they illuminate the transgressive path of several large estuary mouths seaward of Delaware and Chesapeake Bays.

Those former shelf-valley complexes, which are preserved in the subsurface, are now buried beneath surficial sand ridges or thin sedimentary cover. There former presence, however, can sometimes be inferred on bathymetric maps where they often appear as surficial channels/valleys or as broad, smooth, featureless bathymetric lows (Swift et al., 1980; Duane and Stubblefield, 1988).

One such drowned shelf-valley complex, identified as the Delaware Bay Outwash Basin on Figure 4-2, is present to the northeast of the Maryland Wind Energy Area. Within that shelf valley area, the seafloor generally appears to be relatively flat and featureless, but broad areas with topographic relief are located to the north and south of the shelf valley (Figure 4-2). These topographic highs form shoal-retreat massifs. Their positions mark the former positions of estuary mouths where littoral drift converges on one or both sides of the estuary to create levee-like highs that are preserved on the seafloor, after the estuary mouth has transgressed landward (Swift 1973; Swift et al., 1980).

Stratigraphic Complexity

The combined effects of the processes described above produce a subsurface stratigraphy that is composed of sequences of layered deposits. Estuary and lagoon deposits are generally fine-grained, may contain organics, and can be channelized to varying degrees. Barrier deposits (islands, spits, or bars) are generally sandy sediments. After the shoreline transgressed to near its current position, the shelf was then inundated, and Holocene-age marine sediments were deposited over the shelf. These marine deposits have buried and masked the underlying geology.

In some locations, individual layers may be many tens of feet thick and extend over significant distances. Elsewhere, the layers may be much thinner and laterally discontinuous. Figure 5-6 provides a conceptual profile of that sequence of deposits and illustrates and how the near-surface sediments may vary laterally within the lease area, due to those processes.

Current Conditions

The modern seafloor on the Continental Shelf reflects the reworking of former pre-Holocene deposits by marine transgression, and much of the present shelf is covered by a thin veneer of Holocene-age sediments.

These sediments were reworked and winnowed from oblique shoreface ridges and have obscured the location of former drainage systems that were infilled during transgression. Today, the local continental shelf is covered by a layer of Quaternary sediments.

As descibed in the Section 4, the seafloor is comprised of predominantly sand, which locally may include gravel and patches of fined-grained sediments. These Holocene-age sediments are interpreted to have been deposited following the last submergence of this portion of the inner-Atlantic shelf.(see Section 5.3)

Today's Mid-Atlantic Shelf is characterized as a storm-dominated shelf where the regional sediment transport is alongshore in a southwesterly direction. That long-shore sediment transport plus the erosion and re-deposition of the sediments during storms have produced the seafloor variability described in Section 4.

5.3 LATE PLEISTOCENE – HOLOCENE SEA LEVEL TRANSGRESSION

The reconstruction of the past relative sea level requires accurate dating of geologic materials that can be correlated directly to former water levels. For our evaluation of sea levels over the past 20,000 years, we have relied on the Holocene sea level database for the Atlantic coast (Engelhart and Horton, 2009), the sea level information derived from Barbados corals (Fairbanks,1992), and the dates for archaeological periods, significant climate event, and sea level episodes as defined and described TRC Environmental Corporation (2012).

That reconstruction is shown on Figure 5-7. As shown, we can subdivide the lease-area conditions during the post, Late Pleistocene period as being:

- Emergent land from at least 25 kya until about 10 to 11 kya in the southeast and until perhaps 8 to 9 kya in the west,,
- Within about 10 meters of sea level for perhaps 1,000 to 2,000 years, and
- Submerged, since about 9 to 10 KYA in the southeast and since 7.5 to 8.5 kya in the west.

Those date ranges and the previously described geologic processes are our basis for the subsurface interpretations presented in Section 6.

5.4 PRE-QUATERNARY GEOLOGY

As discussed in Section 6, a continuous, seawrd-sloping seismic reflector (geologic horizon) is interpreted to represent the base of the Quaternary sediments. This horizon appears to be a continuous, semi-planar surface that regionally slopes to the east-southeast.

The sediments and formations that underlie the horizon have been historically interpreted to be Tertiary age, or older; for simplicity and discussion, we will consider these formations to be Tertiary deposits.

The multi-channel, seismic reflection data suggests that the top of the Tertiary is underlain by other semi-parallel, generally continuous geophysical horizons. In contrast to the layering of the overlying Quaternary deposits, the geophysical character of the Tertiary sediments appears more consistent.

6.0 SUBSURFACE CONDITIONS

6.1 HRG DATA AND INTERPRETATIONS

Data Synopsis

Multi-channel, seismic reflection (and Chirp, sub-bottom profiler) data were acquired (by CB&I) in 2013 (refer to Section 3). That data provides a grid of seismic records, which include:

- 158, primary, North–South shiptrack-lines at 150-m-line spacing and
- 28, secondary, East–West shiptrack-lines at 900-m-spacing.

The survey included a total of about 2,800 line-km of multi-channel, seismic reflection data, consisting of approximately 2,480 line-km of N-S (primary direction) data and 380 line-km of E-W (secondary [tie-line]) data.

980 line-km of that data were re-processed (to the extent possible using the available data files) by Oceaneering (refer to Section 3). The reprocessed data, whose locations are shown on Figure 3-6, included:

- 46 line (approximately every fourth line) of the 158, primary, North–South shiptrack-lines to provide data at 600-m-line spacing and
- All 28, secondary, East–West shiptrack-lines of data at 900-m-spacing.

Several examples of the original record, as provided by CB&I are shown on Figures 3-2 to 3-4, and two examples of the reprocessed records are shown on Figure 3-7. Figure 6-1 shows the locations of those records, as well as other seismic records that: a) have been previously presented by CB&I or b) are shown herein as examples of the reprocessed data..

Interpretation Overview

Those data and the subsequent interpretations provide the basis to define the subsurface stratigraphy (geologic section), down to well below the general depth of engineering interest. The data show the site to be underlain, in descending sequence, by:

- Holocene sediments,
- Late Pleistocene sediments,
- Earlier Pleistocene sediments, and

- Older, Tertiary deposits.

The boundaries between the Holocene and Late Pleistocene and between the earlier Pleistocene and underlying older Tertiary deposits correlate to seismic reflectors (geologic horizons) that can be mapped across the lease. The boundary between the Late Pleistocene and earlier Pleistocene sediments is less distinct and requires more detailed interpretation. In addition, multiple reflectors that underly the interpreted Pleistocene/Tertiary boundary can be mapped across the lease.

CB&I (2013) Interpretation

CB&I grouped the imaged, stratigraphic sequence (described above) into three units (refer to Figure 3-4), consisting (in descending sequence) of:

- An upper sequence (CB&I unit 1) interpreted as (primarily) sandy, marine sediments deposited and/or reworked during the Holocene.
- A middle sequence (CB&I unit 2) of layered, transgressive sediments that include multiple paleochannel erosional and depositional complexes containing a mixture of muds, sands and gravels that were deposited and/or reworked by a combination of fluvial, tidal, estuarine, and marine processes during the Pleistocene.
- A lower sequence (CB&I unit 3) of offshore-dipping, layered deposits interpreted (by CB&I) to be Neogene in age and likely comprised of predominantly coastal and marine sediments with lesser quantities of fluvial or estuarine sediments.

CB&I's 2014 report (of the 2013 survey results) provides their interpretation of the structural elevation contours of the seismic reflector (sic. geological horizon) that is the boundary between their seismic units 1 and 2. This interpretation and mapping was presumably based on the combined data sets provided by their sub-bottom profiler and multi-channel seismic reflection data. That structural contour map is reproduced on Figure 6-2, while the thickness of the marine Holocene (sand) above that horizon is reproduced on Figure 6-3.

Upon examination, it is apparent that CB&I's interpretation for the base of their unit 1 is a map of the base of the modern sand dune system and a very limited thickness of surface marine sediment, elsewhere

CB&I noted that within their seismic unit 2, it was possible to trace some, individual reflectors over significant distance, whereas, lower in the seismic unit it was rarely possible to track individual reflectors across similar distances. CB&I, however, provided no mapping of this interpretation of what we subsequently refer to as the geological horizon between units 2a and 2b.

Oceaneering Reinterpretation

As described in Section 3, Oceaneering was hired to reprocess (to the extent possible) the prior CB&I multi-channel seismic reflection records. The locations of the reprocessed lines are shown on Figure 3-6, and two examples are shown on Figure 3-7.

The total of about 980 line-km of multi-channel seismic reflection data re-processed by Oceaneering includes about 600 line-km of N-S (primary direction) data (every 4th line plus additional lines that pass nearest to the 2015 Gardline borings) and 380 line-km of E-W (secondary [tie-line]) data. The re-processed data images the seismic section down to more than 250 milli-seconds two-way travel time, which is approximately 200 meters below the sea surface.

The results of Oceaneering's reinterpretation provided the basis for them to map five seismic reflectors (geologic horizon) and significantly expand on the interpretation and mapping originally provided by CB&I. Page-sized versions of four of the horizon maps (note the fifth horizon is below the depth of engineering interest) are shown on Figures 6-4 through 6-7, and briefly described below..

Horizon A (underlying Unit 1) is shown on Figure 6-4. This horizon is a different interpretation (than CB&I's interpretation) of the Holocene – Late Pleistocene boundary. We infer Oceaneering's Horizon A corresponds to the base of the latest Pleistocene and Early Holocene sediments deposited since the sea level rose to the site's elevation circa 7,000 to 8,000 years ago, following the last glacial maximum.

Channel Base Horizon (separating Units 2a and 2b) is shown on Figure 6-5. This interpretation corresponds to the base of the deepest continuous paleochannel identified within the Pleistocene deposits. This is equivalent to the internal reflector described (but not mapped) by CB&I that separates sediments (within their unit 2) with preserved paleo-channeling from the underlying sediments where evidence of channeling is more difficult to define.

Horizon B (underlying Unit 2) is shown on Figure 6-6. This is the boundary between the earlier Pleistocene sediments and older (presumably) Tertiary deposits identified and described by both Oceaneering and CB&I

Horizon C (within Unit 3) is shown on Figure 6-7. This is one of several continuous seismic reflectors (geologic horizon) present below the Horizon C. Another deeper mapped horizon is also included within the Oceaneering report, but is not included within this discussion

Discussion

CB&I's 2014 interpretation and Oceaneering's 2020 re-interpretation together with our slight modification to Oceaneering interpretation are summarized below. For ease of reference, we refer to:

- CB&I's seismic units are referred to as units 1, unit 2, and unit 3, with the boundaries between their units as horizon 1-2 (which was mapped) and 2-3 (which was not mapped),
- Oceaneering's seismic units are referred to as: Unit 1, Unit 2, etc., with the boundaries between (or within Unit 2) defined by their Horizons A, CB, B, etc.
- As described herein, CB&I's unit 1 is defined differently than Oceaneering's Unit 1, therefore, we define Oceaneering's Unit 1 as including sub-units 1a (equivalent to CB&I's unit 1) and sub-unit 1b (which underlies CB&I's unit 1).

- In addition, CB&I's unit 2 has been interpreted by Oceaneering to include their sub-Unit 1b and Unit 2.
- Finally, Oceaneering's Unit 2 is also divided by Oceaneering's Horizon CB (channel base). Thus, CB&I's unit 2 has been refined to include (what we term as sub-units 1b, 2a and 2b.

6.2 GEOLOGIC HORIZON AND STRATIGRAPHIC UNITS

The following table compares our merged interpretation with the interpretations by CB&I and Oceaneering.

Table 6-1: Definition of Stratigraphic Units and Horizon

Horizon		Description	CB&I		Oceaneering	
	Strata		Horizon	Unit	Horizon	Unit
Seafloor			Seafloor		Seafloor	
	Unit 1a	Modern Sands		unit 1		Unit 1
1-2			1-2			
	Unit 1b	End Pleistocene/Early Holocene Transgressive Deposits		unit 2		
A					A	
	Unit 2a	Late Pleistocene Transgressive Sediments				Unit 2
CB					CB	
	Unit 2b	Earlier Pleistocene Sediments				
B			2-3		B	
	Unit 3	Tertiary (?) or older sediments		unit 3		Unit 3
C					C	
	Unit 4	Tertiary (?) or older sediments				Unit 4
D					D	

Geologic Horizon

Horizon 1-2 (Figure 6-2) is CB&I's interpretation of the base of the Holocene sediments. Examination of the seismic reflection data shows that Horizon 1-2 corresponds to the base of the prominent sand dunes which extend into the site from the southwest. Elsewhere this horizon generally underlies a thin blanket of surficial sand and is locally absent (i.e. merges with and corresponds to the seafloor).

Horizon A (Figure 6-4) is interpreted to be an erosional surface that pre-dates the final submergence of the site area (circa 7.5 to 8.5 kya). This horizon separates Units 1b and 2a. Whereas CB&I's interpretation of the base of the Holocene sediments (their Unit 1-2 horizon) appears to include only a thin layer of sand and the predominate, modern sand ridges (dunes), Oceaneering's interpretation is a deeper seismic reflector.

Thus, we infer that Oceaneering Unit 1 (i.e., sediments that overlie Horizon A) includes both the marine sands (Unit 1a) plus sediments (Unit 1b) that were deposited during the period when sea level last transgressed across this area of the shelf. Unit 1b that overlies Horizon A likely includes various marine, shoreline, fluvial, and estuarine deposits that were deposited during an approximately 1,000 to 2,000 period early in the Holocene.

CB Horizon (Figure 6-5) is interpreted to be an Internal stratigraphic boundary within the Pleistocene sediments. This Channel Base Horizon mapped by Oceaneering (Figure 6-5) is interpreted as the base of sediments that include continuous paleochannels and other time-equivalent deposits. The deposits both above (defined as Unit 2a) and below (Unit 2b) likely includes various marine, shoreline, fluvial, and estuarine deposits that were deposited as sea level rose and then submerged the inner shelf.

Horizon B (Figure 6-6). is interpreted to be the erosional contact (boundary) between the base of the complex Pleistocene stratigraphy and the underlying Tertiary (or older) sediments. This horizon is identified and described by both Oceaneering and CB&I

Horizon C, (Figure 6-7) is one of multiple seismic reflectors (geologic horizon) present in the presumably Tertiary sediments that underly Horizon B. Other shallower horizon are also apparent in the data. Another deeper mapped horizon is also included within the Oceaneering report, but is not included within this discussion

Continuity of Mapped Horizon

As shown on the horizon maps (Figures 6-2 and 6-4 through 6-7), with the exception of the base of the modern sands mapped by CB&I (which in some locations matches the seafloor), the horizons chosen for mapping are continuous and extend across the entirety of the lease.

Those horizons generally slope downward to the east or south-southeast. While the regional slope of the horizons is to deepen in that direction, there is significant local variation that is included (to a various extent) on the uniformity of each horizon.

Sequences of re-processed, east-west and north-south seismic records are shown on Figures 6-8a and b, and 6-9a and b, respectively. All records, on these figures, are shown at the same horizontal and vertical scales to allow the reader to scan the differences in conditions from line to line. The east-west lines are presented from north to south (Figure 6-8a and b); and the north-south lines are presented from west to east (Figure 6-9a and b).

The locations and depths of nearby Gardline borings are shown, and Oceaneering's interpretation of Horizons A, CB, B and C are noted (although Horizon C is below the maximum depth shown on many of the records).

The depth scale is provided as two-way travel time (relative to the seismic source - about a meter below the sea surface). The maximum 160 milliseconds two-way travel time converts to an elevation of about -130 meters.

The east-west seismic records (Figures 6-8a and 6-8b) are presented looking to the north and are shown from north to south. Six east-west lines (see Figure 6-1 for line locations) are shown. The lines have been chosen to include the maximum number of lines near to most of the Gardline borings. . They generally include about every fourth or fifth tie-line, to provide a horizontal spacing of either 2.7 or 3.5 km between the adjacent lines.

Seven north-south seismic records (Figures 6-9a and 6-9b) are presented looking from west to east and looking west. Every 20th line (which includes lines near to most Gardline borings) is shown to provide a 3-km-interval between adjacent lines.

Table 6-2 shows the slope direction of the mapped horizon and the elevations of the horizon at nine locations in the lease. These locations are shown on Figure 6-1 and have been chosen to provide an overview of the horizon depths and strata thicknesses (i.e., differences between adjacent horizon depths) across the lease.

Table 6-2: Structural Horizon Elevations, as mapped by CB&I and Oceaneering

Horizon	Slope Direction	Horizon Elevation, meters (see Figure 6-1 and notes for locations of points)								
		1	2	3	4	5	6	7	8	9
SF	ENE to ESE	-21.5	-26.3	-26.8	-21	-22.5	-31.2	-27.3	-24.2	-41
1-2	ESE	-22.5	-27	-27.8	-22.5	-26.8	-32.5	-29	-26	-42.2
A	East	-31	-39	-39	-33	-38	-48	-38	-38	-54
CB	ESE	-39	-46	-48	-45	-55	-65	-60	-55	-72
B	ESE	-53	-58	-62	-60	-68	-83	-82	-76	-103
C	SE then SSE	-116	-135	-146	-135	-158	-160	-178	-176	-204

SF = seafloor-
Horizon 1-2 mapped by CB&I; other horizons mapped by Oceaneering
Point 1 – NW corner of 6623 Point 2 – NE corner of OCS 6624 Point 3 – SE corner of OCS 6674
Point 4 – center south limit of OCS 6723 Point 5 - center south limit of OCS 6725
Point 6 – SE corner of OCS 6726 Point 7 – SE corner of OCS 6775
Point 8 – SW corner of OCS 6825 Point 9 – SE corner of OCS 6827

Strata Description

The following paragraphs provide a geologic perspective relative to the different strata (seismic units) that are bounded by the different geologic horizon.

Stratum 1a underlies the seafloor and overlies Horizon 1-2. This stratum consists of modern, Holocene marine sands that have been deposited and reworked since the inner shelf was submerged circa 8,500 to 7,500 years ago. Stratum 1a includes both the thick sands that form the prominent sand ridges (dunes) and a thin blanket of sand that elsewhere, generally underlies the seafloor. Beneath the crest of the sand ridges (dunes), these sands may be up to 12- to 15-meters-thick. Outside of the footprint of the sand ridges (or dunes), the marine sands are rarely thicker than 1.5 to 2 meters and are locally absent. The marine sands may locally contain minor percentages of gravel.

Stratum 1b underlies Horizon 1-2 and overlies Horizon A. Stratum1b likely includes various marine, shoreline, fluvial, and estuarine deposits that were deposited during an approximately 1,000 to 2,000 period during the Holocene when the lease area of the Inner Shelf was transition from an emergent to a submerged landscape. Stratum 1b is typically 8- to 15-meters-thick.

Examples of the landforms included in these deposits were described in Section 5. Stratum 1b probably includes layers of clay, sand, and silt. Individual layers may be less than 1-meter to up to 3- to 5-meterer-thick. Individual lays may be laterally continuous of 100s of meters or be localized.

Stratum 2a underlies Horizon A and overlies the Channel Base Horizon. The genesis and composition of this stratum is anticipated to be generally similar to that of the overlying stratum 1b and the underlying stratum 2b. Stratum 2a, however, is differentiated from the overlying and underlying strata in that Stratum 2a includes infilled paleo-channels that can be mapped and followed for several kilometers. The continuity of some layers above the Channel Base Horizon suggest that those sediments are likely to be of Late Pleistocene age. These sediments pre-date the erosional surface, defined by Horizon A, and are inferred to have been deposited during the period when the shoreline was transgressing across this portion of the Inner Shelf.

Stratum 2a is 6- to more than 20-meters-thick. These sediments may be channelized, and the paleo-channels may be infilled with ether sediments of a different texture or younger sediments equivalent to the sediment layer that the paleo-channels incise. The paleo-channel infill also maybe composed of sediments that grade upwardly from coarser to finer. The thicker portions of Stratum 2a correspond to what appear to be more deeply incised paleo-channels (refer to the illustration on Figure 5-6). Individual layers in Strata 2a may be less than 1-meter to more than 10-meters-thick. Individual layers may be laterally continuous for several kilometers or be localized.

Stratum 2b underlies the Channel Base Horizon and overlies Horizon B. As noted, this stratum's genesis and composition are interpreted to be comparable to that of the overlying Stratum 2a. Individual layers in Stratum 2b, however, are more localized and evidence of continuous paleochannels is absent. We infer that the lack of such laterally extensive landforms implies that the sediments underlying the Channel Base Horizon have been affected by multiple phases of erosion and re-deposition.

The thickness of Stratum 2b ranges from about 10- to 30-meters and trends to increase to the southeast. Individual layers within Stratum 2b may range from less than 1-meter to perhaps 5- to 7-meter-thick. A significant degree of lateral and vertical variability is to be expected. The undrained shear strength of clay layers is expected to increase with depth, as is the density of sand layers.

Strata 3 and 4 underlie Horizon B and are separated by Horizon C. The sediments and formations that underlie the horizon have been historically interpreted to be Tertiary age, or older. For simplicity and discussion, we will consider these formations to be Tertiary deposits. Various internal geophysical reflectors that are subparallel to both Horizons B and C are present.

In contrast to the layering of the overlying Quaternary deposits, the geophysical character of the Tertiary appears more consistent. This may indicate that the thickness and laterally continuity of individual layers within the Tertiary strata are greater than that of the overlying, Quaternary sediments of Strata 1b, 2a, and 2b. However, review of the Gardline boring data shows that significant layers within Stratum 3 commonly include significant bedding and inclusions of different sediments.

6.3 GEOPHYSICAL – GEOTECHNICAL CORRELATION

Gardline (2015) Interpretation

During their 2015, preliminary exploration program, Gardline revisited the CB&I seismic data records, supplemented their interpretations, and compared the stratigraphic lithology in the borings with the seismic signature of the stratigraphic sequence. One of the two resulting geotechnical profiles is shown on Figure 3-5. Gardline opined that the boring lithologies compared favorably to the geophysical interpretation. Their correlation of their geotechnical units with that of CB&I's previous geophysical interpretation is shown in Table 6-3.

Table 6-3: Correlation between Seismic Units and Geotechnical Strata

Seismic Units		Gardline Geotechnical Units (layers)	
Unit Designation	**Geologic Description**	**Unit Description**	**Geotechnical Descriptions**
1	Surficial Sediments	1a	Sand
2	Transgressive Sequence containing extensive Paleo-Channeling	1	Sandy Clay
		2	Sand
		3	Sand
3	Dipping, sub-parallel bedded Sediments	4	Sandy Clay
		5	Clayey Sand to Sandy Clay
		6	Silty Sand
		7	Sandy Clay

Our examination of the description of the layers included in the borings show the presence of significantly more cohesive sediments than would be assumed from Gardline's descriptions of the geotechnical strata. This is not surprising to us and is consistent with our experience elsewhere on the mid-Atlantic continental shelf.

The Gardline report does not attempt to correlate the borings and layering within the borings to whether the borings are located within an area underlain by the various seafloor and near-seafloor, geologic features described by CB&I.

Comparison of Gardline Interpretation with Reprocessed Seismic Records

As noted in Section 3, the Gardline Volume 3 report (2014) includes the construction of two geophysical profiles (one of which is reproduced as Figure 3-5) and correlates those profiles to the soil borings. We have reviewed the Gardline interpretation and compared their interpretation to the additional insight provided by the reprocessed, multi-channel seismic reflection data. Observations from that comparison as summarized below:

- Gardline's observations remain generally correct.
- The newly reprocessed seismic reflection records allow opportunity to better appreciate the context of the sediment layering and conditions, as encountered in the Gardline borings, with the overall geologic interpretation as provided by the integration of the geophysical and geotechnical data.
- Specifically, details with respect to the presence or absence of interbedded sediments (largely ignored in Gardline's prior correlation) are more apparent.
- Some of the layering in the borings can be correlated to minor difference in the character of the seismic records in Strata 2a, 2b and 3 and/or internal reflectors within those seismic units.
- Much of the layering in Stratum 3 correlates to unmapped interval reflectors that underlie. Horizon B.
- The reprocessed seismic data increases the confidence that the seven Gardline borings should provide representative engineering data for the subsurface conditions that underlie the Lease.

6.4 SUBSURFACE FEATURES

Surficial Sediments (Stratum 1a)

CB&I interprets that the post-sea level rise sediments underlying the lease consist of a variable thickness of primarily granular, Holocene sediments (seismic unit 1; strata 1a). Their interpretation of the thickness of those surficial sediments is shown on Figure 6-3. As shown, the thickness of the surficial sediments are interpreted, by CB&I to vary from less than 1 meter to nearly 10 meters. None of Gardline's seven borings are drilled through the crest of a sand ridge. This is not considered to be a significant limitation relative to preliminary foundation design, as the sediments that create the mid-Atlantic sand dunes are well defined, as are their engineering properties.

Presence of Channeling (with Strata 1b and 2a)

The stratigraphy that underlies the surface layer of marine sands includes extensive evidence of channeling. The channeling includes both features that can be correlated across multiple, seismic-reflection survey lines and features that can be correlated between only a limited number of survey lines. CB&I's report includes maps showing both well-organized (i.e. areas where channels extend over larger distances) and poorly-organized (i.e., areas where individual channels do not appear to be continuous over large distances). CB&I does not map the thalweg, trends, or depth of the paleo-channeling that underlies the site.

The presence of such conditions is consistent with deposition that occurs as areas are submerged as sea level rises (i.e., sea level transgression). In such areas, repeated cycles of channel cutting (sic., erosion) and channel filling (sic., deposition) typically produce complex and highly varied stratigraphy. In these areas, it is often difficult to correlate individual soil layers over significant distances. However, the last episode of channel erosion and deposition can sometimes be preserved, and such last-stage channeling can therefore extend over considerable long distance.

Figure 6-10 shows CB&I's mapped presence of these two types of channeling. The locations of the seven Gardline borings with respect to CB&I's mapping of the paleochannels is provided in the following table.

Table 6-4: Mapped Channeling at Boring Locations

CB&I's Paleochannel Mapping	Gardline Boring Designation						
	G7	H10	MT	K16	D14	G17	I21
Organized Channeling	no	yes	no	yes	no	no	yes
Poorly-organized Channeling	no	no	no	no	no	no	no

As shown, three Gardline borings are at locations that CB&I interprets to be underlain by organized channeling, but none of the Gardline borings are in areas that CB&I interprets to be underlain by poorly-organized channeling. Considering the extent of the channeling within strata 1b, 2a and 2b, it appears that the Gardline borings may underrepresent the amount (and possibly types) of channel-fill sediment that may be present beneath the site.

7.0 INITIAL GEOHAZARDS EVALUATION

Various geohazards are described in the section. These potential geohazards are described in order of their decreasing significance to the proposed project.

7.1 SEDIMENT TRANSPORT AND SCOUR

Background. Sediment transport and scour are potentially one of the more significant geohazards for offshore wind farm development in the Maryland Wind Energy Area. Migration of seabed waves (e.g. dunes and sand waves) and scour around turbine structures and cable trenches has been a significant geohazards for some European wind farms. Mitigating sediments and scour problems can require costly maintenance and remedial work. In the extreme, scour can locally create unexpected risk for the structural performance of wind turbines and compromise the delivery of energy through inner array and export cables.

The lease area is an area prone to bottom currents that are capable of transporting sediments and causing scour at future turbines. The presence of morphologic features support that inference. Sediment transport processes may result in net erosion or deposition. Erosion processes may be problematic for structures if scour occurs at the base of the structure. Removal of material can: a) lead to reduced skin friction resistance and reduced lateral resistance, b) cause softer load-response characteristics of the substructure, and/or c) modify the resonance of the turbine structure.

Evaluation of Conditions. The Mid-Atlantic continental shelf is considered a storm-dominated environment. Therefore, site-specific investigation of bottom flow is important to understand the processes modifying the seafloor.

Large-scale features (i.e., sand waves and sand ridges) are likely modified only during large storms that occur infrequently (Swift, 2010). A single storm event, however, can alter the seafloor bedforms including large sand waves and sand ridges that were stable under non-storm conditions. Such modifications may be produced by either: a) tropical storms and hurricanes in the late summer to fall and b) late fall to early spring Nor'easters.

These features may be altered due to currents produced by extreme storm events. This is because 1) the water depth is shallow enough that wave energy can reach the seabed and possibly modify these features, and 2) some of these features are located within a channel that may focus current flow and possibly cause higher current velocities through it.

Seafloor sediments are mobilized and/or transported by bottom flow, whether due to currents (e.g., tidal currents, wind-driven circulation, etc.), wave oscillatory motion, or a combination of both. Waves (especially waves due to large storm events) are capable of suspending sediments into the water column due to the wave-orbital motion of the wave and its interaction with the seafloor.

Bottom flows may cause scour at the base of the structure where it encounters the seafloor. Scour processes are important because the removal of sediments from around a structure could reduce skin friction resistance (and transfer axial pile loads farther down the pile shaft), reduce lateral resistance, or modify the resonance of the structure.

Mobile sediments pose potential hazards to piles (potential for scour) and buried cables (potential for exposure). Figure 5-1 shows areas, in the lease, where we anticipate a relatively higher potential for sediment transport and scour. Examples of potential hazard areas include:

- Within the Delaware valley – which extends southeast from about the mid-point of the northeastern lease boundary – bottom current flow may be higher due to channelization of flow and currents,
- On sand ridges in shallower water depth. Such as along the eastern and southeastern lease perimeter, where wave-induced bottom flow may be stronger than in the adjacent swales, and

- In areas where large-scale features (e.g., sand waves or dunes) may be mobile.

The placement of piled-structures in the area will locally increase the bottom currents and scour potential around the legs of the structures. In addition, during future wind farm development, jet plowing or other cable burial methods will loosen the seafloor sediments and increase their erosion susceptibility. The uncertainties relative to and important implications of seafloor mobility and scour have been described by a BOEM Technology Assessment and Research (TAR) study (McNeilan and Smith, 2011).

7.2 SUBSURFACE CONDITIONS AND VARIABILITY

The upper portion of the subsurface stratigraphy beneath the project area is anticipated to be composed on late Pleistocene and Holocene sediments. The subsurface conditions underlying the lease are most influenced by the presence, or absence, of: a) sand ridges and dunes, b) buried, relict drainage systems, c) clay-filled paleochannels, and d) "back-bay" estuary deposits. This is typical off all the mid-Atlantic coast.

There are two primary types of risks associated with highly variable and/or very layered subsurface conditions. Those types of risk can be broadly defined to include:

- Variability of conditions that creates different foundation load-carrying capacity, load-deflection behavior, dynamic response, or other structural performance or risk differences among a group of structures.
- Variability of conditions, either vertically or laterally that affects installation risks. An example of this type of risk is potential punch-trough failures of jack-rig rigs during installation and commissioning of structures.

The first type of variability can be mitigated by using site-specific design of each, individual structure, and/or careful grouping of structures for design analyses. Section 9 presents the results of static axial pile capacity calculations, based on global upper and lower bound assumptions of subsurface conditions and design parameters. As additional subsurface geophysical data are collected and subsurface exploration conducted, the evaluation of these uncertainties and risks will be refined and evaluated.

The character of the geologic deposits on the Mid-Atlantic shelf is consistent with the need to carefully define and evaluate performance risk for both temporary installation activities and long-term structure foundation performance. As mentioned, jack-up vessel installation risks are considered to be an important risk, if such vessels are used to place and drive foundations and erect towers, nacelles and blades.

Subsurface variability is considered an important risk factor, we consider it to be a manageable risk. This risk at the US Wind site is viewed to be no greater, nor no less than is typical for any site on the mid-Atlantic OCS.

7.3 SEAFLOOR CONDITIONS AND VARIABILITY

The seafloor conditions in the Mid-Atlantic shelf are complex. Like all of the mid-Atlantic OCS, the seafloor in the lease includes significant local topography that includes alternate ridges and swales. These features are typically oriented NNE-SSW, and the crests of the ridges and base of the swales tend to deepen to the east. The seafloor geomorphology includes both relict features that are inferred to date back to the area's submergence as sea level rose following the last period of glaciation, and more contemporary features that reflect the complex interaction of bottom currents and seafloor sediments.

The seafloor topography means that regardless of where structures are sited within the lease:

- Turbines will be in various water depths that will vary between adjacent structures and
- Cables will be routed over complex seafloor topography.

7.4 BOULDERS

The Lease is far enough to the south of the maximum glacial advance that direct deposit of boulders due to glacial processes is not a risk in the Lease. However, icebergs that have calved from the front of glaciers could have floated southward to the Lease area. When such icebergs thaw, boulders encapsulated in the iceberg fall to the seafloor. Therefore, the potential presence of boulders cannot be entirely discounted. In addition, various fluvial processes can deposit boulders in landforms such as those anticipated to be present beneath the site.

7.5 SHALLOW GAS

There is potential for biogenic gas to be present in the Pleistocene sediments. They likely accumulate as organics in lagoonal, paleo-channel infill, and fluvial-estuarine deposits decay. When the gas accumulates in overlying sandy deposits that are capped with clay, the gas can become pressurized. While shallow, biogenic gas may be locally present, it is not considered a large risk.

7.6 SEISMIC HAZARDS

The lease is not located in a region considered to be seismically active. Thus seismic-related geohazards are not considered to be a high risk for the proposed offshore wind project. The study area is in an area of low seismic activity. Based on our review of historical earthquakes, such events that occurred within 100 nm of the study area were less than a magnitude 5.

Earthquake Ground Motions and Ground Shaking

Earthquakes generate ground motions that can affect a structure by shaking, especially if a site's resonance matches that of the turbine, substation, or meteorological tower structural system. We anticipated that longer period ground motions will control the seismic hazard.

Earthquakes may pose potential hazards to wind turbines and substations by: 1) causing ground shaking that may affect the structure, especially if the site resonance matches the structural resonances resulting in a double resonance; 2) causing liquefaction that will decrease lateral resistance and/or the skin friction of the soils around the foundation; 3) generating a tsunami; and/or 4) inducing submarine landslides. While the earthquake magnitudes that the known faults are capable of generating are limited, the ground motions from earthquakes in the eastern U.S. are capable of travelling larger distances than the western U.S. due to differences in the attenuation properties of the crust.

Fault Rupture Hazard

Based on our review of publicly-available information and data acquired as part of this study, no known active faults (defined as ruptured during the Holocene or last 10,000 years) or potentially active faults (defined as ruptured during the Quaternary or last 1.6 million years) were identified within the lease area. Nor are any such faults know or trend toward the lease. Thus, potential fault rupture is not anticipated to be a hazard to a project in the Lease area.

7.7 SLOPE INSTABILITY

The only significant slopes within the Lease are the flanks of the large sand ridges (dunes) that extend into the Lease from the west and southwest. Thus, slope instability is not considered a significant geohazard.

7.8 TSUNAMI RISK

A tsunami is a series of sea waves generated by rapid displacement of a large volume of sea water. Tsunami waves have been document to reach the Maryland shoreline. The rapid displacement of water may result from vertical warping of the seabed, large scale submarine or coastal landslides, or volcanic eruptions in or near ocean basins. Tsunami waves are generally produced by displacement of the seafloor during an earthquake. Uplift of the seafloor elevates the sea surface upwards, while subsidence of the seafloor produces a drawdown of the sea surface. Tsunami waves may also be triggered by offshore landslide. Tsunamis are usually described as local- or distant-sourced. The potential for significant, local-sourced tsunamis is probably small, but distant-sourced tsunamis may have a higher potential.

In the open ocean, distant-source tsunami waves have a very long period and wavelength and can travel at speeds of greater than 300 miles (500 km) per hour. As a tsunami moves into shallow water; the wave height increases, and the wavelength and speed decreases. Historical records indicate that the character of tsunami waves varies greatly depending on factors such as the shape of the coastline, coastal seafloor topography, the existence of offshore islands, and the direction of the incoming waves. However, the passing of tsunami waves across the lease is not considered to be a threat to the project structures.

7.9 VOLCANISM

There are no known active volcanoes, seamounts, volcanic vents, rifts, or mud diapirs in the region.

8.0 INITIAL GROUND MODEL

8.1 GROUND MODELING PROCESS

The following approach has and will continue to be used to develop the ground model for the project::

- Interpret and map the sub-surface stratigraphy as imaged by available: a) Chirp, sub-bottom and b) mid-penetration, sparker seismic reflection data.
- Use the available subsurface geotechnical exploration to define the engineering character of the sediments and predict the engineering properties of those sediments.
- Correlate soil lithologies, as encountered by the borings, with seismic (sic, stratigraphic) units mapped from the subsurface geophysical data.
- Interpret representative: a) average, b) strong/stiff (i.e., upper-bound), and c) weak/soft (i.e. lower-bound) soil properties for the layers in the representative soil stratigraphy that correlate to anticipated average, stronger/stiffer and weaker/softer soil response for each zone.
- Define representative soil stratigraphy for mapped seismic units and define representative layering and layer thicknesses in each site development area zone.

This process will be used to

- 1st define the global character of the seafloor and subsurface conditions, stratigraphy and sediments.
- Then zone the proposed development area to define areas with a defined range of subsurface stratigraphic conditions, as imaged by the sub-surface geophysical survey records.

The evaluation of the global conditions are the basis for the interpretations included in this Initial Site Characterization Report. The results of the COP-Phase geophysical survey (described in Section 10) will then be used to zone the site for the Preliminary, Site Characterization Report, and the design-phase geotechnical exploration results will be used to further zone and refine the interpretations to be included in the Final Site Characterization Report.

This process was used to: a) first define the global upper- and lower-bound soil profiles (as included herein) and b) then will be subsequently used define the average, lower- and upper-bound soil profiles for the different defined areas (or zones) within the project development area.

Considerations and objectives as used during the initial global interpretation are described below, as are some of the considerations and objectives that will be employed during the second phase of interpretation for the different site areas.

8.2 GEOPHYSICAL HORIZON MAPPING

Overview of Mapping Stages

The initial CB&I geophysical reports provide maps of: 1) the thickness of post-glacial, seismic unit 1, 2) the shallowest mappable horizon (i.e., the contact between seismic units 1 and 2), and 3) the presence or absence of near-surface paleo-channeling.

As noted, in Section 3, the initial CB&I reports, did not attempt to interpret and map the deeper geophysical reflectors (present within the expected depth of pile foundations) nor the continuity or lack of continuity of the deeper subsurface conditions across the site.

Thus, US Wind hired Oceaneering to perform additional processing, interpretation and mapping of the CB&I data, as described in Section 3. As described in Section 6, this significantly enhanced and added to the value of the prior CB&I data.

Pre-COP-Phase HRG Interpretation & Mapping

To prepare the pre-COP, preliminary Ground Model development, Oceaneering re-processed and interpreted 46 primary-direction (N-S) lines and 27 secondary-direction (E-W) lines (Section 6). This provides a 600m by 900m grid of re-processed seismic reflections records.

As described in Sections 3 and 6 the following products have been developed from that effort:

- A catalogue of the 73 re-processed seismic reflection records has been output at common horizontal and vertical scales.
- Structural Contour maps have been interpreted for five different subsurface horizons.
- Thickness (isopach) maps of the sediments overlying the five horizons (i.e. depth below seafloor maps of the horizon) have been prepared.

Upcoming COP-Phase HRG Subsurface Interpretation

The process will be repeated following the collection of additional subsurface sub-bottom profiler and multi-channel seismic reflection data during the upcoming HRG survey described in Section 10.

Site Zonation

The stratigraphic variations based on both the re-mapped CB&I data and the upcoming COP-Phase HRG survey (Section 10) data will be evaluated to define zones of common or definable variations in seafloor and subsurface conditions. The definition of zones will consider:

- Range and variation of water depth (seafloor elevation),
- Thickness of surface sands and elevation of underlying layered stratigraphy,
- Areas underlain or not underlain by extensively channelized sediments,
- Areas where channelized sediments extend down to near (or into) the top of the dipping, sub-parallel bedded stratigraphy (underlying Horizon B), and

- Other factors as defined during the evaluation.

The number of zones will depend on the uniformity or variability of the geologic framework as defined in the prior task. Conceptually, we are anticipating that 4 to 7 zones will be identified and defined.

8.3 SEDIMENT LITHOLOGY AND SEISMIC STRATIGRAHY CORRELATION

Initial, Global Interpretation

For our initial, global interpretation, we accepted Gardline's conclusion with respect to the correlation between their geotechnical units and seismic units (as discussed in Section 6). Because the depth and elevation intervals, for a geotechnical unit vary among the borings, we indexed the stratigraphic interpretation to the depths of the different soil layers relative to the depth and elevation of Horizon B (refer to Section 6).

We chose to represent the upper-bound (strongest/stiffest conditions) soil profile as being a location where: 1) the water depth is shallowest, 2) a course-grained sand ridge underlies the turbine location, 3) Horizon B is relatively shallow, 4) the soil stratigraphy includes a relative abundance of thick granular sediments and a limited amount of relatively thin, cohesive layers, and 5) the site is not underlain by a paleochannel. This results in a soil profile which includes the oldest likely sediments within a specific depth interval.

For the lower-bound (weakest/softest subsurface conditions) soil profile, we have chosen a location where: 1) the water depth is deepest, 2) the turbine location is not underlain be a course-grained sand ridge, 3) Horizon B is relatively deep, 4) the soil stratigraphy includes a relative abundance of thick cohesive sediments and a limited amount of relatively thin, granular layers, 5) the site overlies the axis (or thalweg) of a deeply-incised paleochannel, and 6) the paleochannel fill consist of a thick sequence of slightly, over-consolidated clay sediments. This results in a soil profile which includes the youngest potential sediments within a specific depth interval.

We note that for the upper-bound stratigraphy, the surface sand sediments are thicker than are present at any of the 7 boring locations, since as noted previously none of those 7 locations is located over the axis of a sand ridge. Similarly, for the lower-bound conditions, we have included the potential that a site is underlain by a thick sequence of slightly over-consolidated clay deposits, even though such conditions were not encountered in any of the seven borings. But as noted previously, the potential exists that the extensively channelized sediments will contain relative deeply incised channels that have been backfilled with fine-grained sediments.

Future, 2nd Pre-COP, Preliminary Evaluation

As our evaluation moves forward, the preliminary correlation as reported by Gardline can be reviewed and extended. As noted, we anticipate that further review may suggest that the Gardline comments, while correct in a general sense, could be simplistic.

This phase of evaluation will look at the consistency and variability of the stratigraphy, soil layering, and sediment characteristics with respect to: 1) seismic units (geologic strata), 2) locations within and outside of major paleochannel complexes, 3) spatial variations, and 4) variations consistent with position of layers within the geologic strata, etc.

The analyses will be used to develop representative stratigraphy for each zone, that account for:

- Water depth variations,
- Seafloor and near seafloor geomorphology,
- Depth to, top elevation of, and thickness of seismic unit 2,
- Variations within the Pleistocene sediments, both with and outside of paleochannel complexes,
- Apparent differences in the seismic character of Stratum 2 in the northwest (where Stratum 2 is thinnest) and the southeast (where Stratum 2 is the thickest) – preliminary review suggests that the deepest paleochannel thalweg penetrate to the base of Stratum 2 in the northeast, but that the deepest thalweg in the southeast only penetrate to about 2/3rd the maximum depth of Stratum 2,
- The depth to and elevation of Horizon B,
- Possible variations in all stratigraphic units and soil layers based on differences associated with location and elevation of those units and layers.

Figure 8-1 shows how the interpreted layer thickness and strata boundaries variations are included in the definition of the lower and upper bound *profiles.* The +/- variations in strata boundaries (and thickness) are intended to: a) provide reasonable conservatism relative to defined variations as documented by the various exploration data as well as b) recognize the possibility that other undefined variations in layer and strata thicknesses may be present within the Lease. While Figure 8-1 illustrates how the constructed profiles are adjusted at granular/cohesive soils boundaries, the same principles can be applied to boundaries between different granular strata or different cohesive strata with different properties.

8.4 DEFINITION OF SOIL PROPERTIES

The testing data from the seven Gardline borings have and will be used to interpret representative: a) lower bound, b) average, and c) upper bound soil properties for the soil layers that comprise each unit. For this interpretation, the lower bound soil properties are defined as the engineering parameters that will generate the least pile capacity and softest soil response, while upper bound soil properties are defined as the engineering parameters that result in the highest pile capacity and stiffest soil response.

Initial, Global Interpretation

For our initial, global interpretation, we generally adopted the engineering parameters for each of the seven borings, as defined by Gardline. There were two exceptions to our use of

Gardline's interpreted parameters. Those related to Gardline's interpretation of the effective friction angles, based on CPT correlations in: 1) clayey sand and very layered sediments and 2) two locations where the sediments are defined as silt. For those locations, we believe that the angles of internal friction, ø', as interpreted by the CPT correlations underestimate the in-situ strength of the sediments. Our basis is that the sediments in situ were likely to have developed positive pore pressure during the advancement of the cone, and thus the cone resistances did not represent the drained strength of the sediments.

While Gardline provided their interpretations of the various engineering parameters for each specific boring, their reports do not discuss or evaluate the variations of those parameters among the borings. Hence, for our global interpretation, we plotted Gardline's interpreted parameters versus both depth and elevation and correlated those parameters by geotechnical units. The resulting plots for: a) effective unit weight, b) undrained shear strength (of cohesive sediments), and c) the effective angle of internal friction (of granular sediments) are shown on Figures 8-2 through 8-4. As shown on those figures, we have differentiated Gardline's interpreted strengths for the different seismic units, as described herein.

2nd COP-Phase Evaluation

As our interpretation move forward, we will re-visit and further evaluate the testing data and interpretations provided by Gardline. This re-interpretation will consider and review the consistencies, or inconsistencies, of different correlations between different engineering parameters. This process will be used to define the representative and lower-/upper-bound engineering parameters associated with the different geotechnical strata and their possible variations versus spatial location and depth/elevation across the project development area.

9.0 CONCEPTUAL PILE DESIGN & INSTALLATION EVALUATION

The conceptual pile design and installation evaluations included in this Initial, Site Characterization Report are based on the global evaluation of the subsurface stratigraphy and conditions across the Lease. As described in Section 8, the evaluations to be included in the Preliminary, Site Characterization Report, will include consideration of the spatial (and vertical variations in different "zones" of the Lease.

9.1 CONCEPTUAL PILE CAPACITY EVALUATION

Definition of Representative Soil Stratigraphy

After analyzing the uniformity and variations, across the Lease, as described in Sections 6 and 8, we developed representative soil stratigraphies that consider those subsurface variations across the Lease. The representative stratigraphy considered variations in: 1) soil layering, 2) soil layer thicknesses and character, and 3) engineering properties, etc.

The interpreted range of soil stratigraphy considered how those variations will affect the pile capacity and pile response to cyclic loading.

For the Lease, *Idealized Soil Profiles* were developed for our:

- Preferred Interpretation,
- Lower Bound Interpretation, and
- Upper Bound Interpretation.

The definition of the Lower and Upper Bounds of the *Idealized Soil Profiles* is listed in the following table.

Table 9-1: Lower and Upper Bound Soil Profile Formulation

Criteria	Lower Bound	Upper Bound
Water Depth	Deepest	Shallowest
Granular Layers	Thinnest	Thickest
Cohesive Layers	Thickest	Thinnest
Soil Strength	Weakest	Strongest
Soil Stiffness	Softest	Stiffest

The interpreted upper- and loser-bound global soil profiles, and their associated soil properties are tabulated in Figures 9-1 and 9-2, respectively.

Pile Capacity and Soil Stiffness

For our global interpretation of the pile capacities for the lower- and upper-bound, we relied on the 2014 version of API, RP2A. The results of those computations, for a 1.83-meter- (60-inch) diameter, driven, steel-pipe pile, are shown on the following figures:

- Figures 9-3 and 9-4 present the calculated, ultimate, unit skin friction and unit end bearing, respectively, for the upper- and lower-bound profiles,
- Figures 9-5 and 9-6 present the calculated ultimate, axial skin friction, end bearing and total compressive pile capacities for the upper- and lower-bound profiles, respectively, and
- Figure 9-7 compares the total ultimate compressive pile capacity for the lower- and upper-bound soil profiles.

The results of the global evaluation suggests the following variability of axial pile capacity for a specific size pile:

- The variation of axial pile capacity at a specific depth may vary by as much as 100%, depending on whether the piles are tipped in a sand layer or not.
- The variability in penetration depth required to reach a specific design axial pile capacity may vary by more than 20 meters, depending on the presence and thickness of sand layers that provide end bearing.

The variability of axial pile capacity for a monopile, however, will be less. This is because the generally thicknesses of sand layers is not anticipated to be adequate for the development of full end-bearing capacity of a large-diameter monopile. For a large diameter monopile, the variation in axial pile capacity at a specific depth should vary by less than 50%, while the range of pile tip penetration for a specified capacity is expected to be no more than 10 to 15 meters.

The next step of the process (to be included in the Preliminary Site Characterization Report) will develop zone-specific pile capacities and pile-soil deformation data to account for: 1) stratigraphic and subsurface variations and uncertainty, and 2) variations between different analytical models and design formulations.

9.2 PILE DRIVABILITY

Pile Drivability Analyses have been completed by Fugro for:

- 60- and 72-in-diameter, driven steel pipe piles and
- 8.3-m-diameter, driven monopoles.

The driven, steel pipe pile analyses was for the planned met tower location in the center of the lease. Those analyses should be meaningful for the evaluation of a pile-supported, jacket foundation with pile between about 2- to 2.5-meter-diameters.

The analyses and the results are provided in the following reports:

- Jacket pile: Fugro (2015): *Engineering Analyses, Boring: Met Tower, Maryland Wind Energy Area, Offshore Maryland,* Report No. 0201-7893, to Keystone Engineering Inc., November 5, 2015.
- Monopile: Fugro (2020). *Evaluation of Pile Drivability, 8300-mm (327-in)-Diameter Driven Pipe Pile, Maryland Offshore Wind Farm, Offshore Maryland*, Report No. 2001-0038 to US wind Inc., 20 July 2020.

The Fugro drivability analyses substantiate that the installation of driven pile foundations should not be problematic at the US Wind Lease on the Maryland OCS.

10.0 FUTURE G&G PROGRAMS

10.1 COP-PHASE HIGH-RESOLUTION GEOPHYSICAL (HRG) SURVEY

Survey Intent and Overview

The planned COP-phase, high-resolution, geophysical (HRG) survey program is described in the (April 2020) Survey Plan (ESS, 2020). As described, the COP-Phase, HRG survey is to include data collection along a tartan-pattern survey grid throughout the Lease. The new data collection is intended to provide:

- Full-coverage, multi-beam, echo-sounder (MBES) data and side scan sonar data within the primary survey corridors.

- Multi-beam, side scan sonar, gradiometer, and sub-bottom profiler data on all survey lines.
- High quality mid-penetration, multi-channel and single-channel, seismic reflection data on lines, as described herein.

Applicable BOEM Guidelines

The requirements set forth in the latest versions of the BOEM Office of Renewable Energy Programs' various *Guidelines* are applicable to the project. The applicable BOEM *Guidelines* include:

1) *Guidelines for Providing Geophysical. Geotechnical, and Geohazard Information Pursuant to 30 CFR Part 585,*

2) *Guidelines for Providing Archaeological and Historical Property Information Pursuant to 30 CFR Part 585 and*

3) Guidelines for Submission of Spatial Data for Atlantic Offshore Renewable Energy Development Site Characterization Surveys are applicable to the US Wind geophysical survey.

Objectives of Bathymetry, Side Scan Sonar, and Gradiometer Data Acquisition

The objectives of the seafloor mapping and gradiometer data collection are to meet the requirements for geological and archaeological evaluations as defined by the BOEM Guidelines and to provide the required data for environmental evaluation and engineering design of the project's structures and cabling.

Objectives of Subsurface Geophysical Data Acquisition

The subsurface geophysical data collection has two objectives; namely collection of sub-bottom data that are:

- Of depth, and detail suitable for definition and mapping of the glacial-age (pre-Holocene) "paleo-landscape," ground surface, and
- Optimal for creation of an integrated geologic-geotechnical-geophysical subsurface model down to about 80- to 120-meters depth below seafloor.

The need for sub-bottom data, more detailed than obtained during previous surveys, is to identify and analyze the paleo-landscape and better define that culturally-significant, buried surface.

In addition, the subsurface model, to be developed from the subsurface data, will optimize the ability to rationally extrapolate site-specific, geotechnical exploration results and to provide a basis for grouping turbine positions for design analyses.

The standard 30-meter line-spacing for sub-bottom profiler data collection and collection of mid-penetration, seismic reflection data along every 5th line (i.e.150-meter-spacing) is to be modified for the project survey. Figures 10-1 and 10-2 show the tartan-pattern, survey grid layout and grid details, respectively.

The premises for system selection are as follows:

- An Innomar sub-bottom profiler has been selected in recognition of the limitations of the previously acquired Chirp sub-bottom data. This system will be operated to provide system frequencies and operating characteristics that provide the optimal opportunity to penetrate and image subsurface reflectors in dense, granular sediments.
- The mid-penetration, seismic reflection data are to be used to: a) define the paleo-landscape in areas where the sub-bottom system lacks adequate penetration for that definition and b) define, map and correlate (with the geotechnical exploration data) the stratigraphic sequence down to 80- to 120-meters penetration.
- The mid-penetration, multi-channel seismic reflection system will consist of a GeoMarine-GeoSurvey system that includes:
    - A flip-flop sparker or multi-plate boomer sound source.
    - A digital, multi-channel, hydrophone array that includes between 40 to 100 channels at no greater than 1.5625-meter-group interval

Survey Corridors and Grid

As shown on Figure 2-1, turbines may be located on eighteen (18) north to south (nominal orientation) rows that are designated, from west to east, as Rows A through Row R, and on thirteen (13) west to east (nominal orientation) cross-rows that are designated, from north to south, as cross-rows 1 through 13.

The COP-Phase geophysical survey program will consist of a tartan-pattern, survey grid (Figure 10-1) with primary survey corridors aligned parallel to the planned (nominal) north-south turbine rows, and the tie-lines are to be oriented to cross in an east-west direction through planned turbine locations. The azimuths of the grid are:

- Primary lines along turbine rows: reciprocal 7º 3’ 40.8” – 187º 3’ 40.8” azimuths.
- Secondary, cross-row lines: reciprocal 89º 59’ 35.9” – 269º 59’ 35.9” azimuths.

As shown on Figures 10-2 and 10-3, the tartan-pattern grid includes the following data collection:

- Primary direction survey corridors:
    - Along the 18 turbine row centerlines.
    - Along 12 wing-lines, at 30-meter-spacing, to either side of the turbine row centerlines.
    - To provide data across 720-meter-wide survey corridors.
- Primary direction tie-lines:

  - At the mid-point between turbine rows (i.e., at about 712 meters from the adjacent turbine rows and 352 meters from the adjacent outermost tartan wing lines) plus
  - Along single lines offset 700 meters to the west of Row A and east of Row R
  - To create 19 mid-row lines in the primary direction.
- Secondary cross-row survey corridors:
  - Along the 13 cross-row centerlines.
  - Along 2 wing-lines, at 60-meter-spacing, to either side of the turbine row centerline.
  - To provide data across 240-meter-wide survey corridors.
- Secondary, cross-row, tie-lines:
  - At the approximate 1/3rd points between the edge of the secondary survey corridors (i.e., at 664 meters from the adjacent turbine rows) plus
  - Along single survey lines offset 600 meters to the north of cross-row 1 and to the south of cross-row 13.
  - To create 26 mid-row lines in the secondary, cross-row direction.

Multi-beam bathymetry, side scan sonar, magnetometer, and sub-bottom profiler data are to be collected on all survey lines. The requirements for single- and multi-channel, mid-penetration, seismic reflection data collection are shown on Figure 10-3.

In addition, supplemental survey will be added for portions of the export cable route and along the inter-array cable routes that are aligned along east-west cross-rows and diagonals between adjacent rows in directions other than the primary north-south direction.

10.2 DESIGN-PHASE GEOTECHNICAL EXPLORATION PROGRAM

Lease Area

The design-phase, geotechnical exploration program is envisioned to include:

- Seabed Cone Penetration Test (CPT) soundings pushed using a 20-ton (or heavier) seabed jacking unit.
- Deep sample borings with downhole CPT to depths below the anticipated pile tip elevation.
- Suspension (P-S velocity) logging will be included in about 15% of the deep borings.

Although the details of the design-phase geotechnical exploration program will be determined by the final numbers and layout of the turbine grid and locations of other structures, the following parameters are provided to bracket the amount of planned exploration:

- 20-Ton CPT Soundings to refusal (with anticipated penetration depths of between 10 and 30m at 80 to 100% of planned structure locations

- Deep sample borings, generally with downhole CPT testing a at 60 to 100% of structure locations
- P-S logging in deep borings at no less than 15% of structure locations

The deep exploration will be advanced to at least 10 meters below the anticipated pile (or mono-pile) tip elevation. Sample borings will generally include semi-continuous sampling to within 1 meter of the refusal depth of the adjacent seabed CPT sounding.

A comprehensive laboratory testing program will be included as part of the design-phase geotechnical exploration program. This program will define the sediment classification, state-of-stress (consolidation), static and dynamic strength and deformation properties of the seafloor and subsurface sediments. In addition, the thermal resistance of the seafloor and subsurface sediment to about 5m-depth will be measured.

Export Cable Route

Future, design-phase geotechnical exploration along the export cable route and at selective locations along inter-array cable routes is anticipated to include:

- CPT soundings to a target depth of at least 4 meters at a nominal interval of 1 to 1.5 km.
- Vibracores (or shallow borings) to a target depth of at least 4 meters at a nominal interval of about 2 to 2.5 km.
- A laboratory testing program to define the sediment classification, strength and thermal resistance of the seafloor and shallow subsurface sediments.

11.0 REFERENCES

11.1 SITE- AND PROJECT-SPECIFIC REFERENCES

Alpine Ocean Seismic Survey, Inc. (2015), Marine G&G Survey Report, Maryland Wind Energy Area, Report to US Wind, Inc., Project Number 1751

Alpine Ocean Seismic Survey, Inc. (2016), *High Resolution Geophysical Survey, Geotechnical, and Environmental Survey Report, US Wind Export cable Route Survey, Offshore Maryland and Indian River Bay, Delaware*, Report to US Wind, Inc. Project Number 1783

Coastal Planning & Engineering, a CB&I Company (2014), *Maryland Energy Administration, High Resolution geophysical Resource Survey, Final Report of Investigations*, prepared for Maryland Energy Administration, Project Number DEXR240005, May 4, 2014.

ESS Group (2020), Maryland Offshore Wind Energy Project, COP Survey Plan, Offshore Maryland, Lease Area OCS-A 0490, Prepared for US Wind, submitted to BOEM, ESS Project No. U167-070, July 2020.

Fugro (2015): *Engineering Analyses, Boring: Met Tower, Maryland Wind Energy Area, Offshore Maryland,* Report No. 0201-7893, to Keystone Engineering Inc., November 5, 2015.

Fugro (2020). *Evaluation of Pile Drivability, 8300-mm (327-in)-Diameter Driven Pipe Pile, Maryland Offshore Wind Farm, Offshore Maryland*, Report No. 2001-0038 to US wind Inc., 20 July 2020.

Gardline Geosciences Ltd. (2015), *Geotechnical Marine Survey Investigation for the Maryland Wind Energy Area, Volume I: Field Operations and Preliminary Results Report*, Report to US Wind, Inc, Project Number10451, July 2015.

Gardline Geosciences Ltd. (2015), *Geotechnical Marine Survey Investigation for the Maryland Wind Energy Area, Volume II: Geotechnical Results Report*, Report to US Wind, Inc, Project Number10451, March 2016.

Gardline Geosciences Ltd. (2016), *Geotechnical Marine Survey Investigation for the Maryland Wind Energy Area, Volume III: Data Integration and Engineering Report*, Report to US Wind, Inc, Project Number10451, March 2016.

Oceaneering International, Inc. (2020), *Geophysical Interpretation, Maryland Offshore Wind, Renewable Energy Lease OSC-A 0490, NJ18-05 Salisbury Area*, Report to US Wind, Inc., Project ID 186541, Report dated 10 July 2020.

11.2 REGULATORY AND RELATED GUIDELINES AND STANDARDS

Bureau of Ocean Energy Management (BOEM; (February 2103), *Guidelines for Submission of Spatial Data for Atlantic Offshore Renewable Energy Development Site Characterization.*

_____ (May 2020), *Guidelines for Information Requirements for a Renewable Energy Construction Operations Plan (COP), Version 4.0.*

_____ (May 2020), *Guidelines for Providing Geophysical. Geotechnical, and Geohazard Information Pursuant to 30 CFR Part 585* (July 2015).

_____ (May 2020), *Guidelines for Providing Archaeological and Historical Property Information Pursuant to 30 CFR Part 585* (March 2017.

DNV-GL (September, 2018), *Data Gathering Process: Geotechnical Departures for Offshore Wind Energy,* BOEM Publication No. 2018-054.

11.3 GENERAL REFERENCES

Dalrymple, R.W., Zaitlin, B.A.; and Boyd, R. (1992), “Estuarine facies models: conceptual basis and stratigraphic implications,” *Journal of Sedimentary Petrology, 62, 1, 1130-1146.*

Dalrymple, R.W. and Choi, K. (2007), “Morphologic and facies trends through the fluvial–marine transition in tide-dominated depositional systems: a schematic framework for environmental and sequence-stratigraphic interpretation,” *Earth-Science Reviews, 81, 3- 4, 135–174.*

Davis, R.A. (1994), “Barrier island systems - a geologic overview,” in Davis, R.A. (ed.), *Geology of Holocene barrier island systems*, Springer-Verlag, Berlin, 1-46.

Duncan, C.S., Goff, J.A., Austin, Jr., and J.A., Fulthorpe, C.S. (2000) Tracking the last sea-level cycle: seafloor morphology and shallow stratigraphy of the latest Quaternary New Jersey middle continental shelf. Marine Geology, V. 170, pg. 395-421.

Fairbanks, R. (1992), "Barbados Sea Level and Th/U 14C Calibration," IGBP PAGES/World Data Center- for Paleoclimatology Data Contribution Series # 92-020. NOAA/NGDC Paleoclimatology Program, Boulder CO, USA.

Fischer, A.G. (1961), "Stratigraphic record of transgressing seas in the light of sedimentation on Atlantic coast of New Jersey," *American Association of Petroleum Geologists Bulletin, 45, 10, 1656-1666.*

Fisher, J.J. (1968), "Barrier island formation: discussion," *Geological Society of America Bulletin,79, 10, 1421-1426.*

Grow, J.A., Klitgord, K.D., and Schlee, J.S. (1988), "Structure and evolution of the Baltimore Canyon Trough," *in* R.E. Sheridan and J.A. Grow, editors, *The Atlantic Continental Margin: U.S. Geological Society of America, The Geology of North America*, v. I-2, pg. 269-290.

McNeilan, T.W and K. Smith (2011), *Seabed Scour Considerations for Offshore Wind Development on the Atlantic OCS*, BOEM Technology Assessment and Research (TA&R) Report 656, February 2011.

Nordfjord, S., Goff, J. A., Austin, J. A. Jr., and Sommerfield, C. K., (2005), "Seismic geomorphology of buried channel systems on New Jersey shelf: assessing past environmental conditions," Marine Geology, vol. 214, p. 339-364.

Oertel, G.F. and Foyel, A.M. (1995), "Drainage displacement by sea-level fluctuation at the outer margin of the Chesapeake seaway," *Journal of Coastal Research, 11, 3, 583-604.*

Oertel, G.F. and Kraft, J.C. (1994), "New Jersey and Delmarva barrier islands," in Davis, R.A. (ed.),*Geology of Holocene barrier island systems*, Springer-Verlag, Berlin, 207-232.

Oertel, G.F.; Henry, V.J.; and Foyle, A.M. (1991), "Implications of tide-dominated lagoonal processes on the preservation of buried channels on a sediment-starved continental shelf," in Swift, D.J.P.; Oertel, G.F.; Tillman, R.W.; Thorne, J.A. (eds.), *Shelf and sandstone bodies - geometry, facies, and sequence stratigraphy* (*Special Publication 14 of the International Association of Sedimentologists)*, Blackwell Scientific Publications, Oxford, 379-394.

Rampino, M.R. and Sanders, J.E. (1980), "Holocene transgression in south-central Long Island, New York," Journal of Sedimentary Petrology, 50, 3, 1063– 1079.

Reading, H.G. and Collinson, J.D. (1996), "Clastic coasts," in Reading, H.G. (ed.), *Sedimentary environments: processes, facies and stratigraphy*, Blackwell Science: Oxford, UK, 154-231.

Swift, D.J.P., Duane, D.B., and McKinney, T.F. (1973), "Ridge and swale topography of the middle Atlantic bight: Secular response to Holocene hydraulic regime," *Marine Geology*, vol. 14, p. 1-43.

Swift, D.J.P. (1975), "Barrier island genesis: evidence from the Middle Atlantic shelf of North America," Sedimentary Geology, 14, 1, 1-43.

Swift, D.J.P., Nelsen, T., McHone, J., Holliday, B., Palmer, H., and Shideler, G. (1977) Holocene Evolution of the Inner Shelf of Southern Virginia. Journal of Sedimentary Petrology, vol. 47, no. 4, pp. 1454 – 1474.

Swift, D.J.P.; Parker, G.; Lanfredi, N.W.; Perillo, G.; and Figge, K. (1978), "Shoreface-connected sand ridges on American and European shelves: a comparison," *Estuarine and Coastal Marine Science, 7, 3, 257-273.*

Swift, D.J.P., Moir, R., and Freeland, G.L. (1980), Quaternary Rivers on the New Jersey Shelf: Relation of Seafloor to Buried Valleys. *Geology*, vol. 8, pp. 276 – 280.

Swift, D.J.P., Parsons, B.S., Foyle, A., and Oertel, G.F. (2003), Between beds and sequences: stratigraphy organization at intermediate scales in the Quaternary of the Virginia coast, USA. *Sedimentology*, vol. 50, pp. 81 – 111.

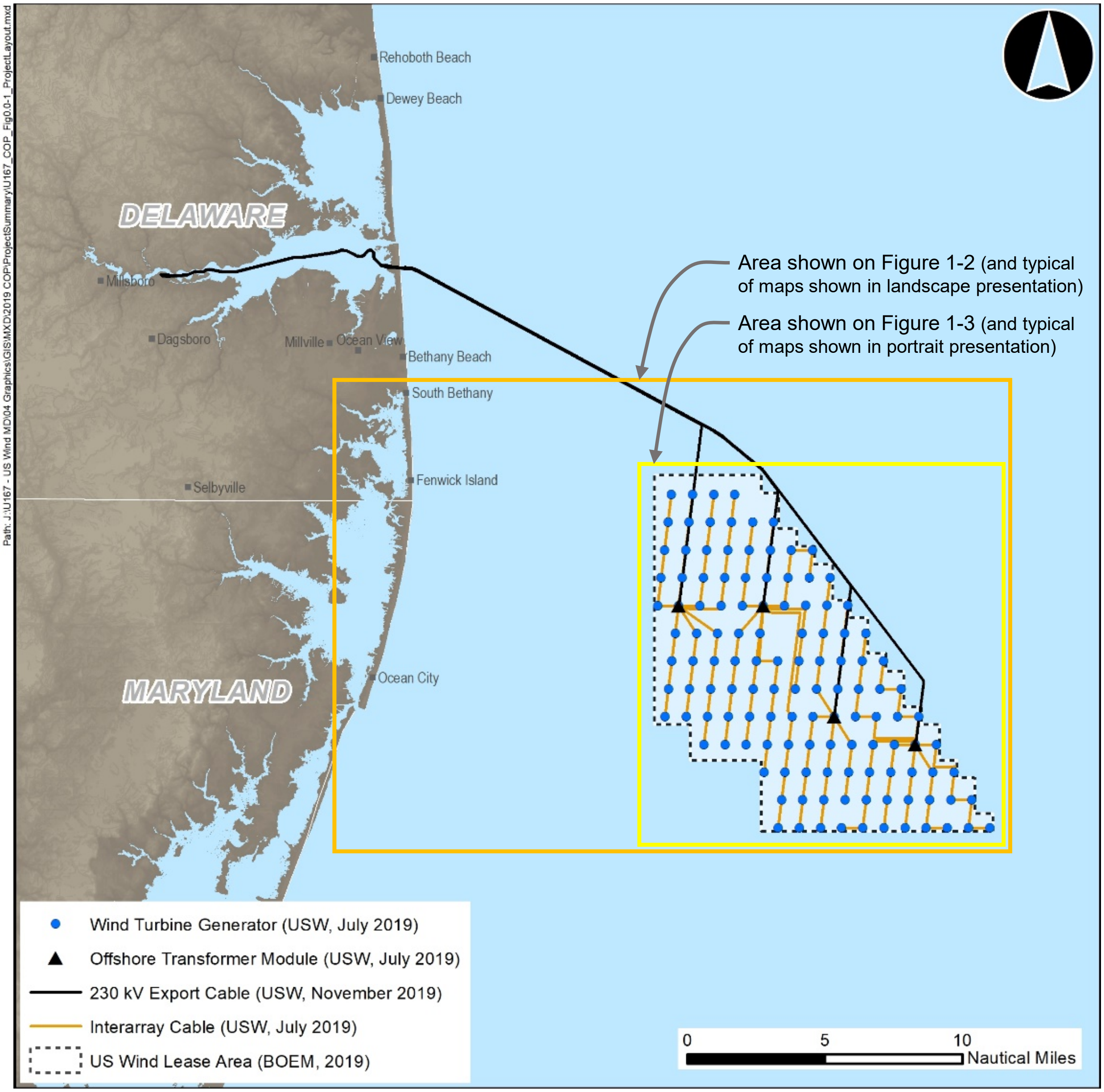
Swift, D.J.P. (2010), personal communication.

Toscano, M.A., Kerhin, R.T, York, L.L., Cronin, T.M. and Williams, S.J. (1989), Late Quaternary stratigraphy of the inner continental shelf of Maryland. *Maryland Geological Survey Report of Investigations*, vol. 50, p. 116.

TRC Environmental Corporation (2012), *Inventory and analysis of archaeological site occurrence on the Atlantic outer continental shelf,* prepared for U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Gulf of Mexico OCS Region, OCS Study BOEM 2012-008, May.

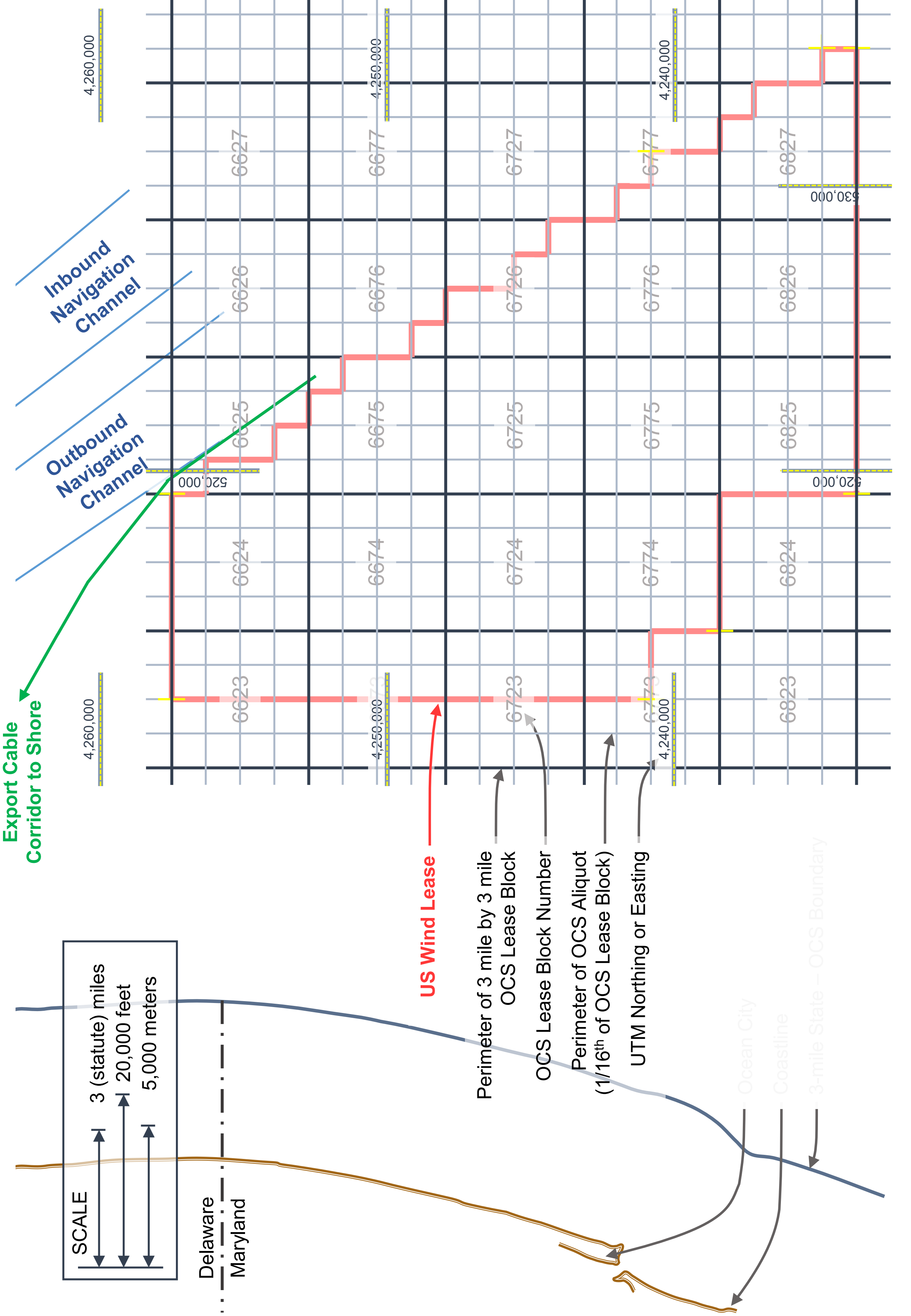
United States Geological Survey (USGS) (2005) usSEABED: Atlantic coast offshore surficial sediment data release: USGS Data Series 118, version 1.0, Online at http://pubs.usgs.gov/ds/2005/118/

this page intentionally blank

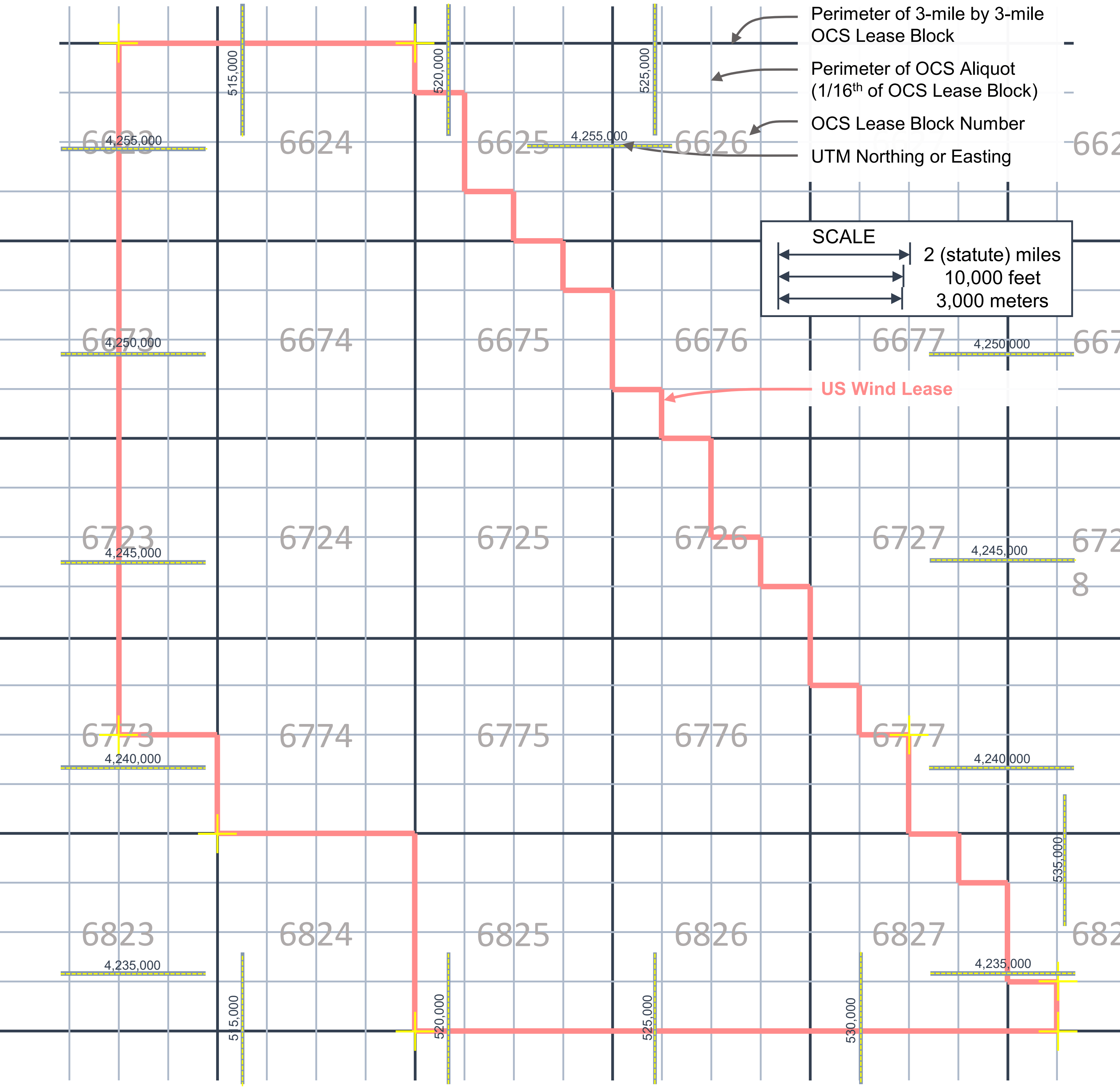


Reference ESS (2020)

PROJECT LOCATION
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area

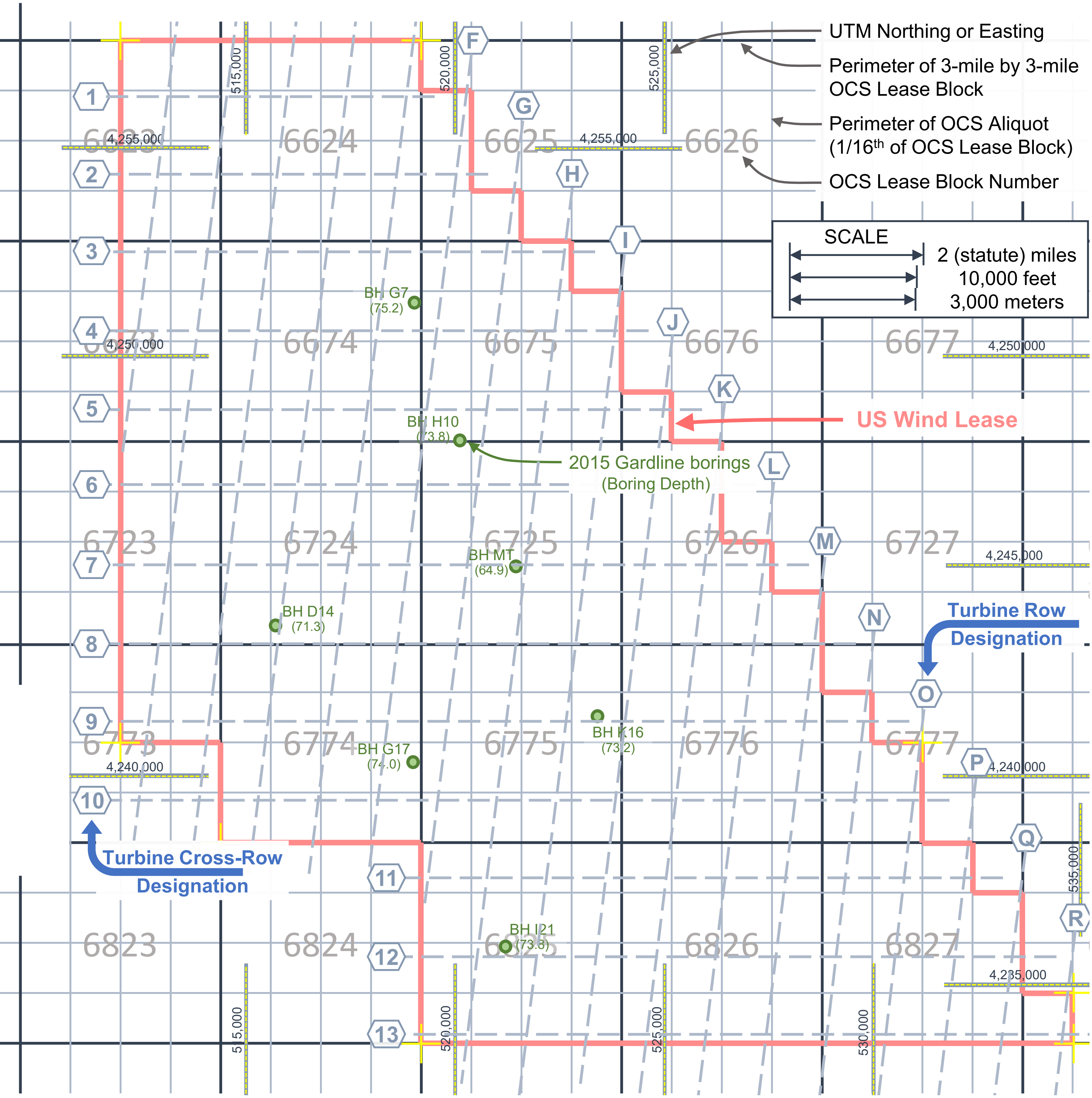


Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Development

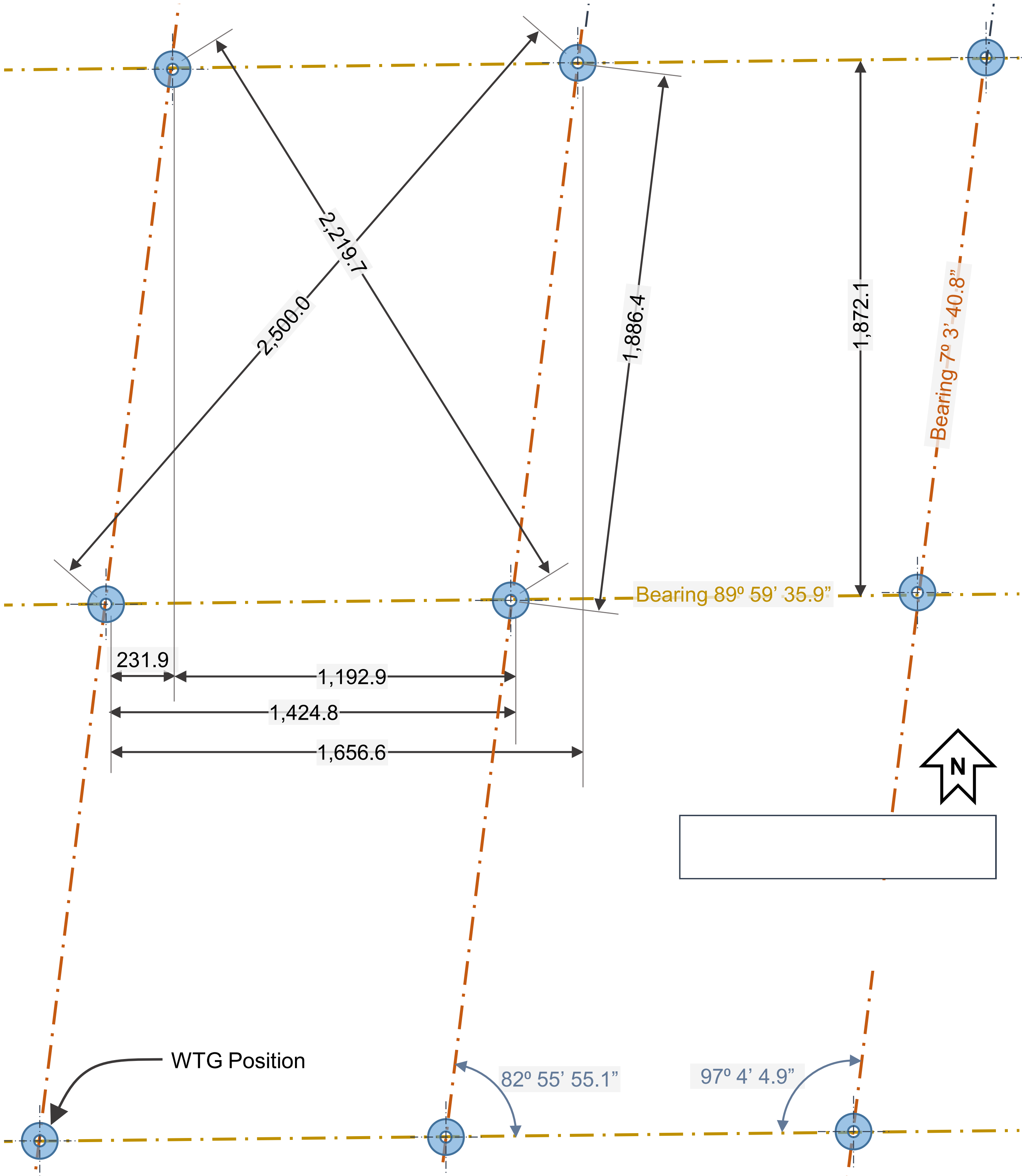


LEASE OCS-A-0490
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area

Figure 1-3

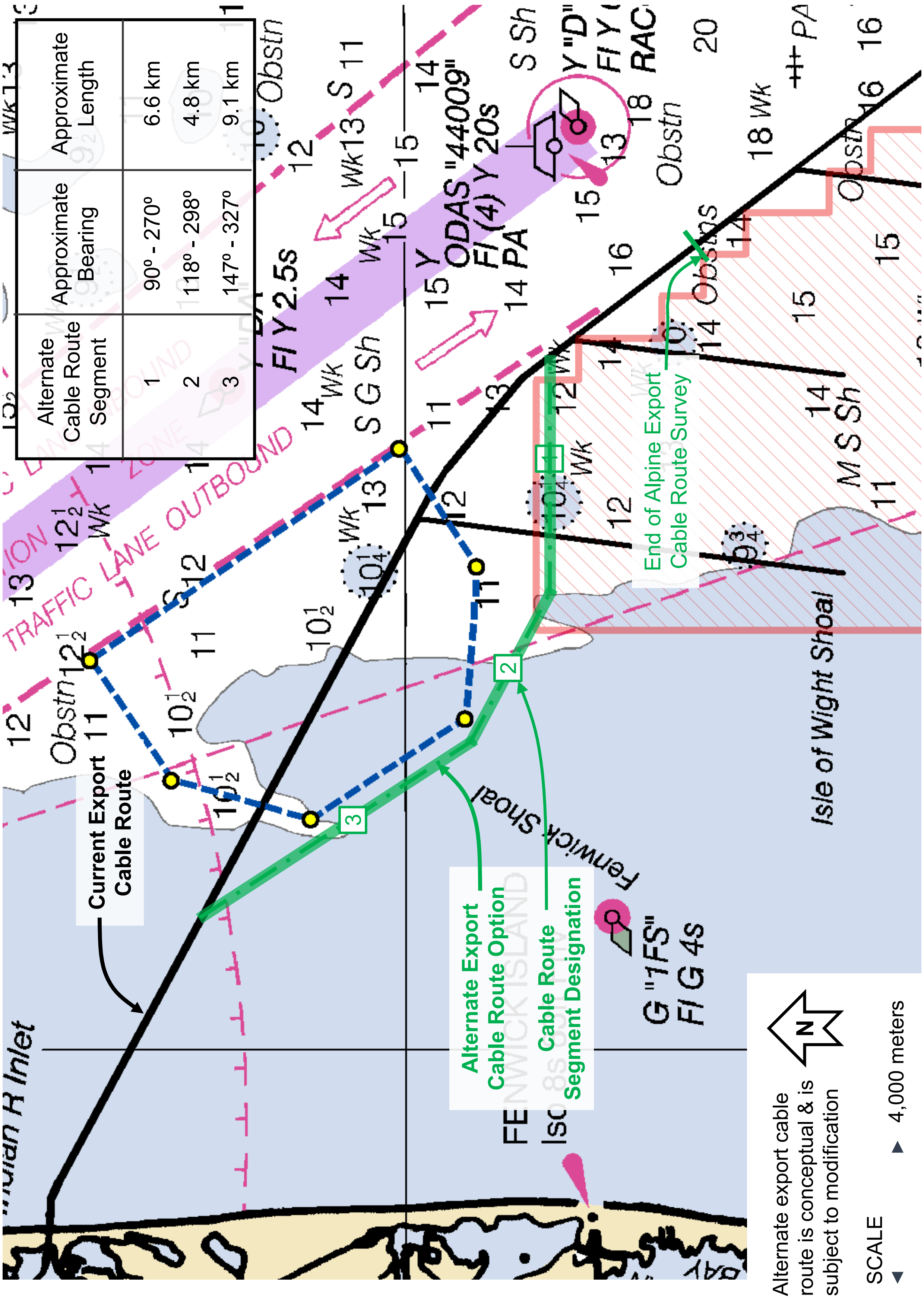


US Wind – Maryland OCS Offshore Wind Energy Area

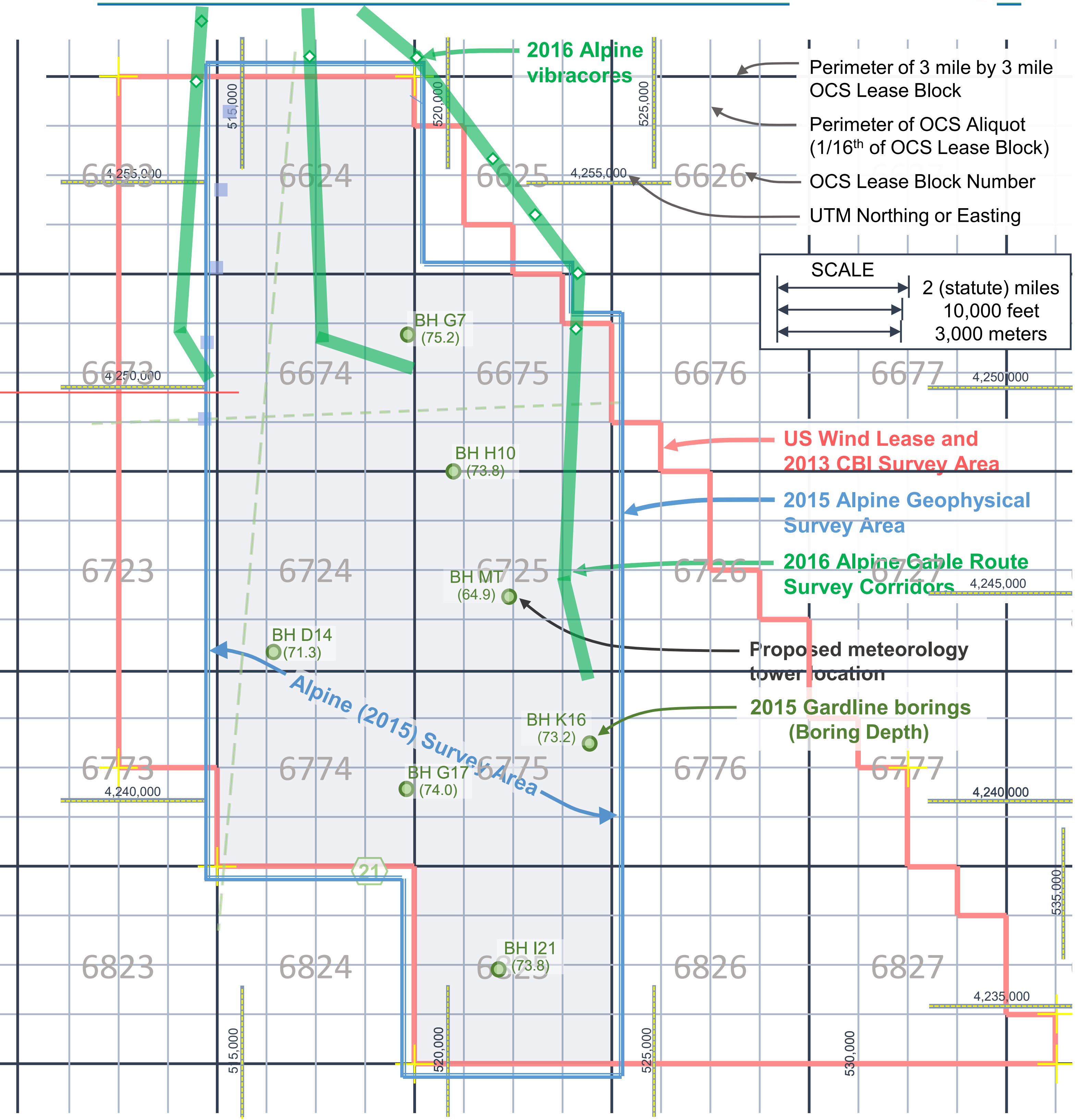


CONCEPTUAL TURBINE GRID GEOMETRY
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area

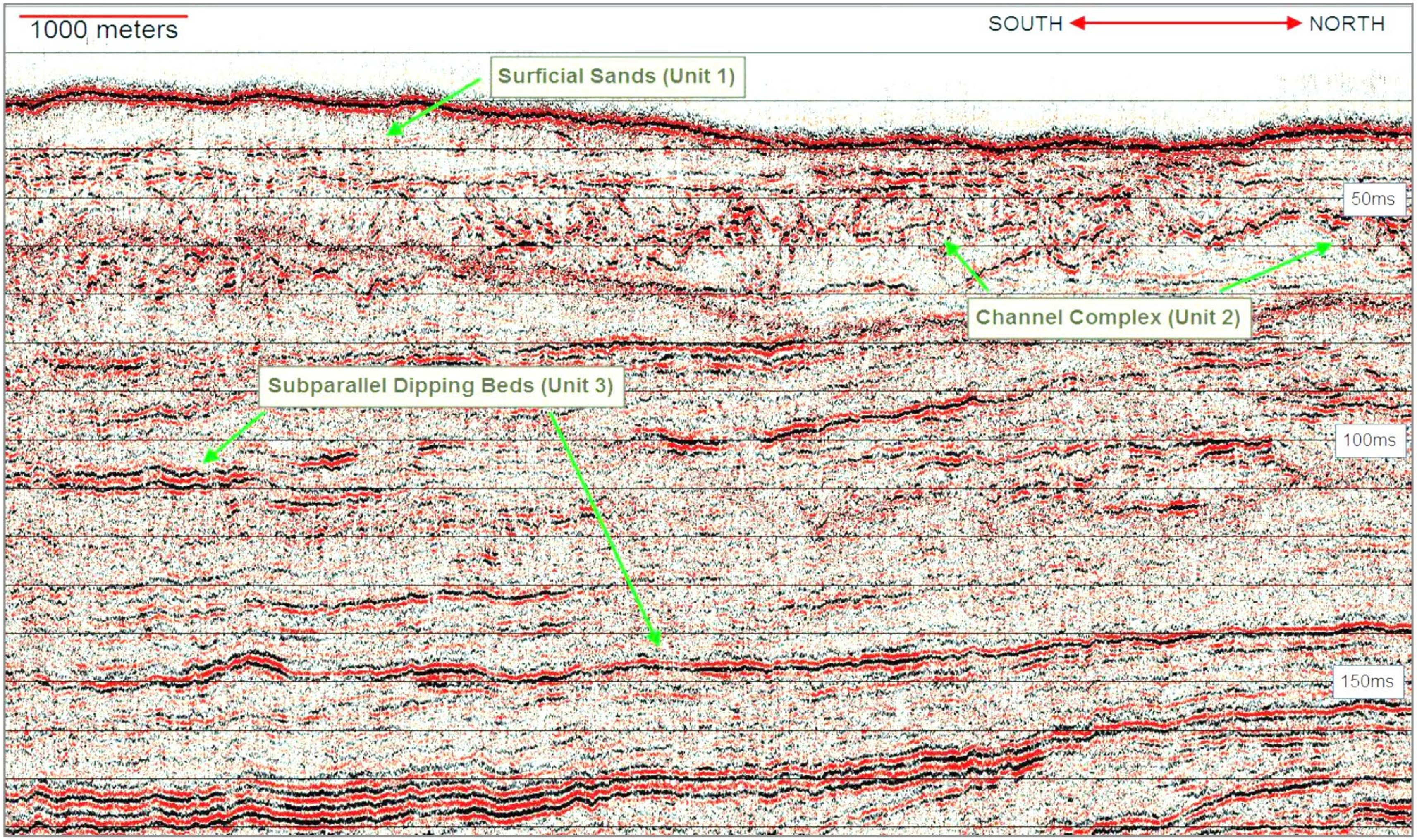
Figure 2-2



EXPORT CABLE ROUTE OPTIONS
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS, Offshore Wind Area



PREVIOUS GEOPHYSICAL SURVEYS & GEOTECHNICAL EXPLOATION, LEASE OCS-A-0490
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area



Reference: CBI (2014) showing three principle stratigraphic sequences as interpreted from multi-channel, mid-penetration, seismic reflection data (using sparker sound source) records.

This is a approximately 8.4-km-long section of their Line 105, which is about 1/3rd of the total line length.

REPRESENTATIVE CB&I NORTH-SOUTH SEISMIC RECORD
Initial, Integrated G&G Site Characterization
US Wind – Maryland OCS Offshore Wind Energy Area

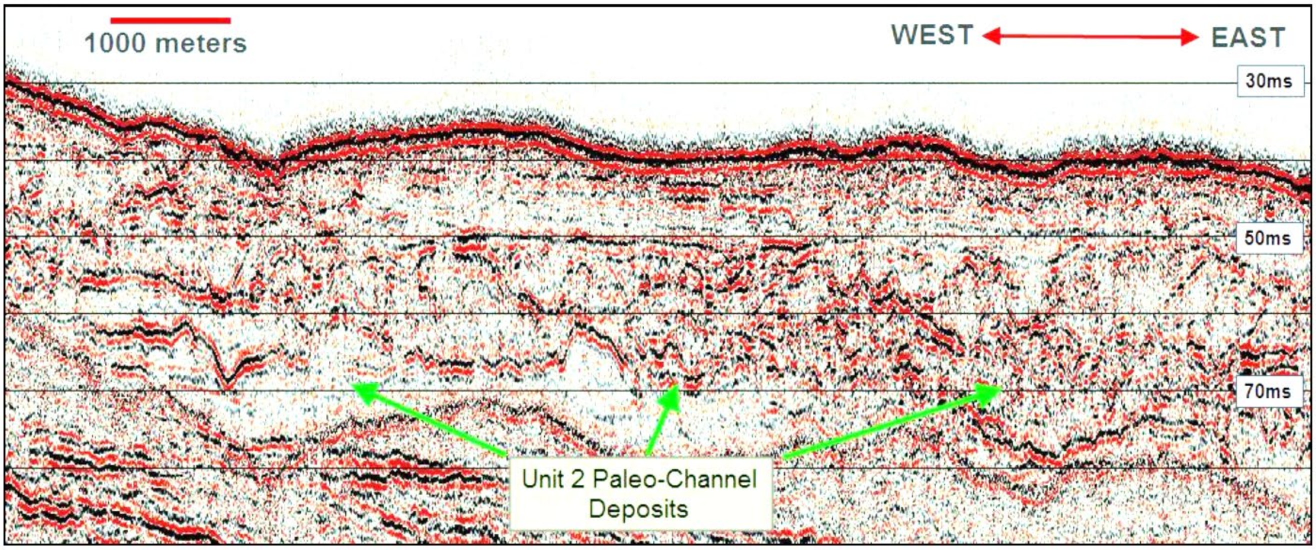


Figure 41: Portion of multi-channel sparker seismic Line 316 showing Pleistocene paleochannels within Unit 2.

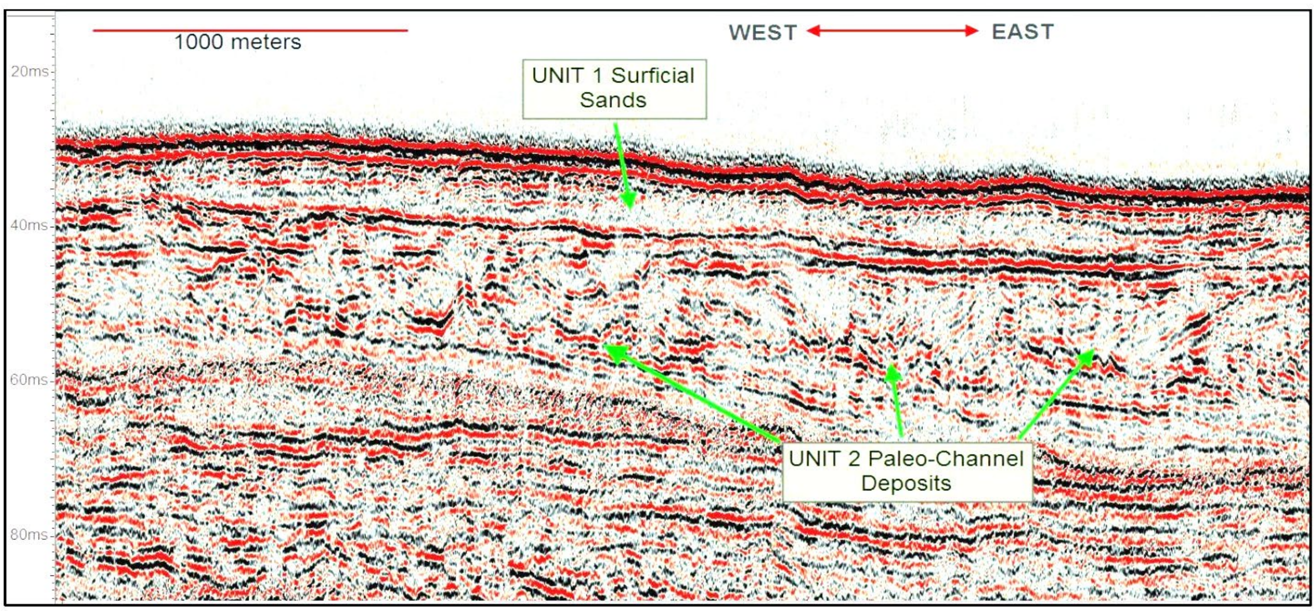


Figure 42: Portion of multi-channel sparker seismic Line 306 showing Pleistocene paleochannel complexes within Unit 2 overlain by the more recent (likely Holocene) sands of Unit 1.

Reference: CBI (2014) data examples of multi-channel, mid-penetration, seismic reflection data (using sparker sound source) records.

The length of the image for Line 316 is about 11 km of the approximately 17.5-km-long record.
The length of the image for Line 306 is about 4 km of the approximately 11.5-km-long record

REPRESENTATIVE CB&I EAST-WEST SEISMIC RECORDS
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area

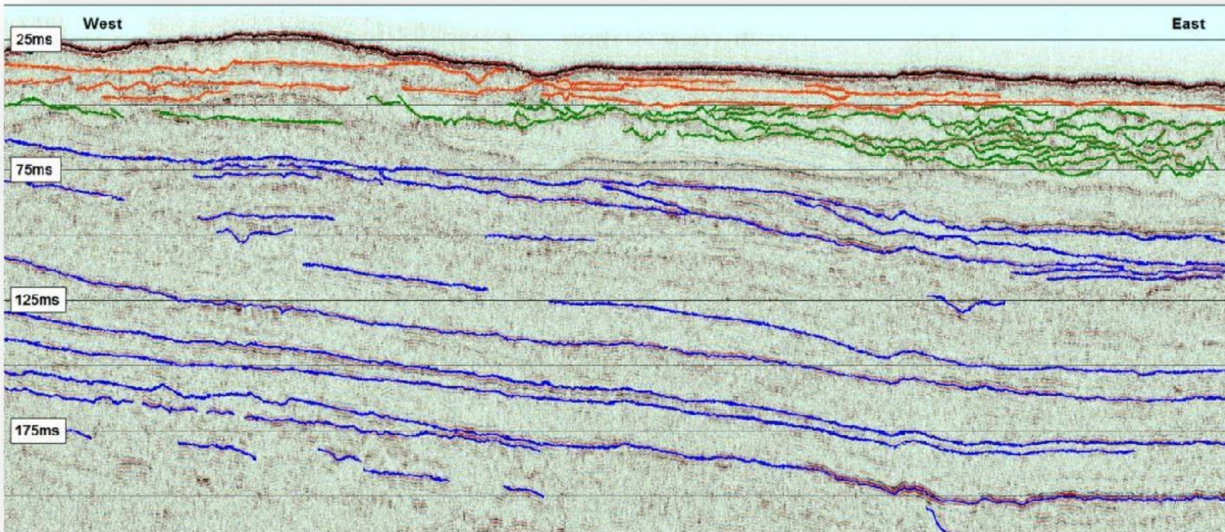


Figure 46: Multi-channel seismic amplitude record for Line 315. Structurally relevant seismic horizons have been traced within the three general Seismic Facies Units identified. Reflectors within Seismic Facies Units 1, 2, and 3 are shown in orange, green and blue, respectively.

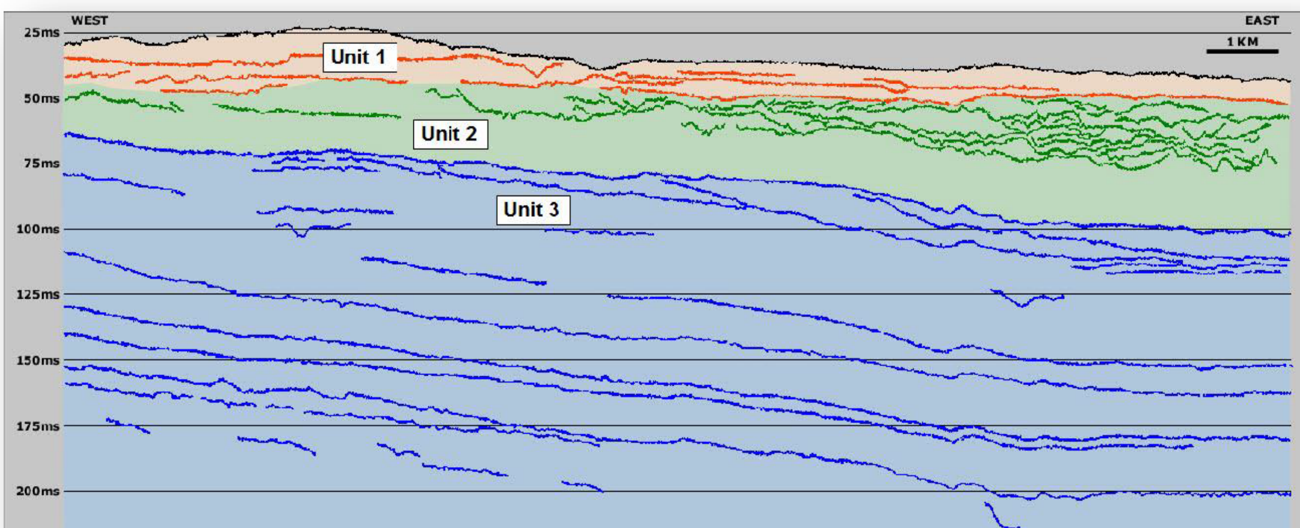
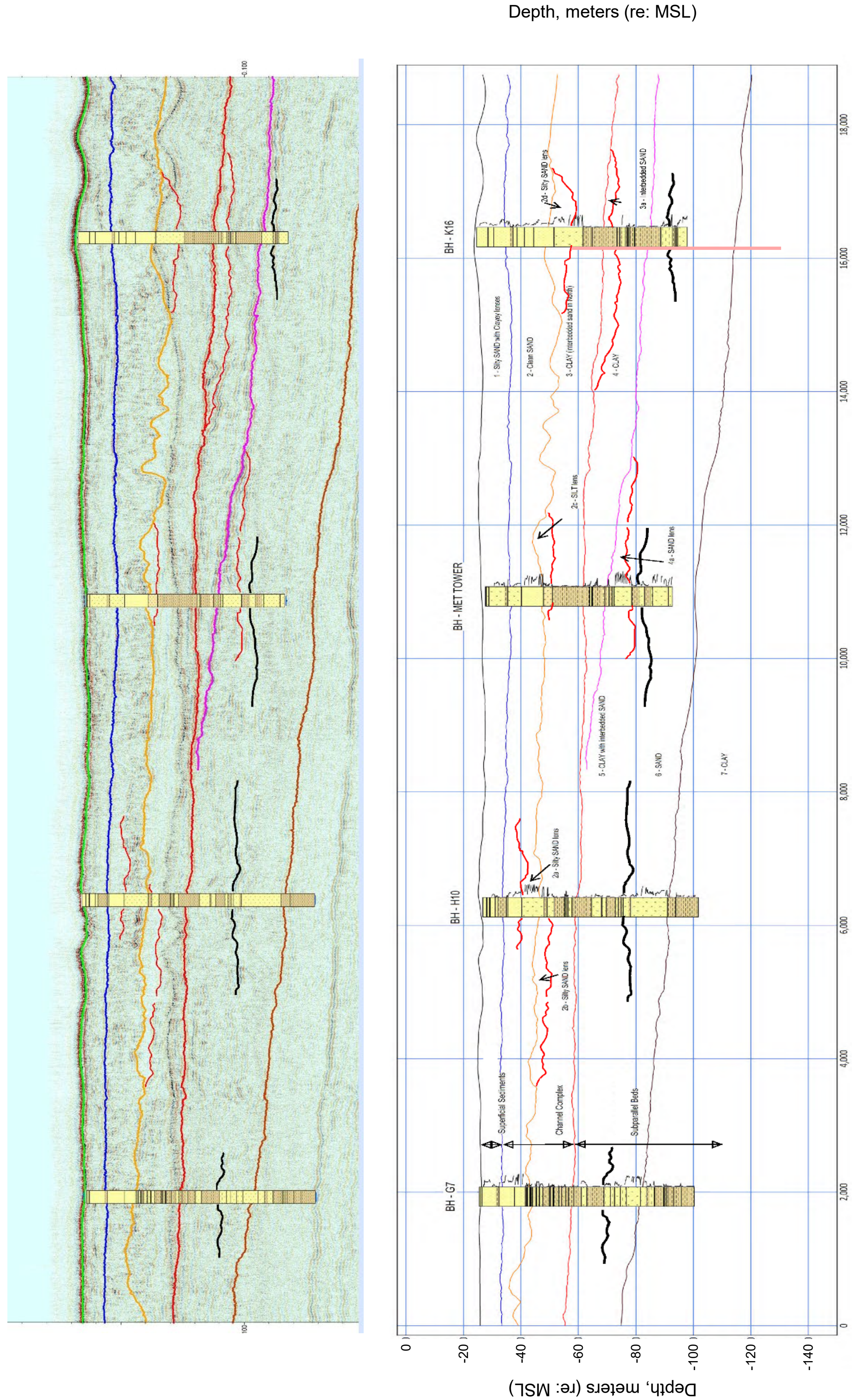


Figure 47: Interpreted seismic section from Line 315. The general stratigraphic structure is depicted for the three Seismic Facies Units.

Reference: CB&I (2014) showing three principle stratigraphic sequences as interpreted from multi-channel, mid-penetration, seismic reflection data (using sparker sound source) records.

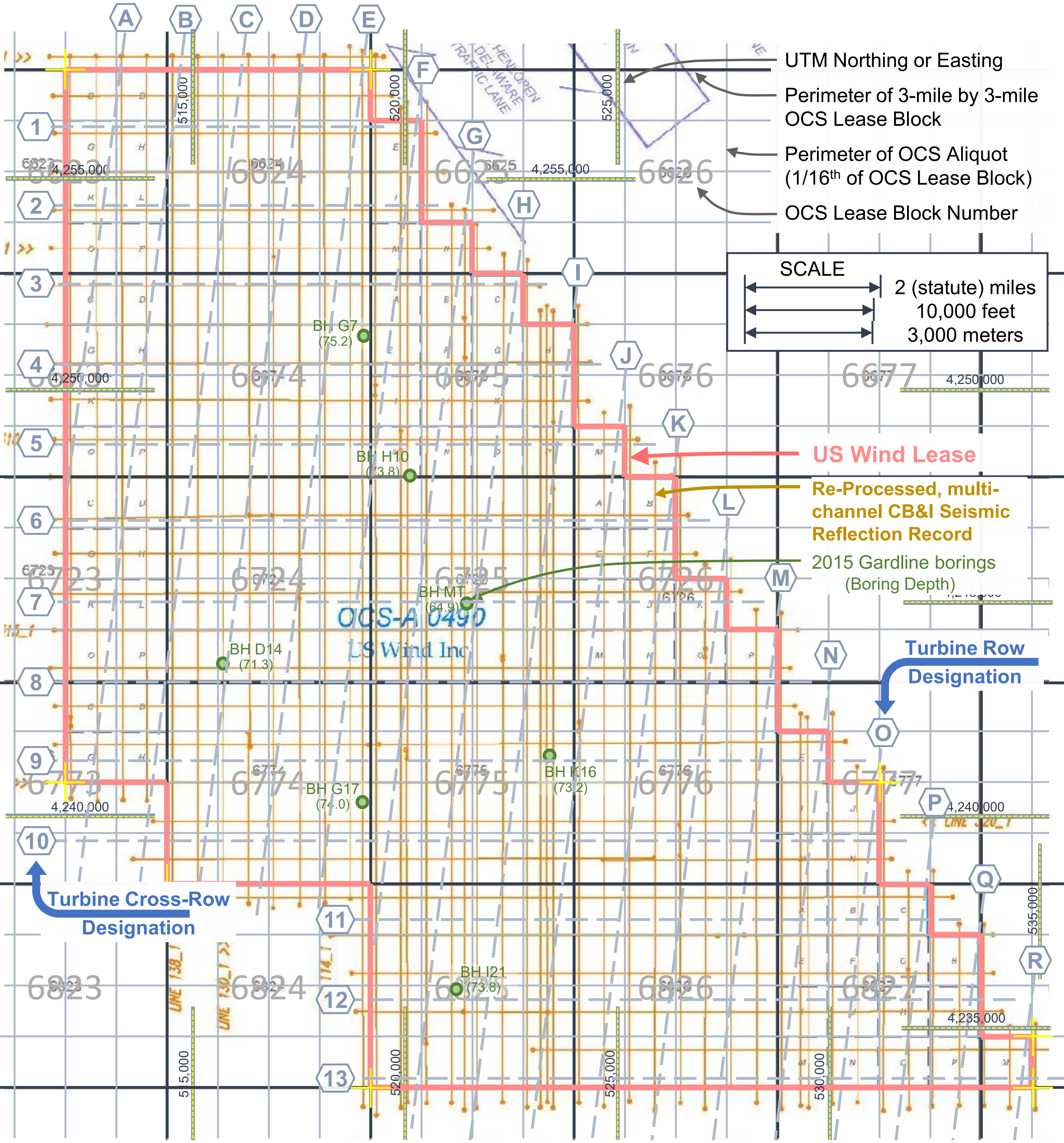
CB&I also provide similar presentations for their Lines 304 and 327.

CB&I (2014) STRATIGRAPHIC INTERPRETATION
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area



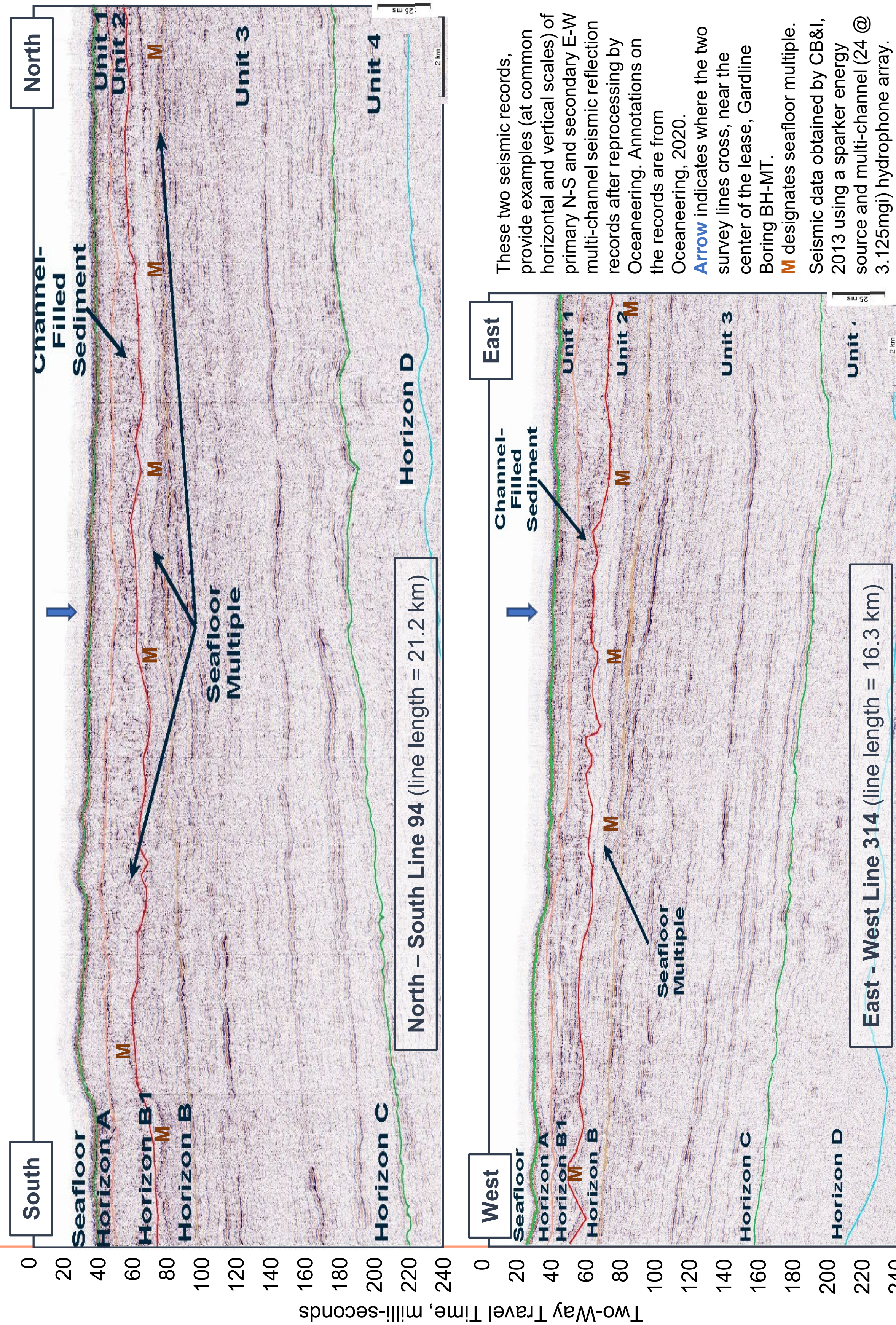
Reference: Gardline (2015) showing preliminary geotechnical borings overlain (in top panel) on CBI mid-penetration seismic reflection data; mapped horizons include those mapped by CBI plus other local horizons mapped by Alpine (2015)

GARDLINE (2016) STRATIGRAPHIC INTERPRETATION
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area



REPROCCESSED, CB&I 2013 M-C SESMIC REFLECTION LINES
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area

Figure 3-6



These two seismic records, provide examples (at common horizontal and vertical scales) of primary N-S and secondary E-W multi-channel seismic reflection records after reprocessing by Oceaneering. Annotations on the records are from Oceaneering, 2020.

Arrow indicates where the two survey lines cross, near the center of the lease, Gardline Boring BH-MT.

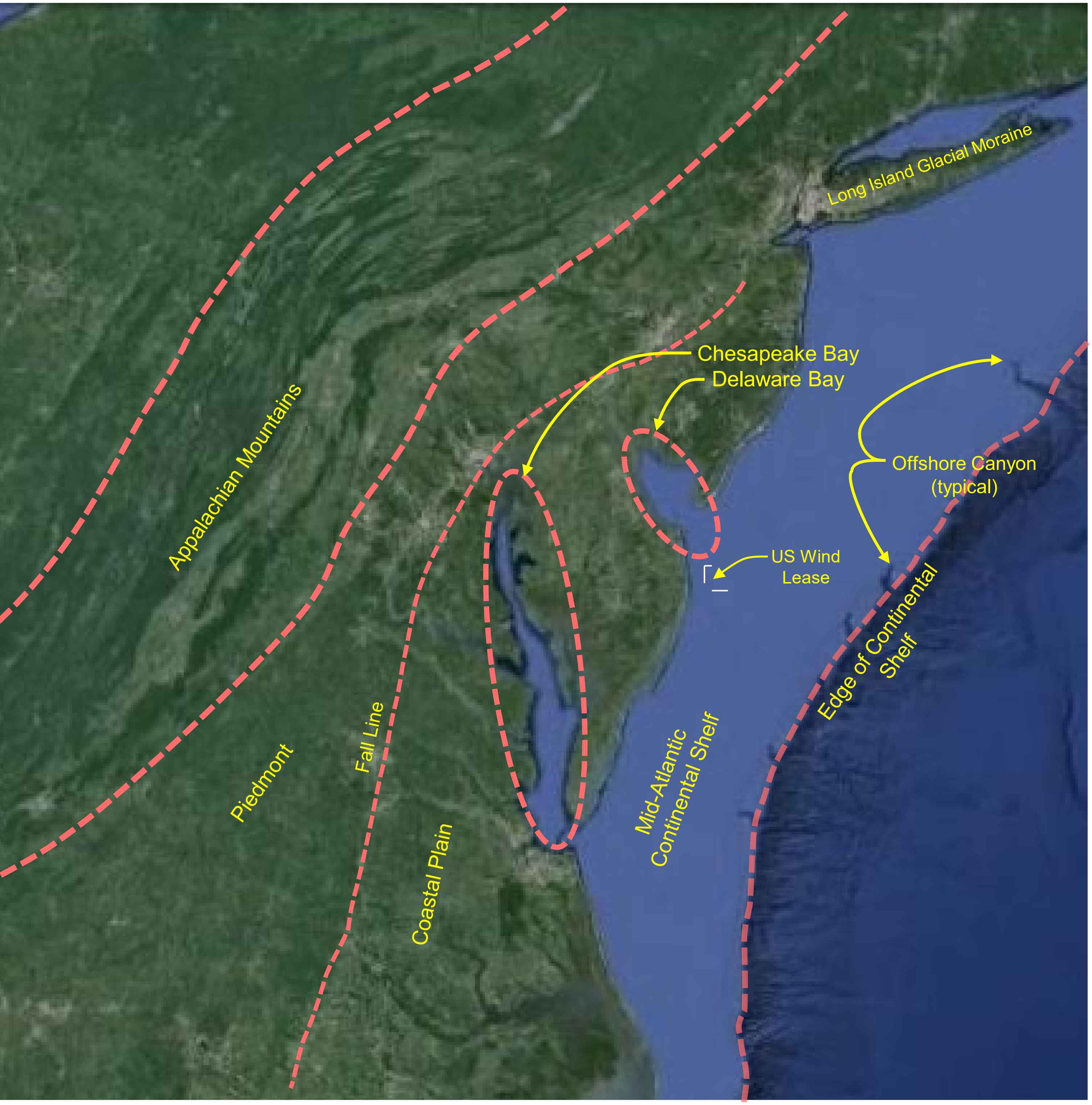
M designates seafloor multiple.

Seismic data obtained by CB&I, 2013 using a sparker energy source and multi-channel (24 @ 3.125mgi) hydrophone array.

REPRESENTATIVE, REPROCESSED CB&I SEISMIC RECORDS

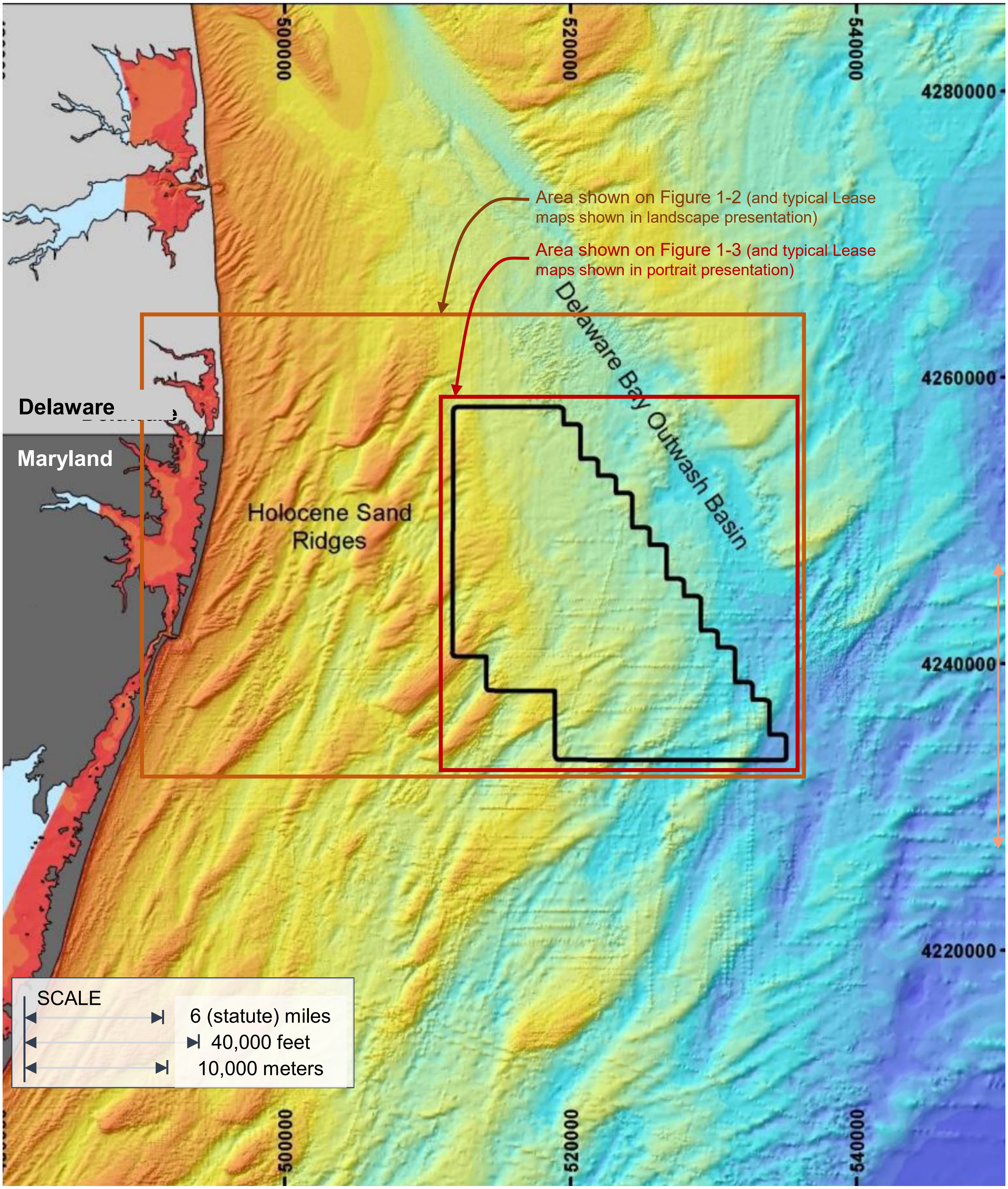
Initial Integrated G&G Site Characterization

US Wind – Maryland OCS Offshore Wind Energy Area



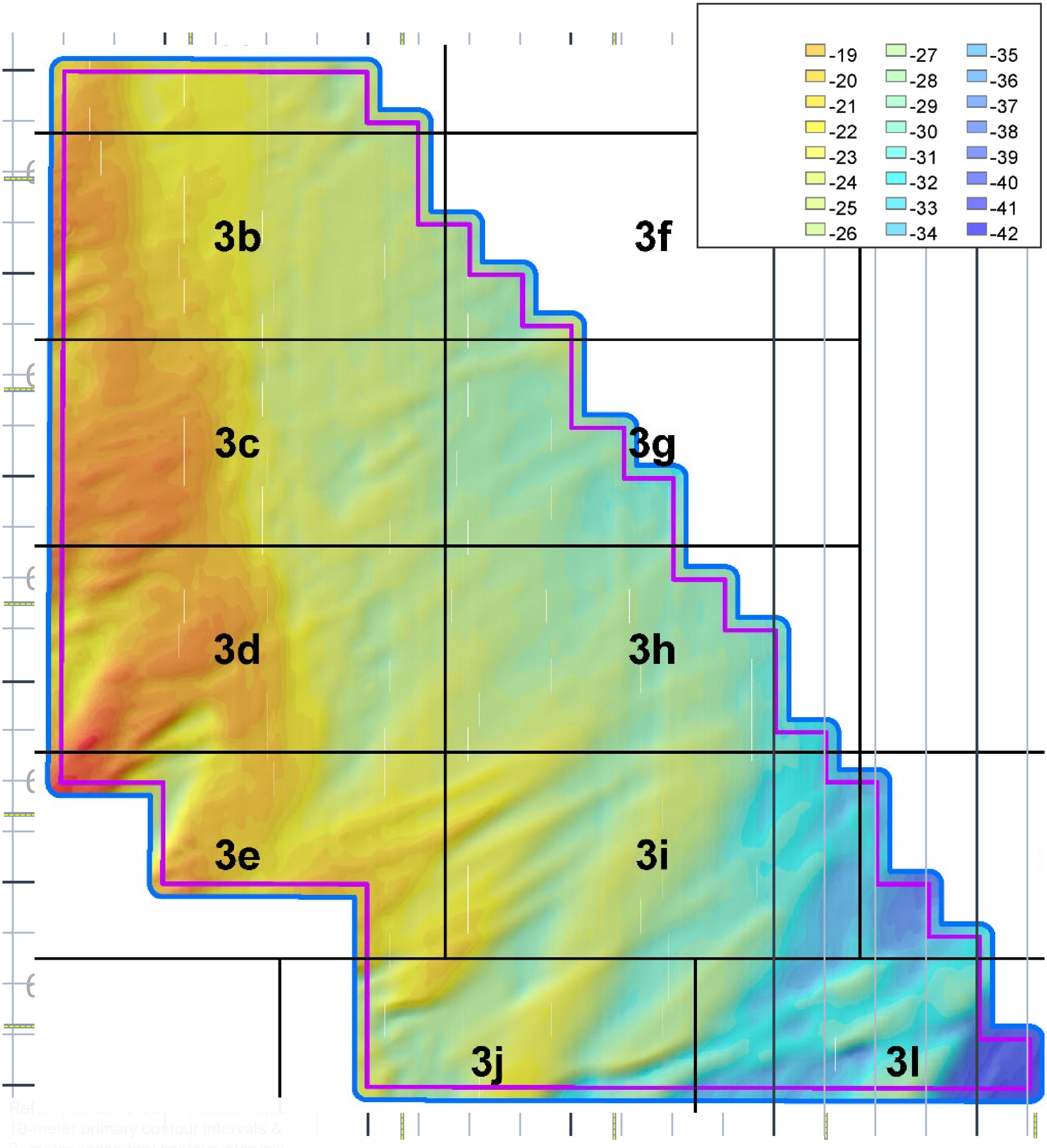
REGIONAL PHYSIOGRAPHY
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area

Figure 4-1

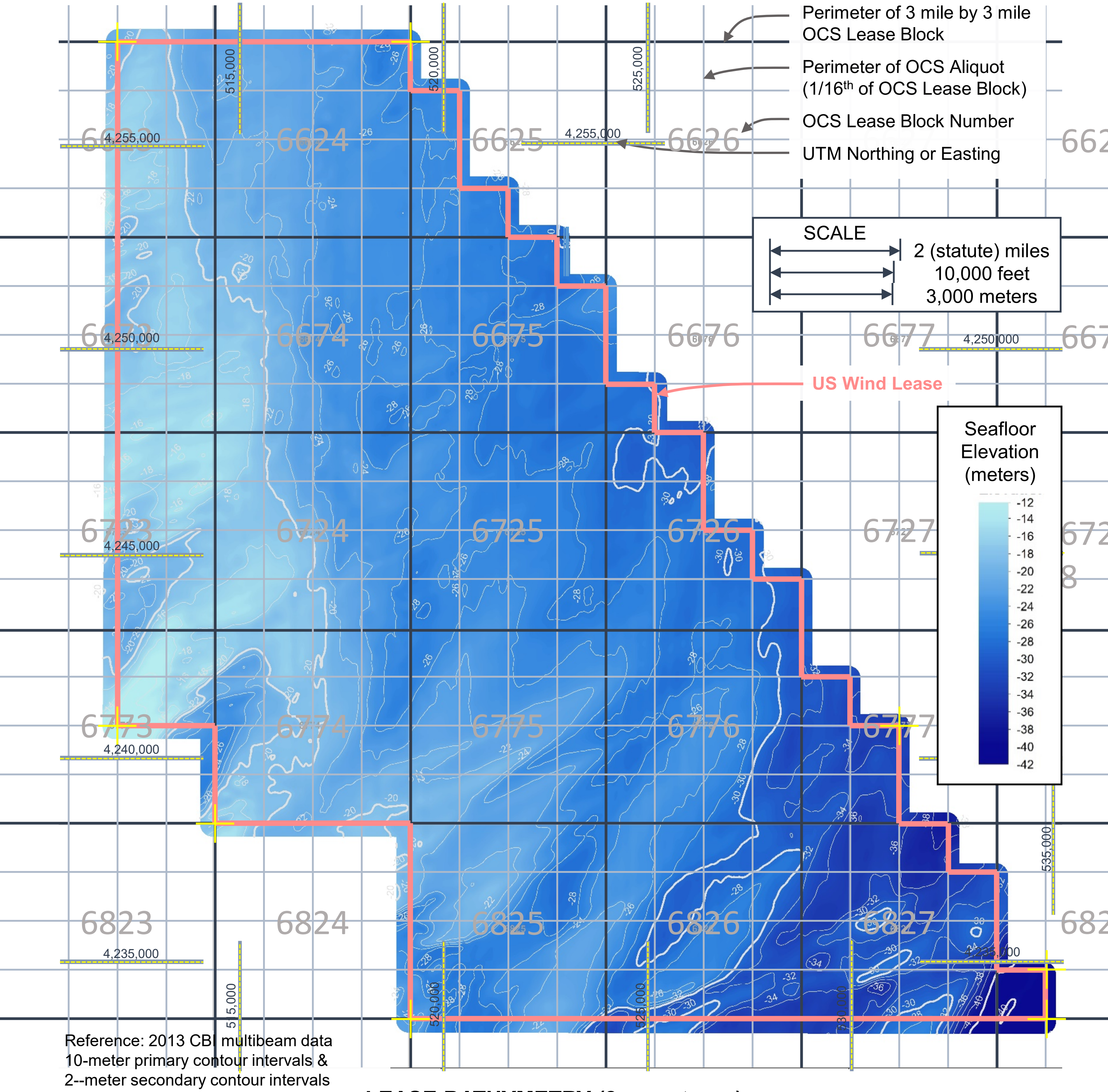


Modified from CB&I, 2014

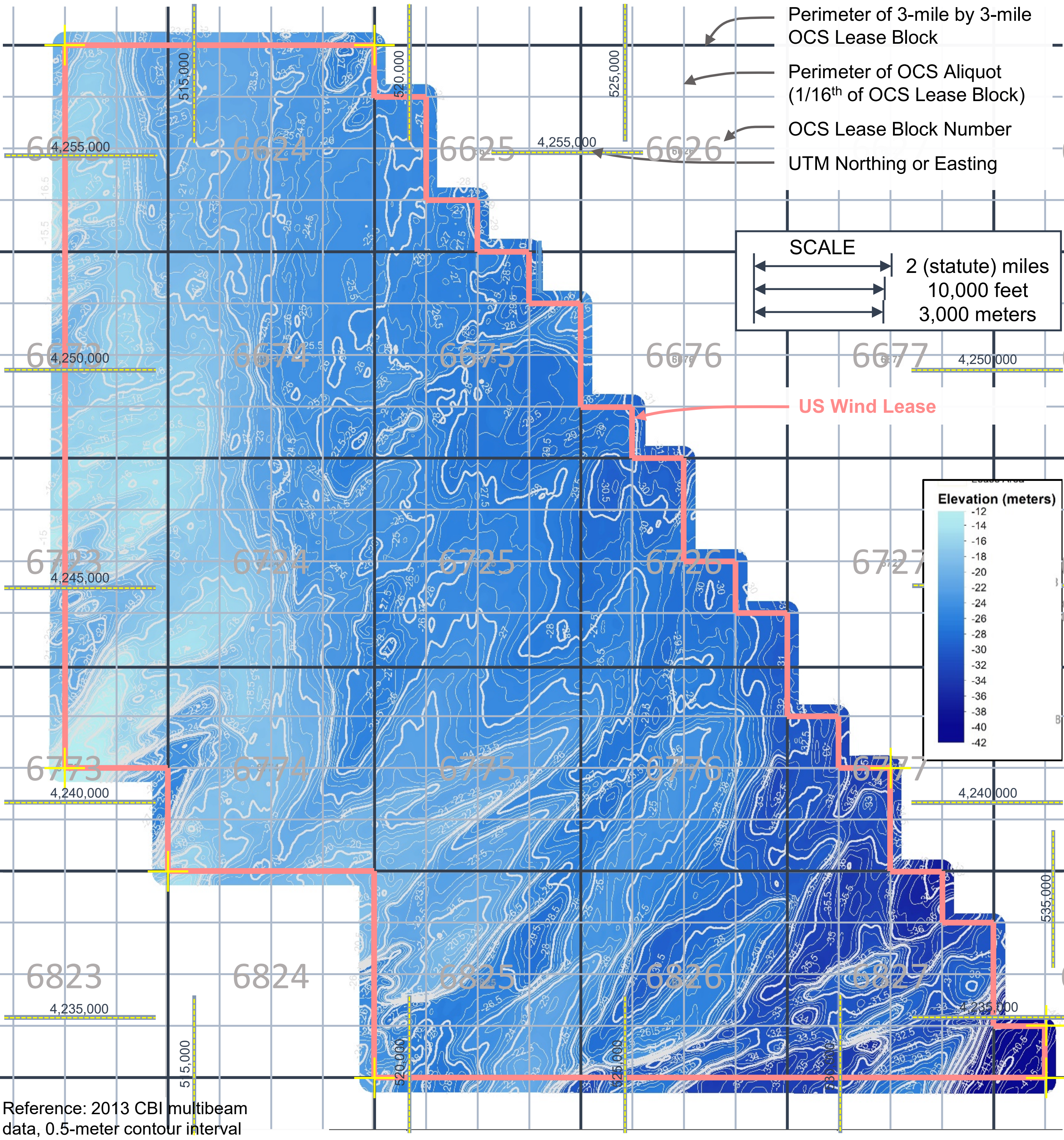
REGIONAL BATHYMETRY
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area



LEASE BATHYMETRY
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area



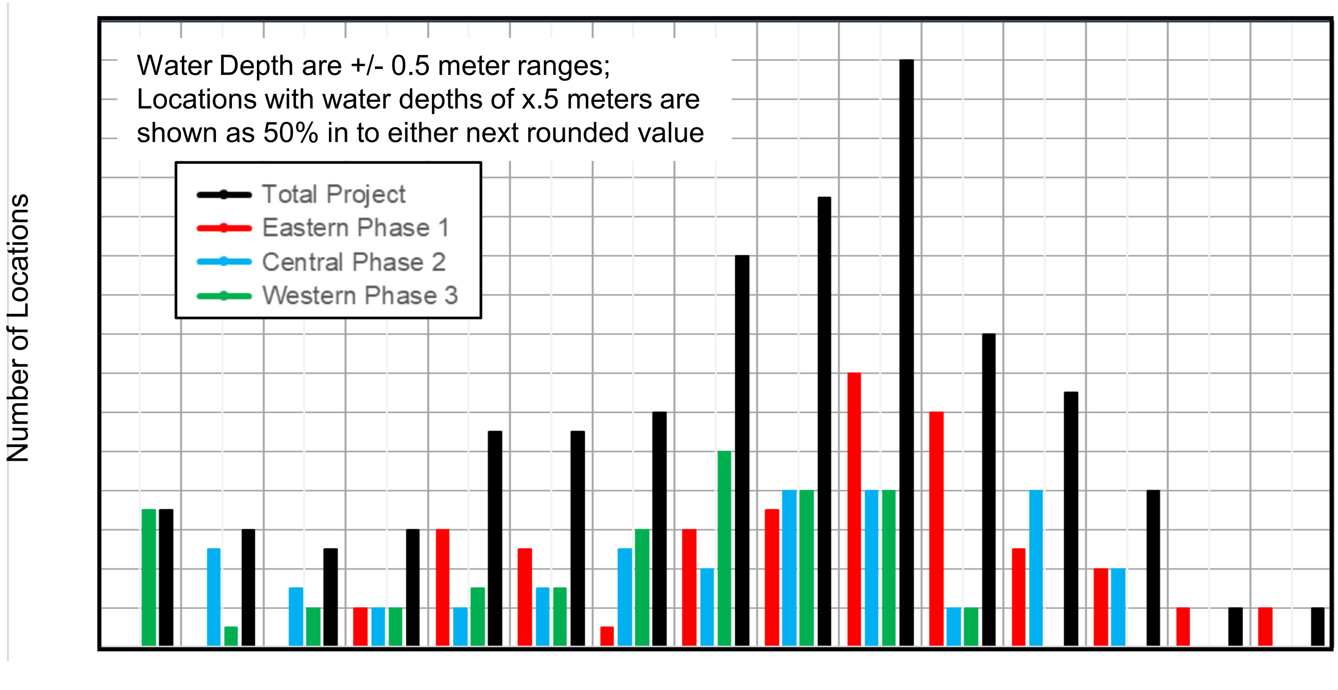
LEASE BATHYMETRY (2m contours)
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area

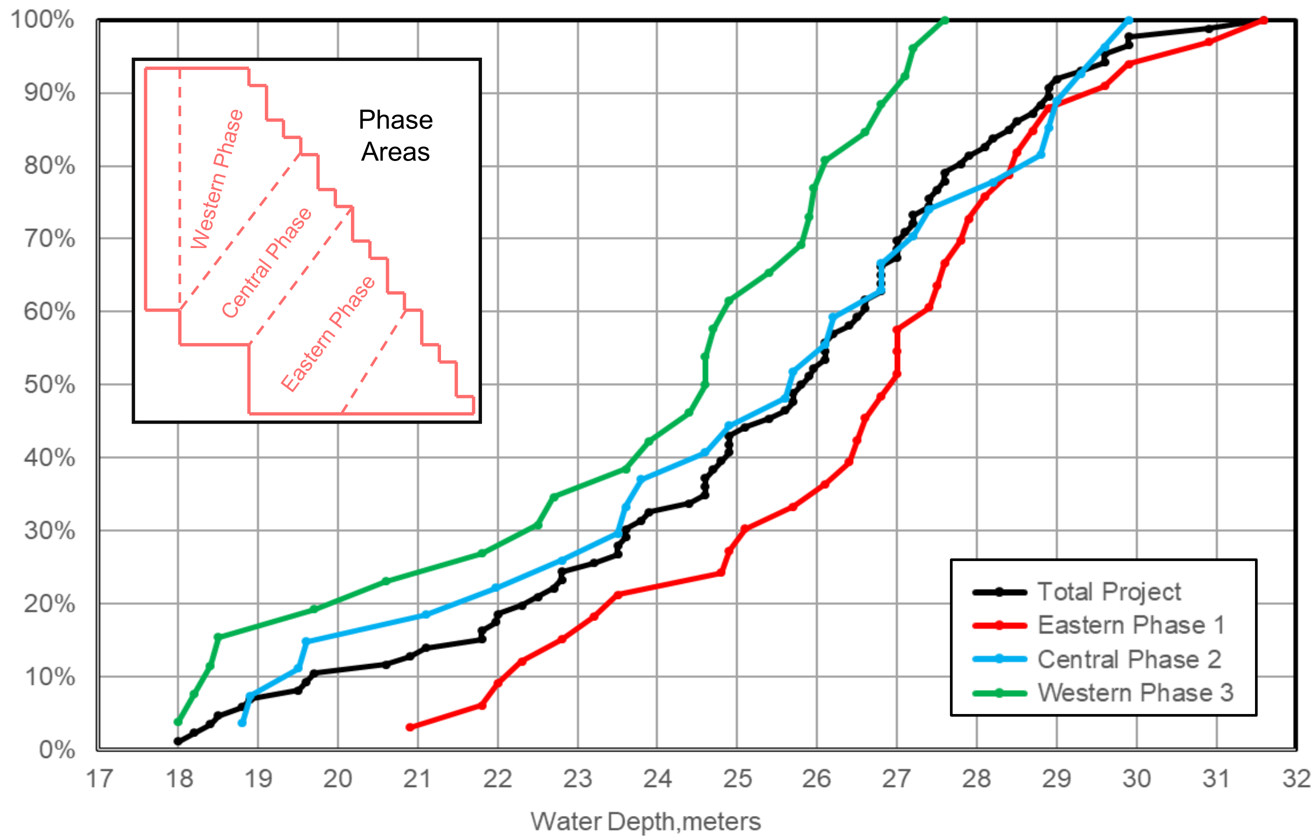


Reference: 2013 CBI multibeam data, 0.5-meter contour interval

LEASE BATHYMETRY (0.5m contours)
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area

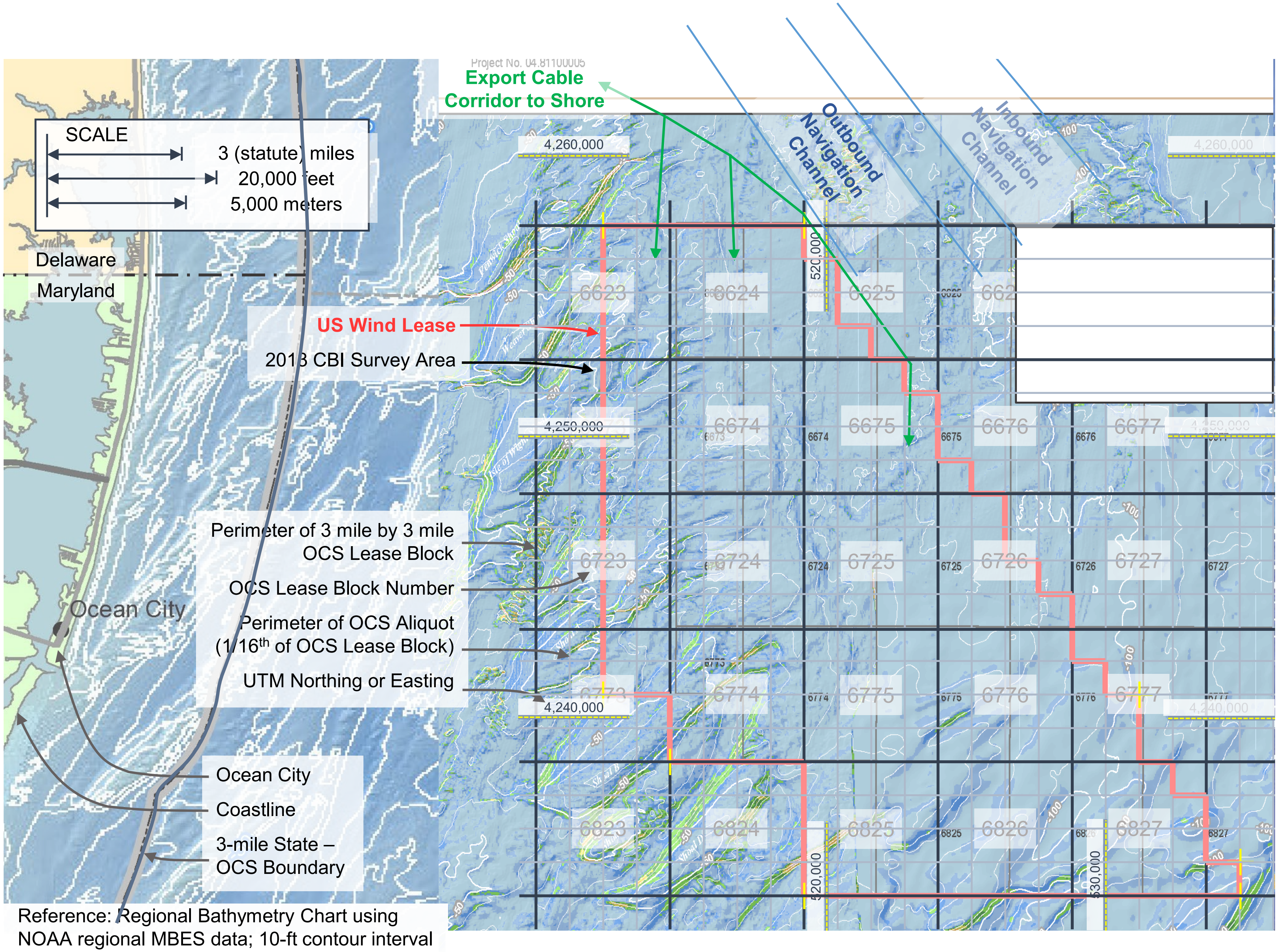
Figure 4-4b





WATER DEPTH AT 86 POTENTIAL TURBINE LOCATIONS
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area

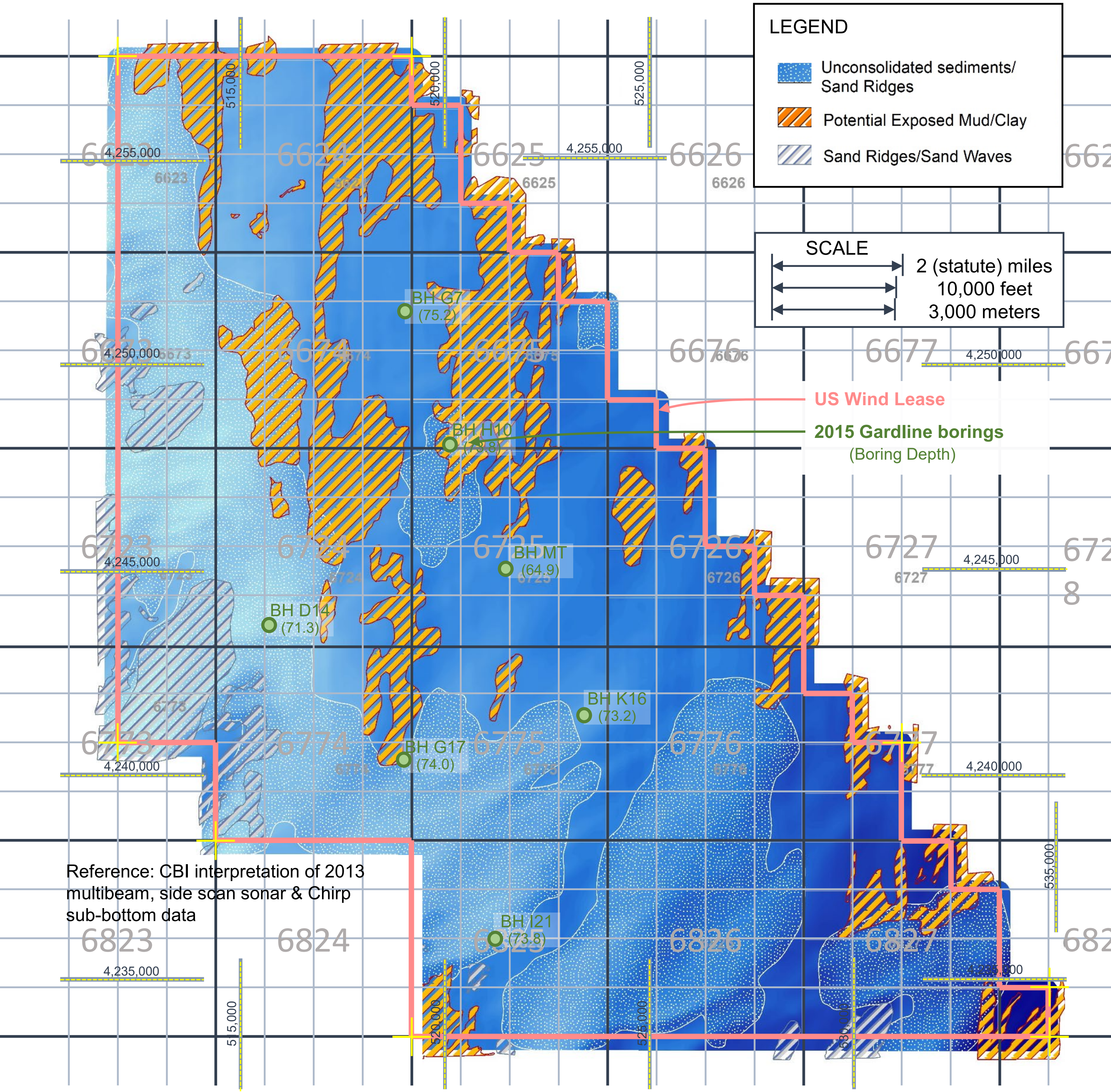
Figure 4-5



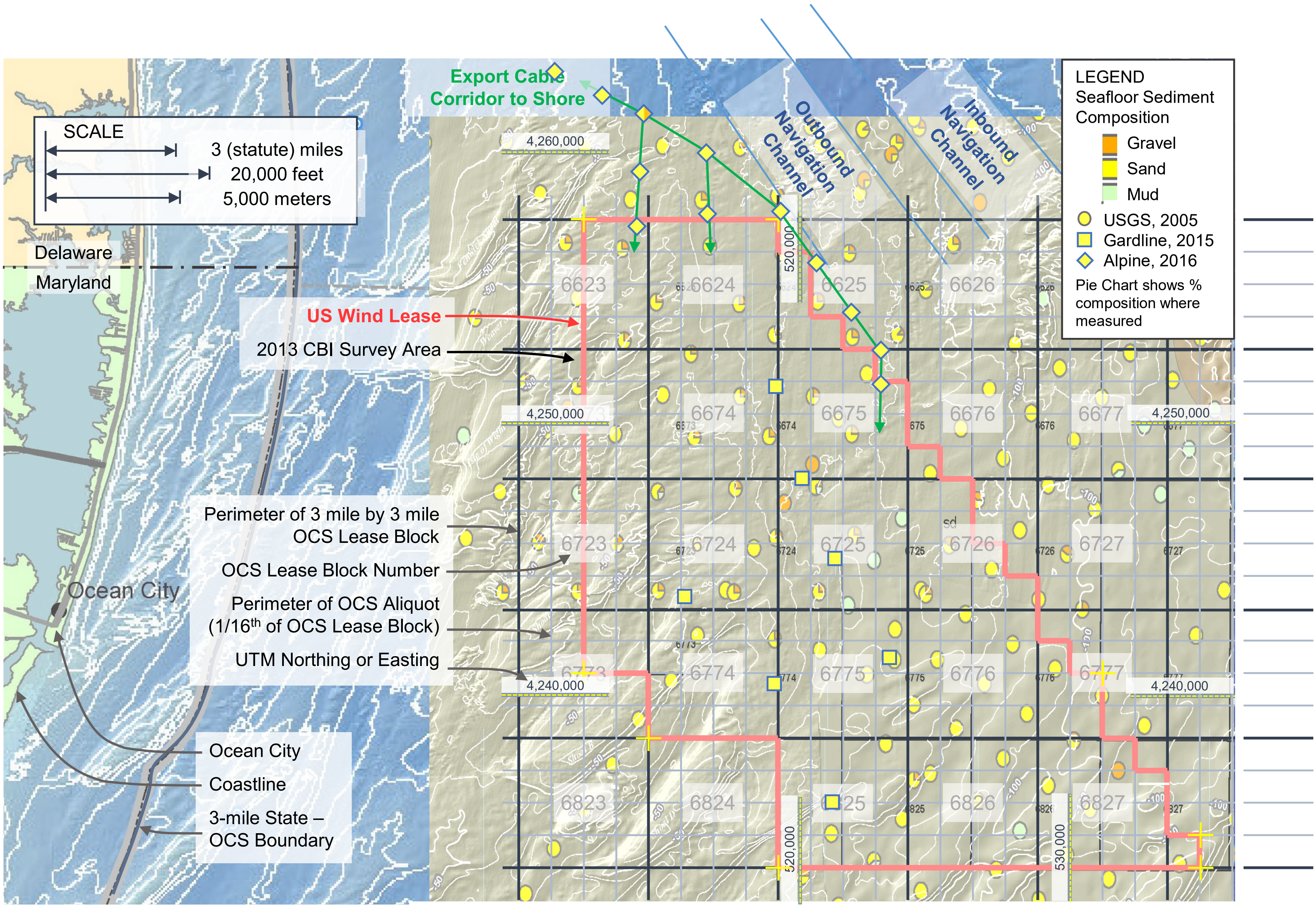
Initia

US Wind -

Figure 4-6

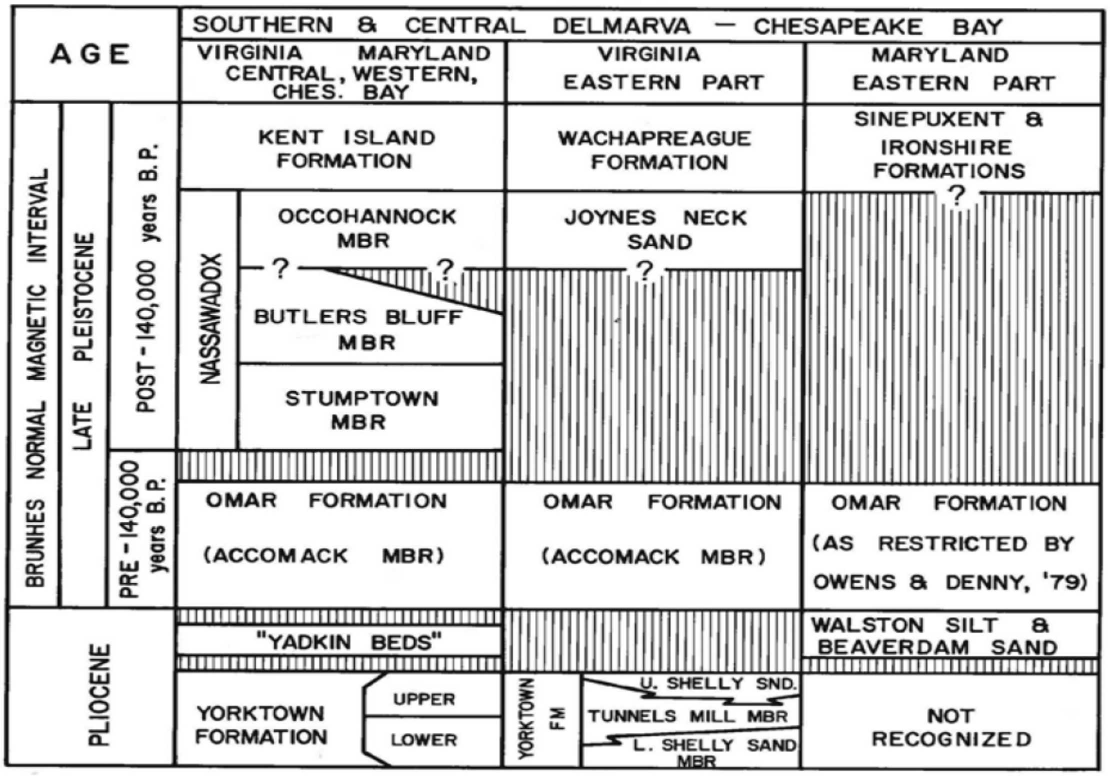


SEAFLOOR MORPHOLOGY
Initial, Integrated G&G Site Characterization
US Wind – Maryland OCS Offshore Wind Energy Area



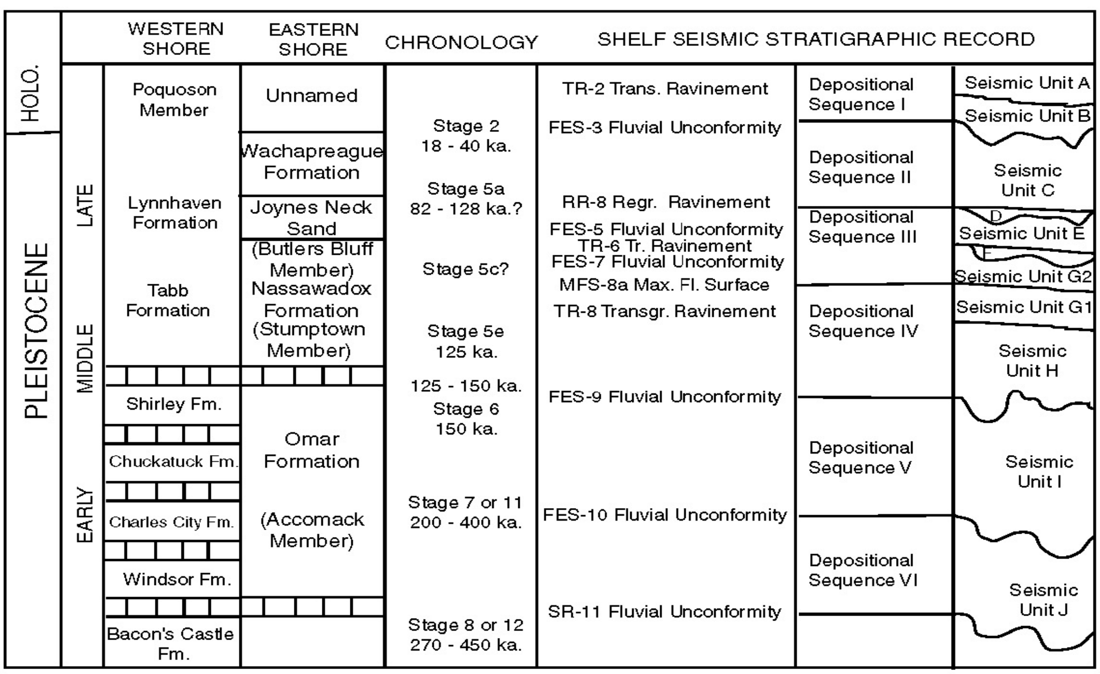
SEAFLOOR SEDIMENTS
Initial, Integrated G&G Site Characterization
US Wind – Maryland OCS Offshore Wind Development

Figure 4-8



Mid-Atlantic Inner Continental Shelf Stratigraphic Chart – Toscano, et al., (1989)

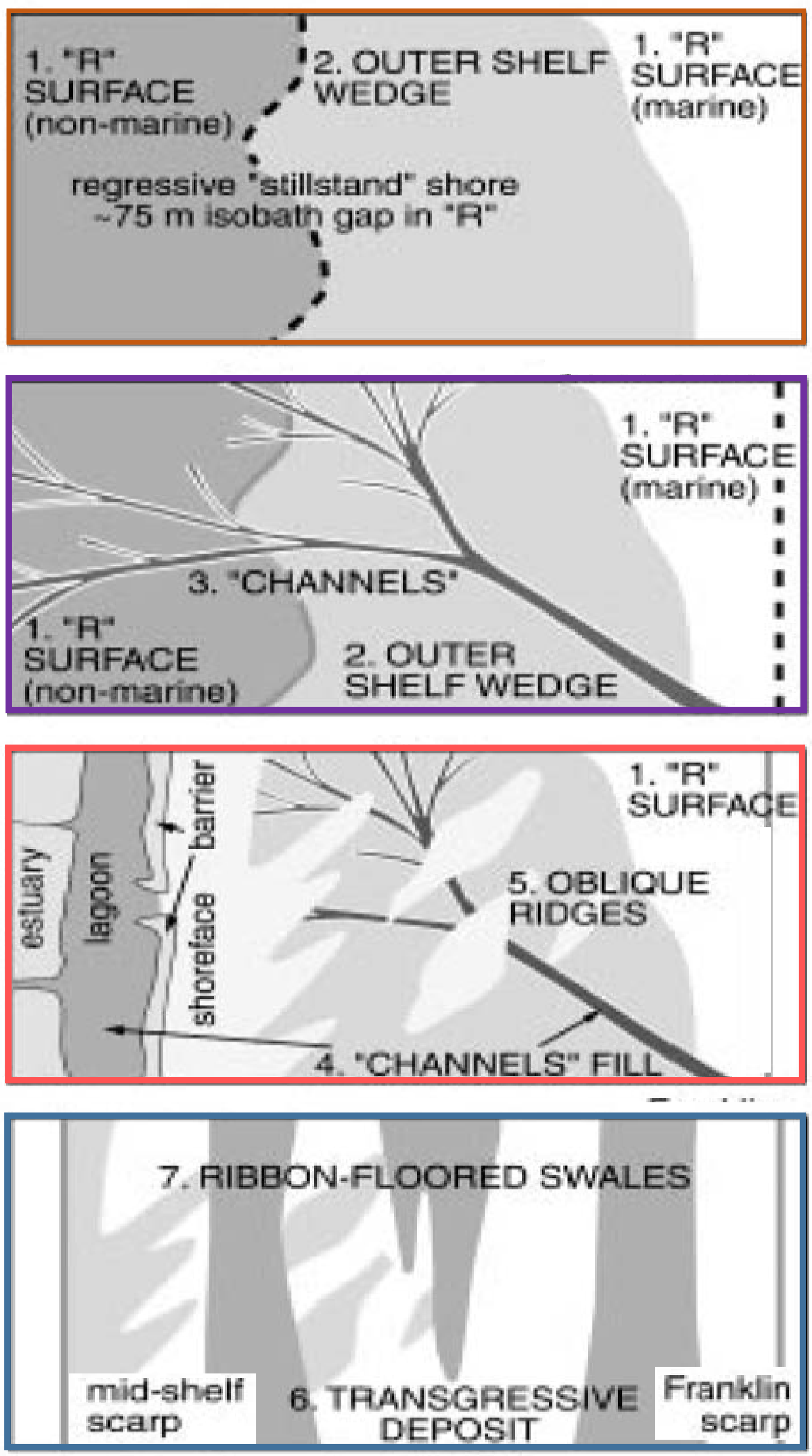
Regional correlation chart for the Virginia inner continental shelf. (Toscano et al., 1989)

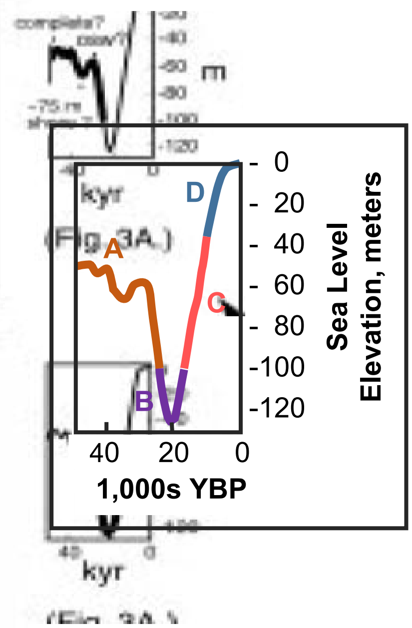


Correlation chart for the shallow seismic stratigraphy of southeastern Virginia and the inner continental shelf. (Swift et al., 2003)

Mid-Atlantic Coastal and Continental Shelf Stratigraphic Chart – Swift, et al., (2003)

REGIONAL STRATIGRAPHIC CHARTS
Initial, Integrated G&G Site Characterization
US Wind – Maryland OCS Offshore Wind Energy Area





C 15.7 to 10.5k YBP

Schematic geologic evolution of the mid shelf since ~120K YBP (Duncan et al, 2000).

Each schematic of the evolution shown in the left panes corresponds to the period shown on the sea level rise curve.

A shows the period when the shoreline moved seaward as glaciers advanced and sea level dropped.

B shows the period during the Wisconsin glacial maximum and channels (rivers) carved across the shelf.

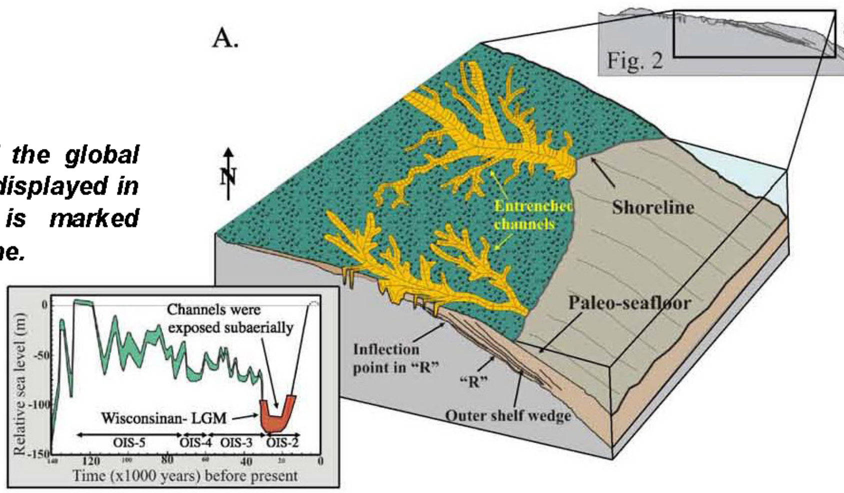
C shows the period when glaciers retreated and sea level rose and the shoreline retreated to the mid-shelf, and

D shows the "modern," inner and mid-shelf seafloor.

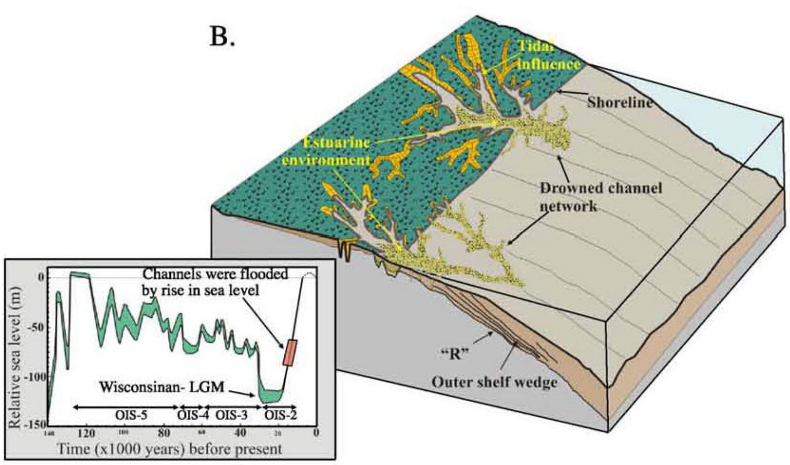
D 10.5 to 0k YBP

MID–SHELF GEOLOGIC EVOLUTION
Initial, Integrated G&G Site Characterization
US Wind – Maryland OCS Offshore Wind Energy Area

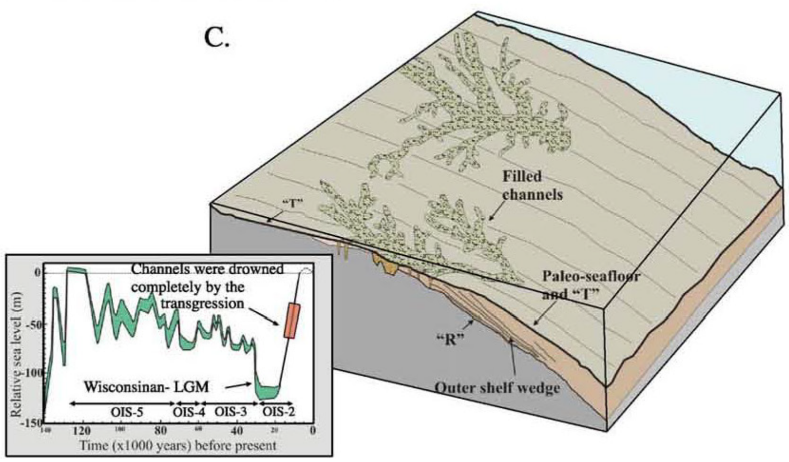
The portion of the global eustatic curve displayed in each cartoon is marked with a red outline.



SEA LEVEL LOWSTANDS
During Sea Level Lowstands (e.g. Wisconsin – Last Glacial Maximum ~25-15.7 kya), drainage systems developed on the subaerially exposed Continental Shelf.



MARINE TRANSGRESSION
As sea level rose, the shoreline transgressed across the shelf which resulted in: 1) fluvial channels transitioning to estuarine environments, and 2) drowning, infilling, and burial of channels; channels infilled with upward deepening succession of lagoonal and estuarine muds.

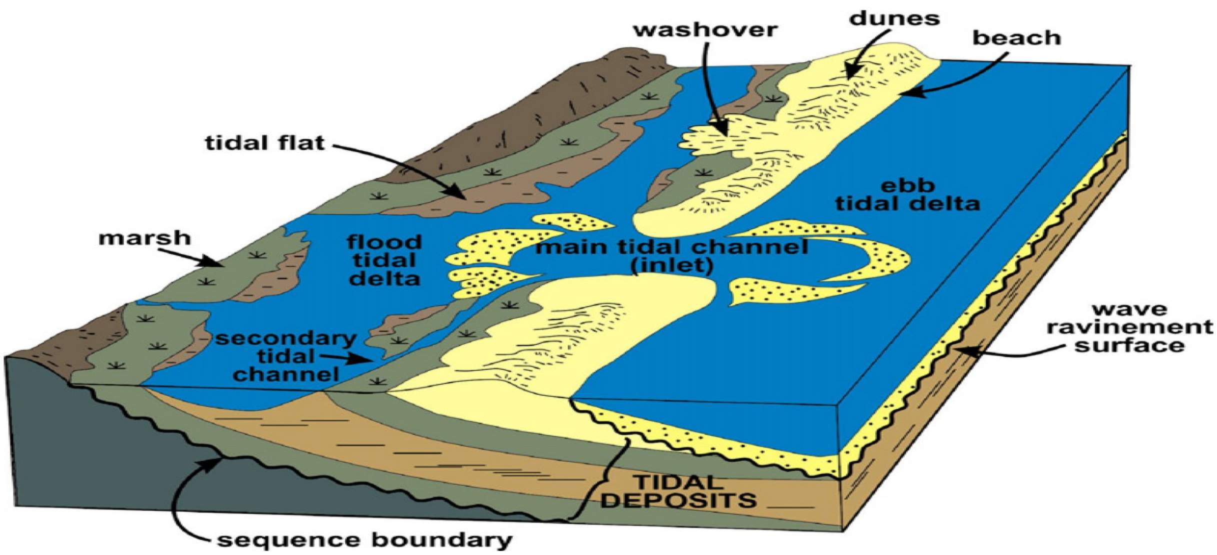


CONDITIONS TODAY
Following transgression, Holocene-age marine sediments mask the location of channels and the materials that infill them. Conditions also underlie barrier spit prograding deposits along the Delmarva Peninsula.

Source: Nordfjord et al. (2005)

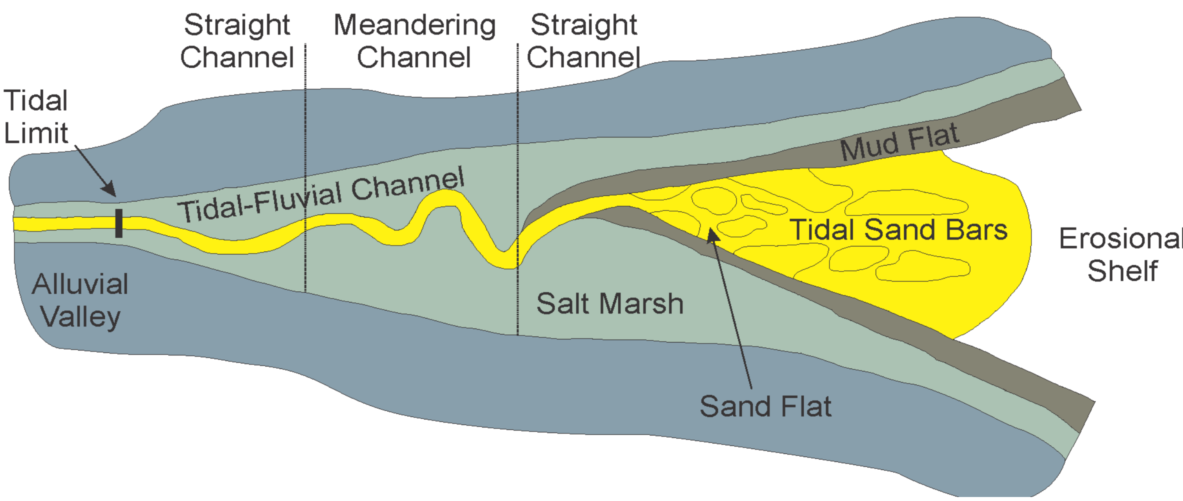
CHANNEL INCISION & BURIAL SCHEMATIC
Initial, Integrated G&G Site Characterization
US Wind – Maryland OCS Offshore Wind Energy Area

Block Diagram of Barrier Island System



Modified from Dalrymple and Choi (2007)

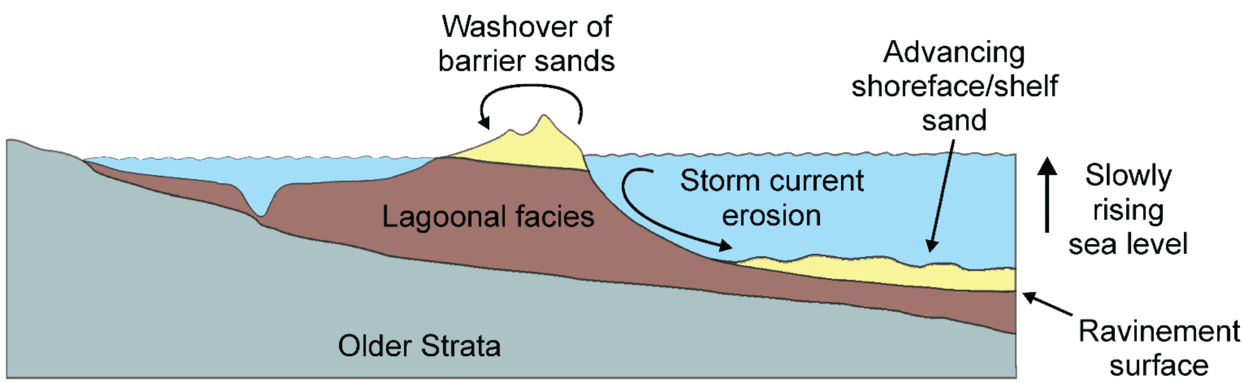
Schematic Diagram of Tidal-Dominated Estuary

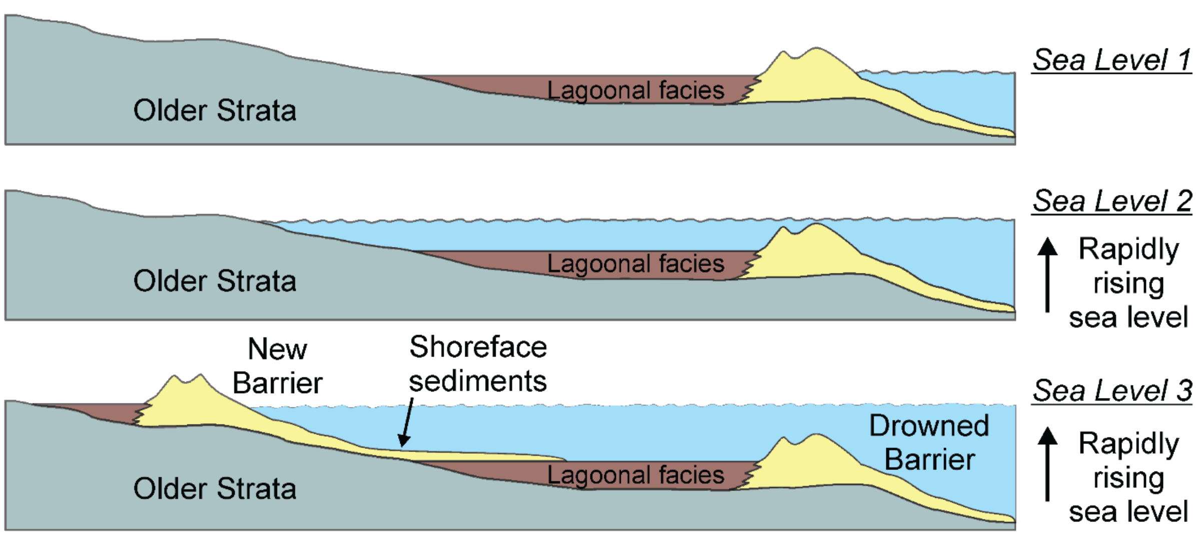


Modified from Dalrymple et al. (1992)

BARRIER ISLAND & TIDAL ESTUARY SCHEMATICS
Initial, Integrated G&G Site Characterization
US Wind – Maryland OCS Offshore Wind Energy Area

Figure 5-4

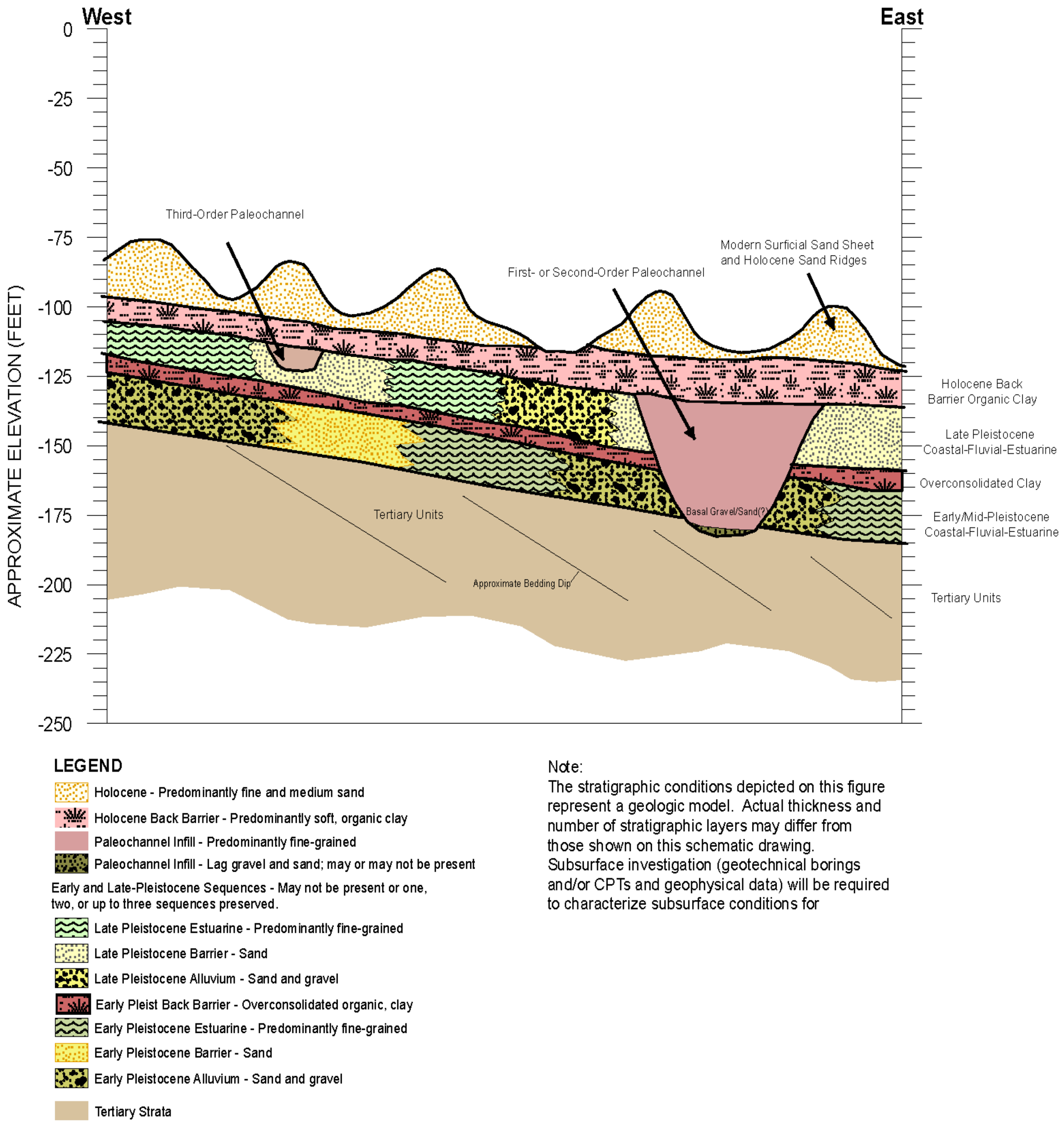




Sources: Fischer, 1961; Swift, 1975; Rampino and Sanders, 1980; Reading and Collinson, 1996

Schematic examples of barrier island evolution during slowly rising and rapidly rising sea levels are shown in the two geologic sketches shown above.

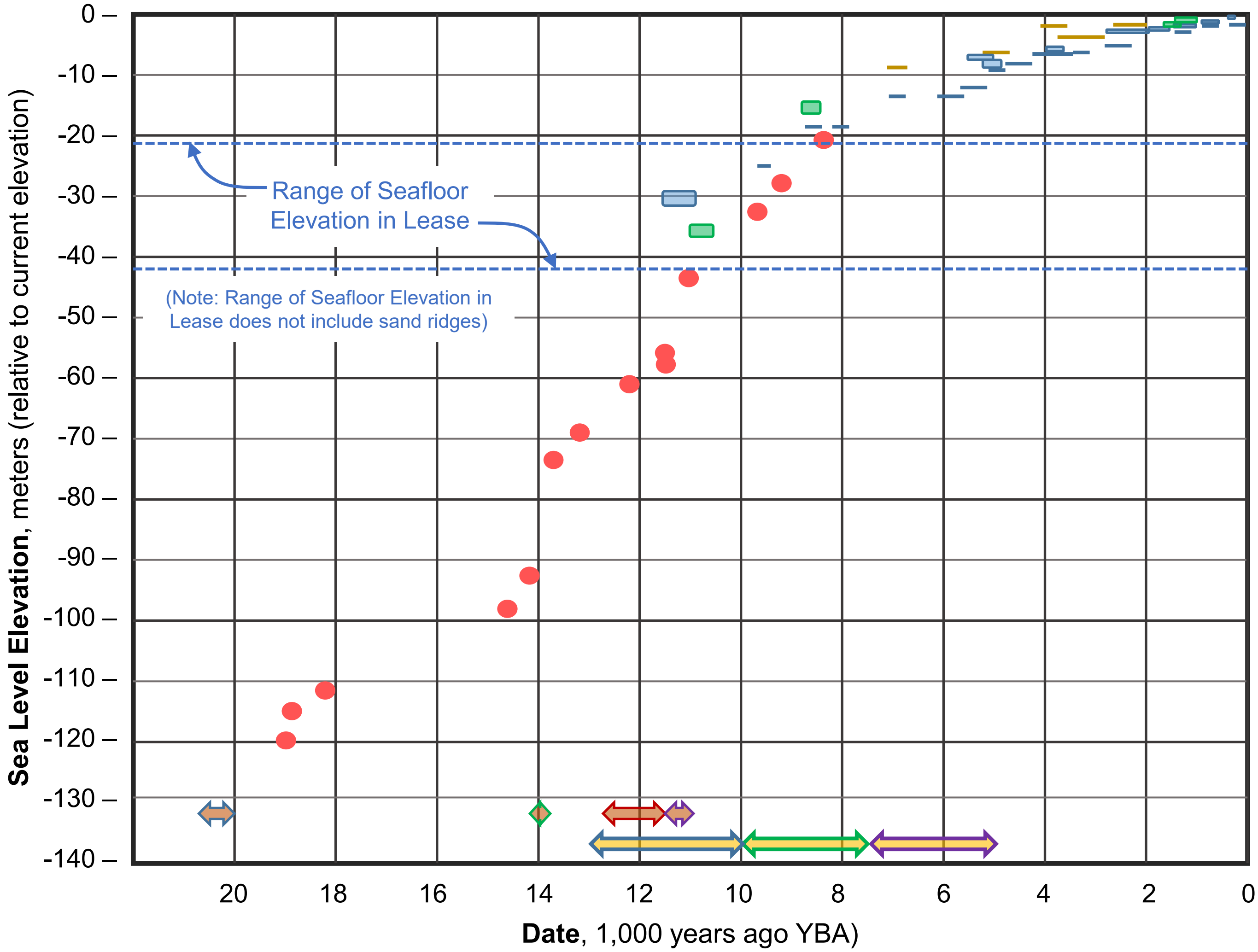
LANDWARD MIGRATION OF BARRIER ISLANDS
Initial, Integrated G&G Site Characterization
US Wind – Maryland OCS Offshore Wind Energy Area



Note:
The stratigraphic conditions depicted on this figure represent a geologic model. Actual thickness and number of stratigraphic layers may differ from those shown on this schematic drawing. Subsurface investigation (geotechnical borings and/or CPTs and geophysical data) will be required to characterize subsurface conditions for

SCHEMATIC MID-SHELF GEOLOGIC PROFILE
Initial, Integrated G&G Site Characterization
US Wind – Maryland OCS Offshore Wind Energy Area

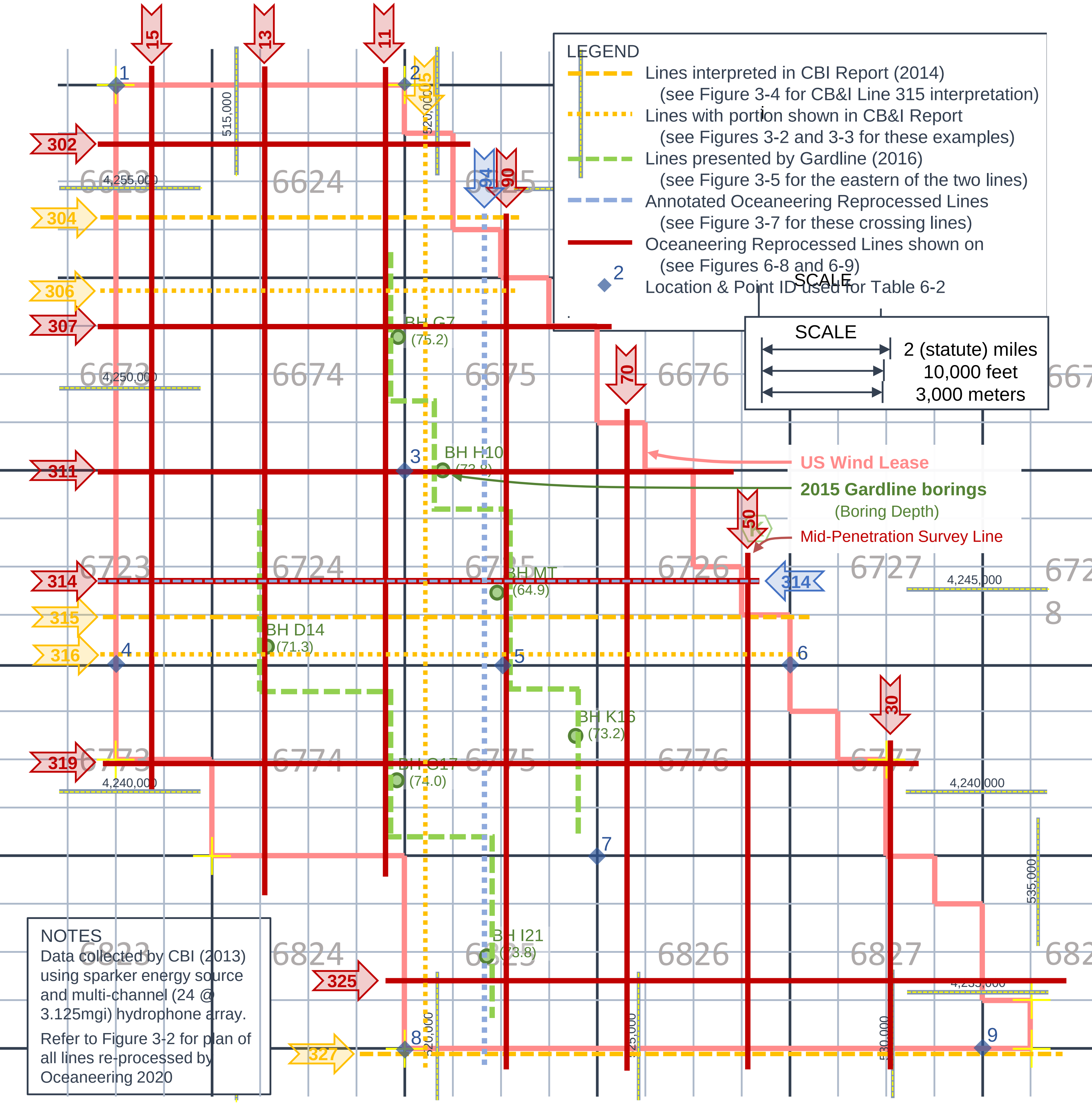
Figure 5-6



LEGEND
Barbados Coral Carbon Dates
Atlantic Coast Sea Level Database:
Basal Index Point
Base of Basal Index Point
Terrestrial Limiting Data
Marine Limiting Data
Note width of Atlantic Cast data = age uncertainty
Height of Basal Index Points = relative sea level elevation uncertainty
References: TRC Corp (2012); Englehart & Horton (2012); Fairbanks (1992)

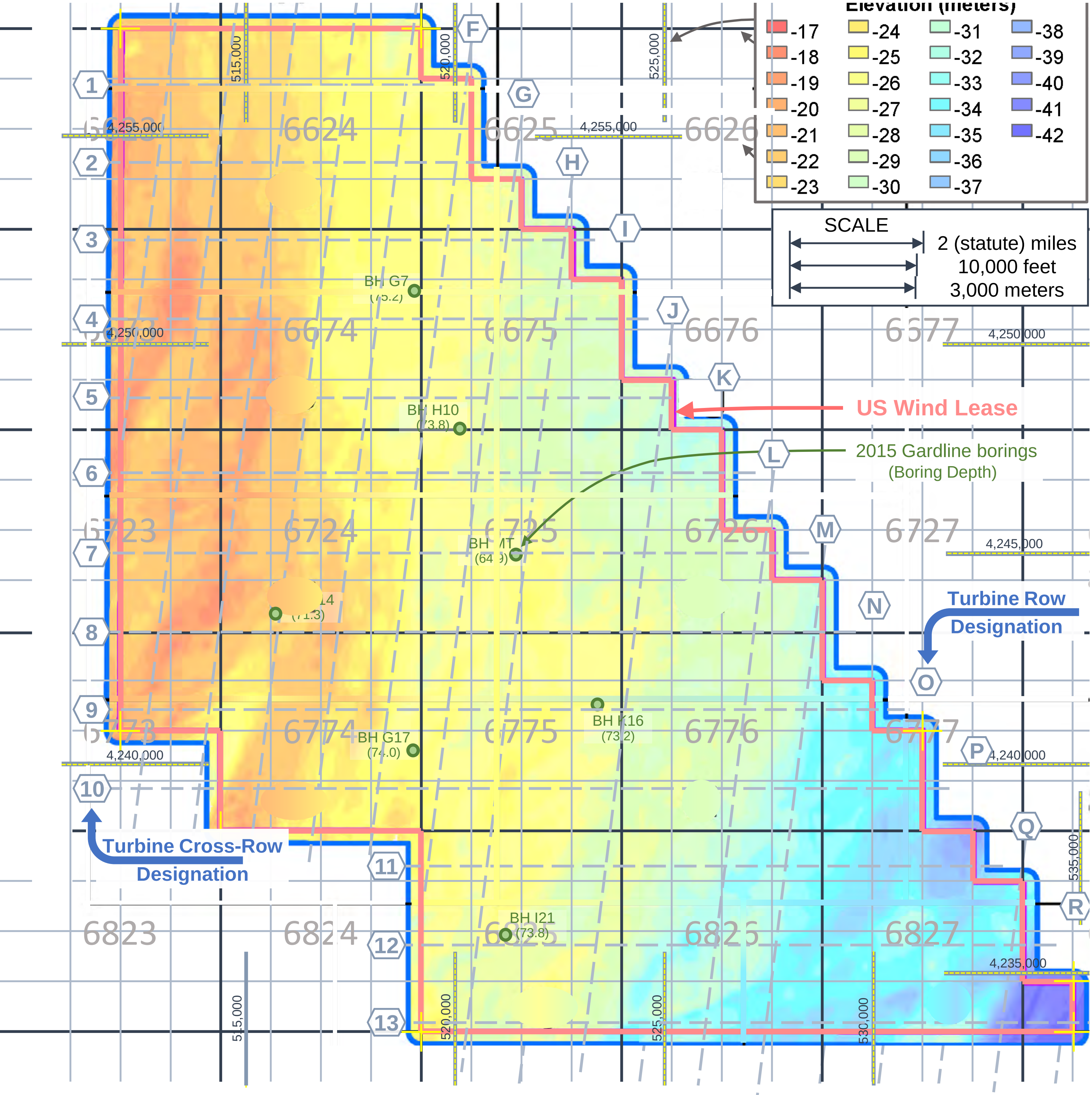
Archaeological Periods:
Paleoindian (10 -13 kya)
Early Archaic (7.5 – 10 kya)
Middle Archaic (5 – 7.5 kya)
Miscellaneous Information:
LGM
MWP 1A
MWP 1B
Younger Dryas

LATE PLEISTOCENE – HOLOCENE SEA LEVEL RISE CURVE
Initial, Integrated G&G Site Characterization
US Wind – Maryland OCS Offshore Wind Energy Area



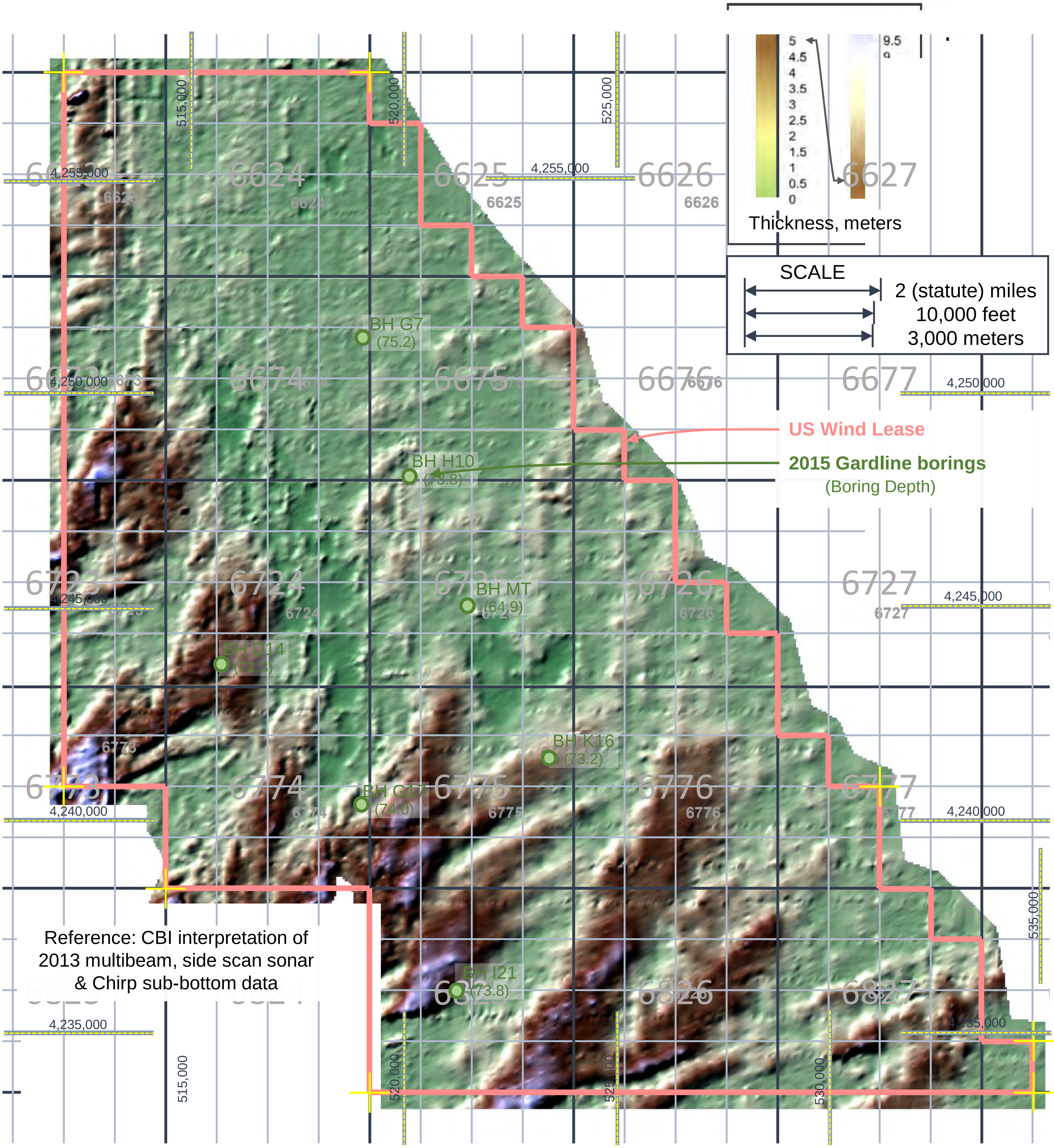
LOCATIONS OF ILLUSTRATED SEISMIC REFLECTION RECORDS
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area

Figure 6-1

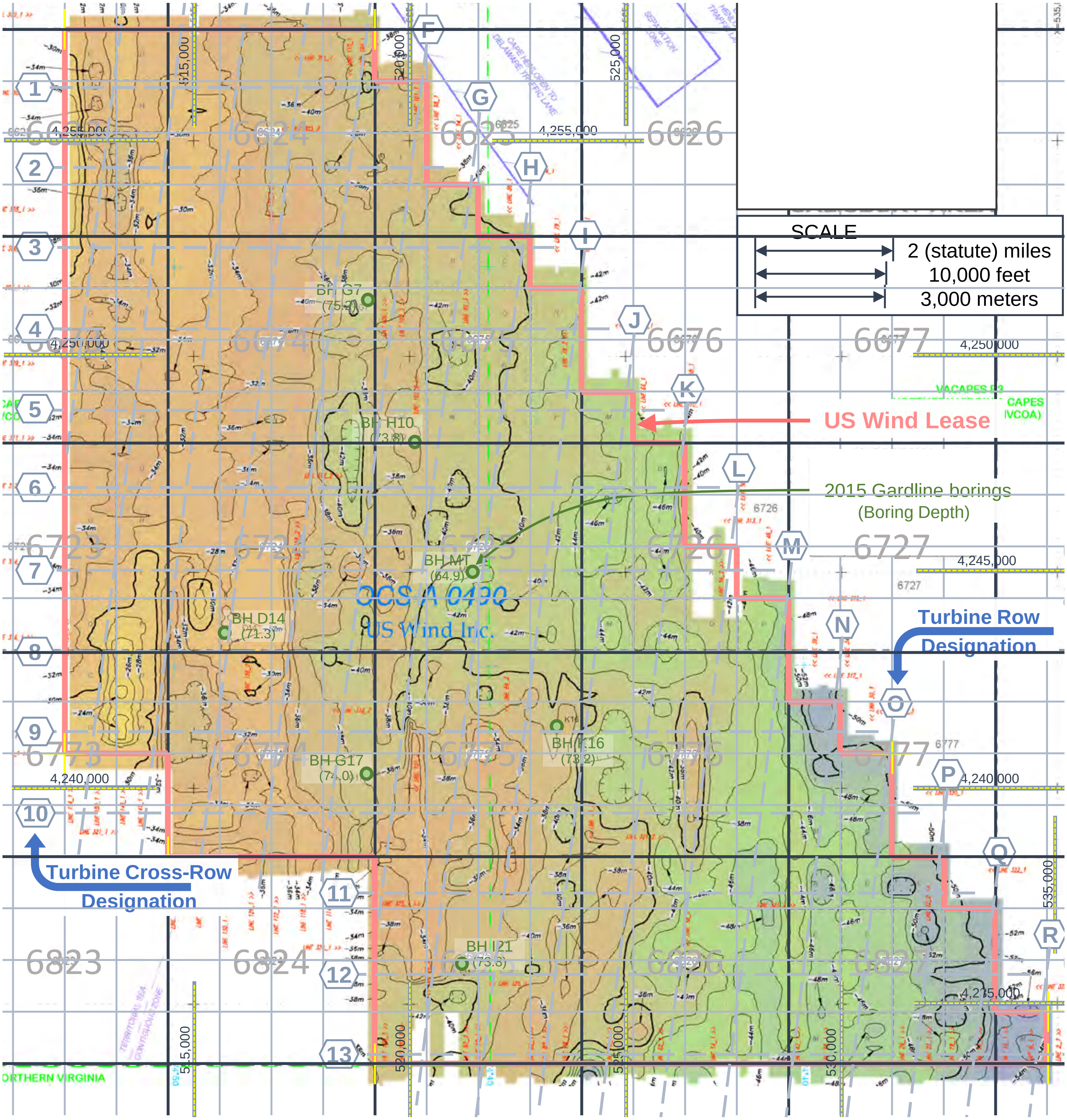


STRUCTURAL CONTOURS on CB&I's BASE OF SURFACE SEDIMENTS
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area

Figure 6-2

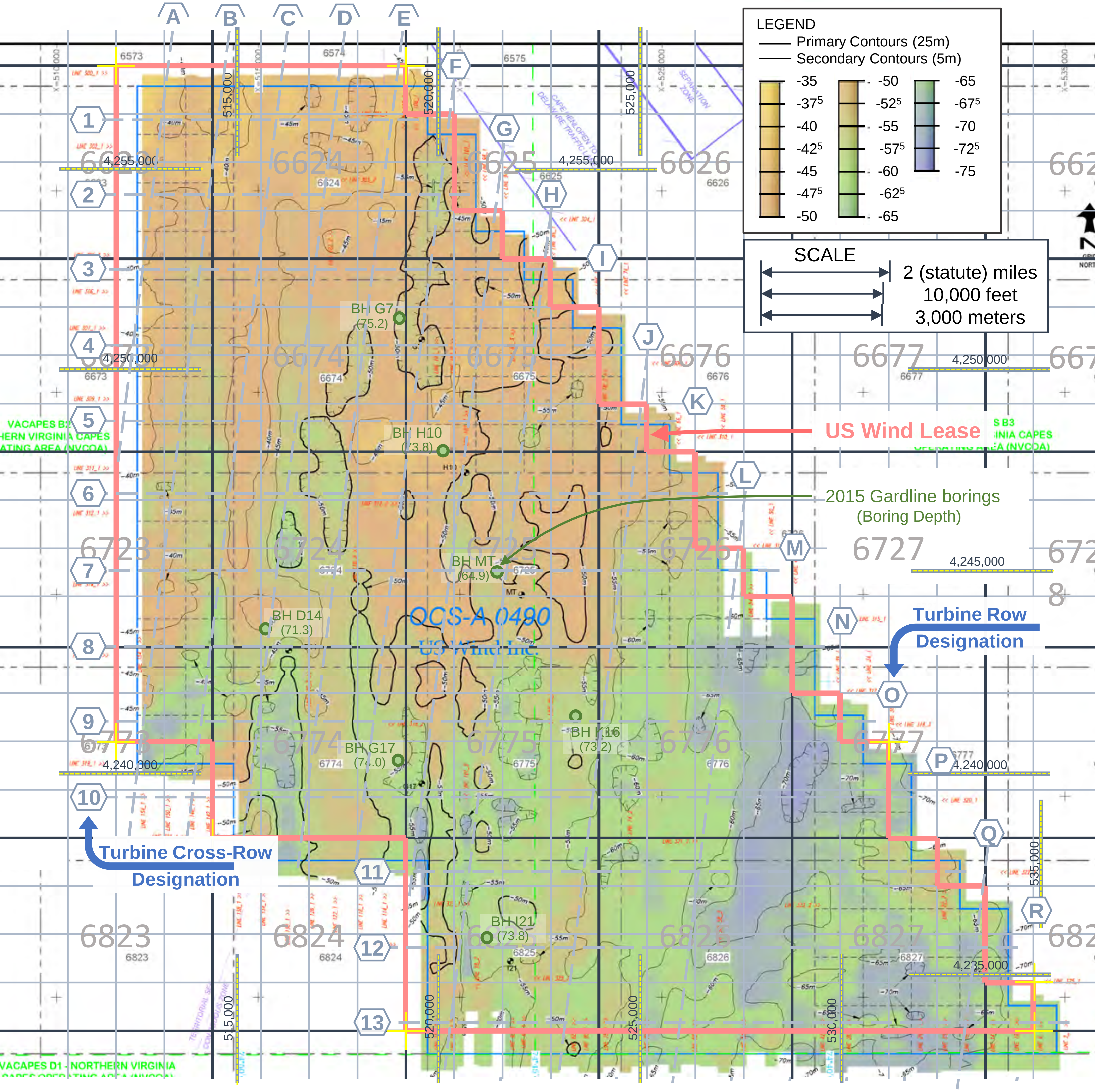


ISOPACH (THICKNESS) OF SURFICIAL, HOLOCENE SEDIMENTS
Initial, Integrated G&G Site Characterization
US Wind – Maryland OCS Offshore Wind Energy Area

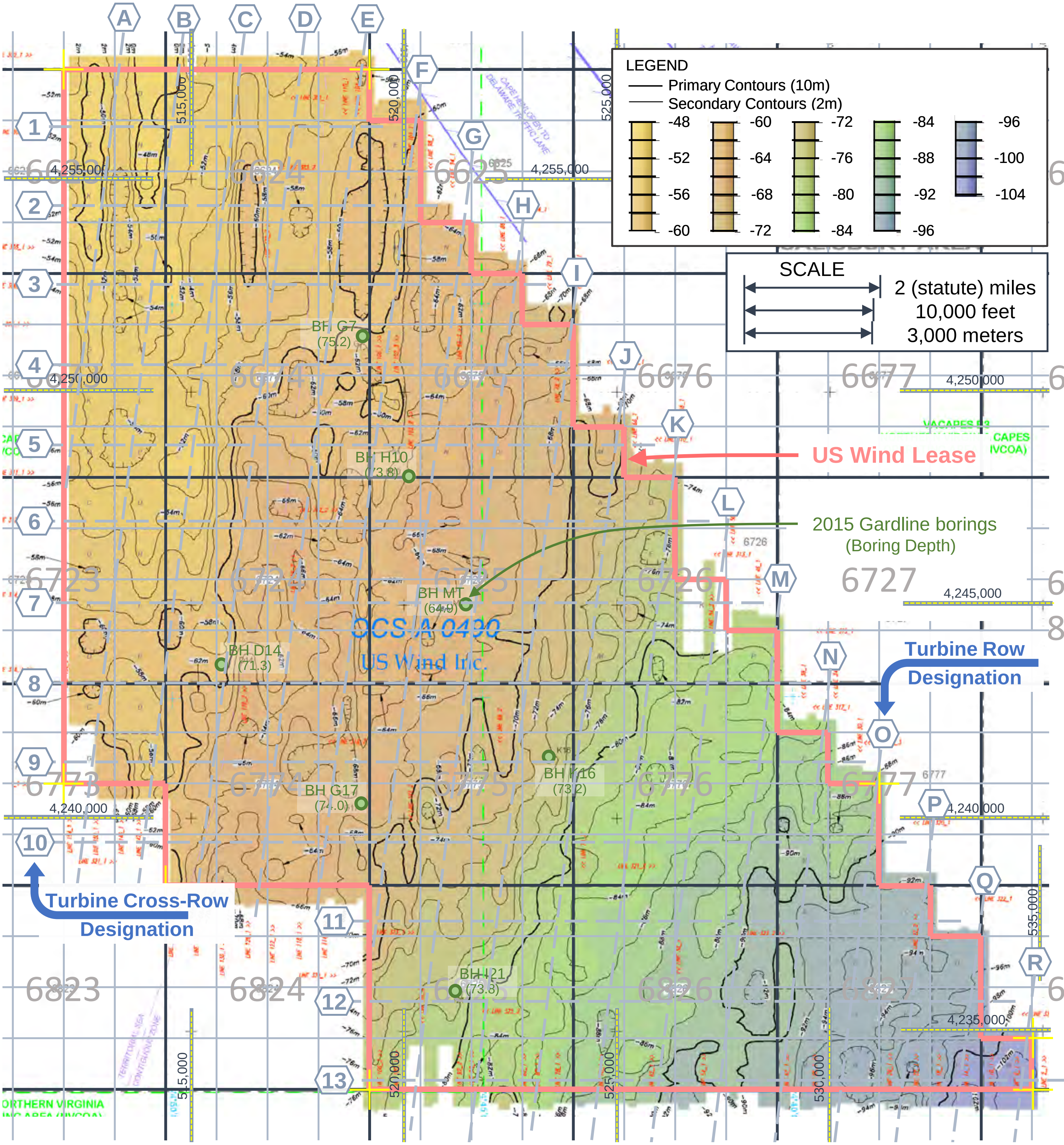


US Wind – Maryland OCS Offshore Wind Energy Area

Figure 6-4

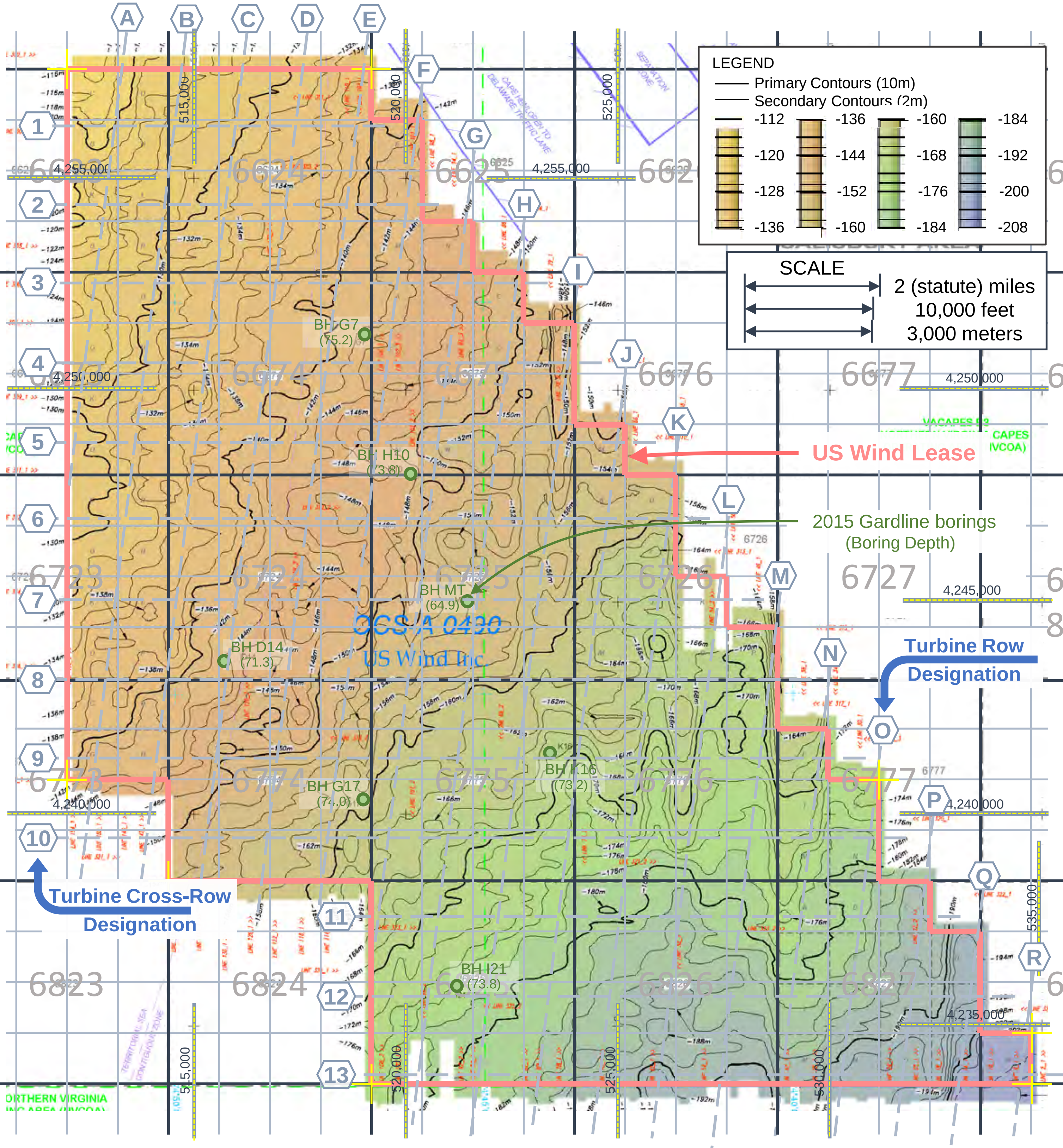


STRUCTURAL CONTOURS on OCEANEERING CHANNEL BASE HORIZON
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area



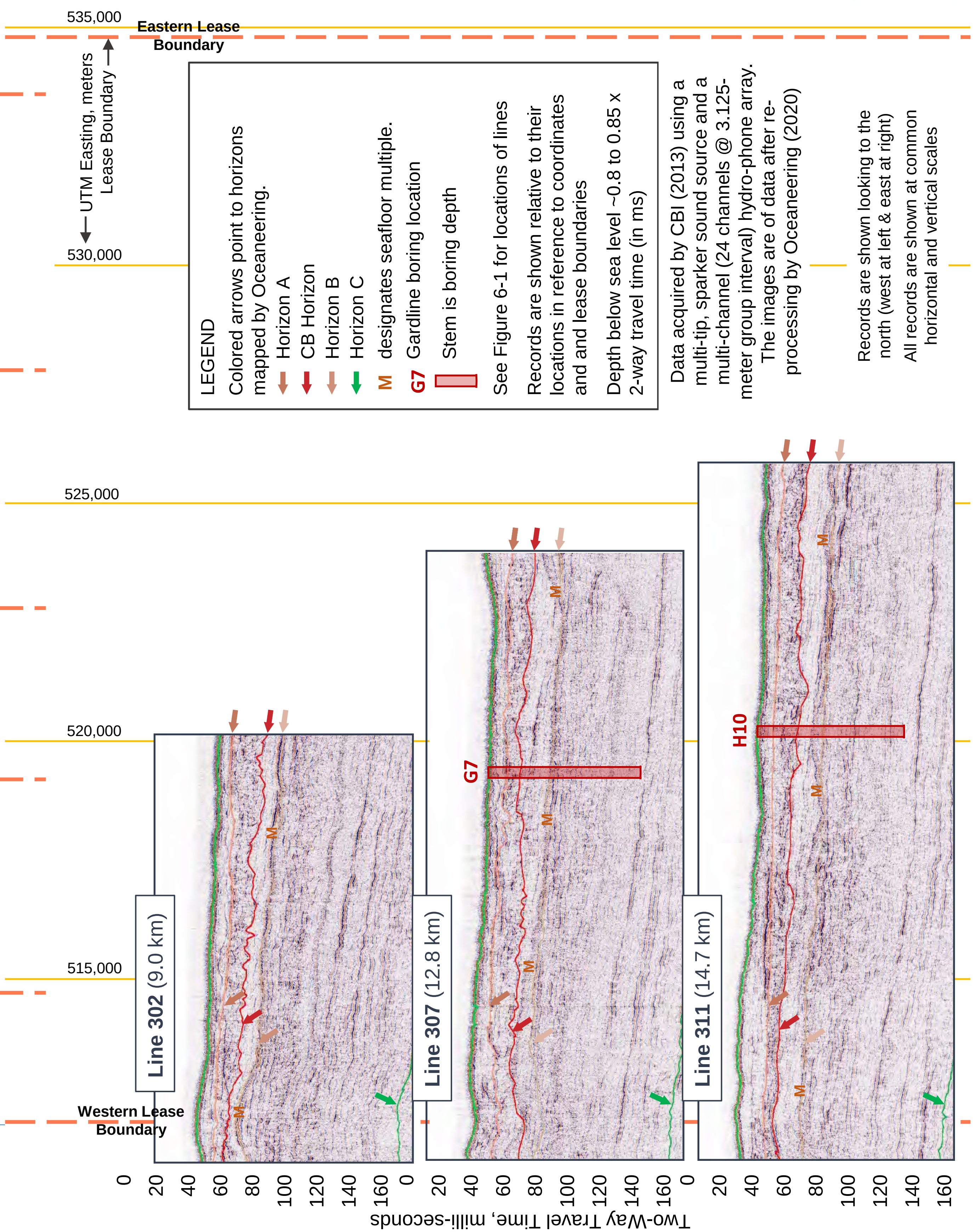
STRUCTURAL CONTOURS on OCEANEERING HORIZON B
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area

McNeilan & Associates



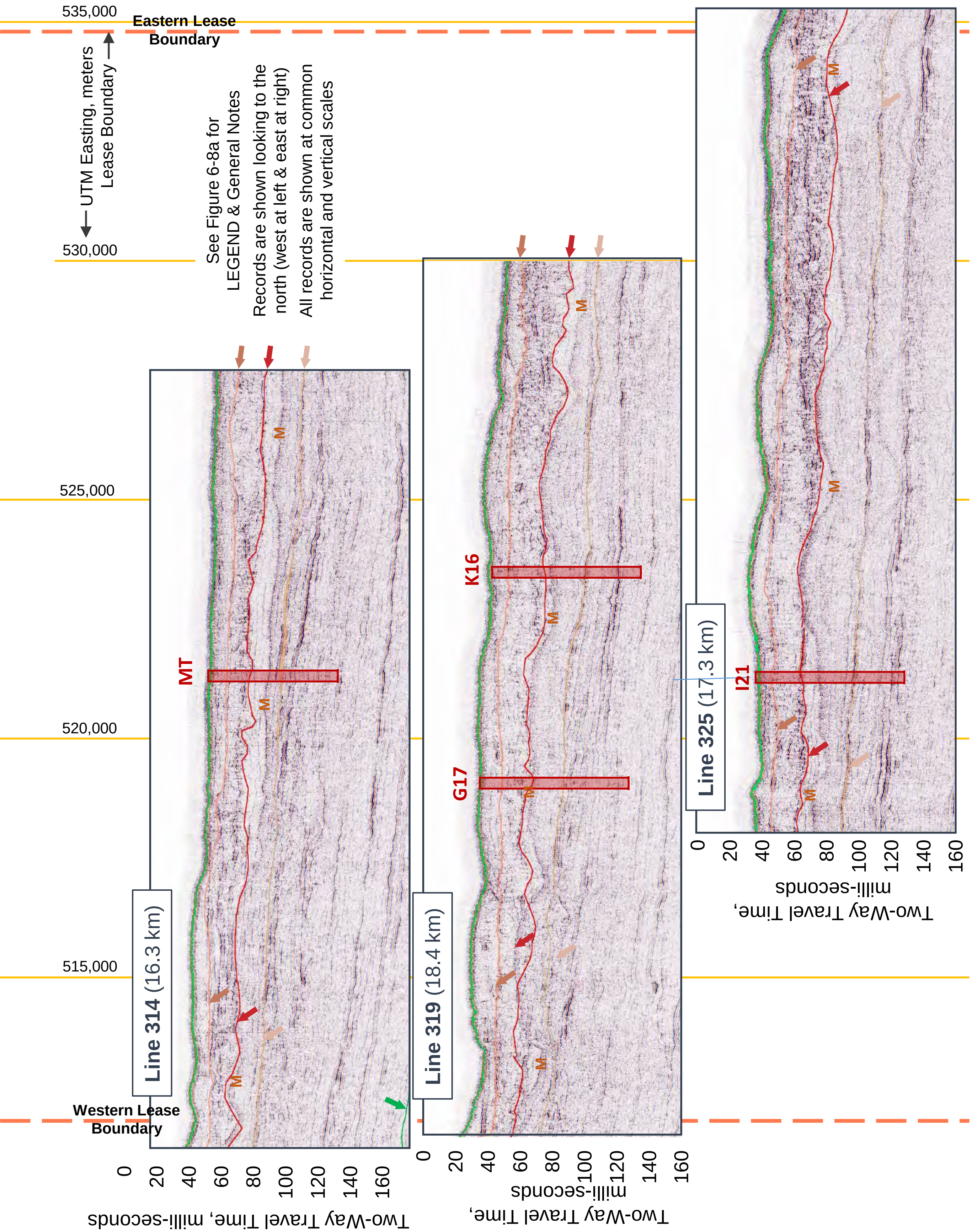
STRUCTURAL CONTOURS on OCEANEERING HORIZON C
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area

Figure 6-7

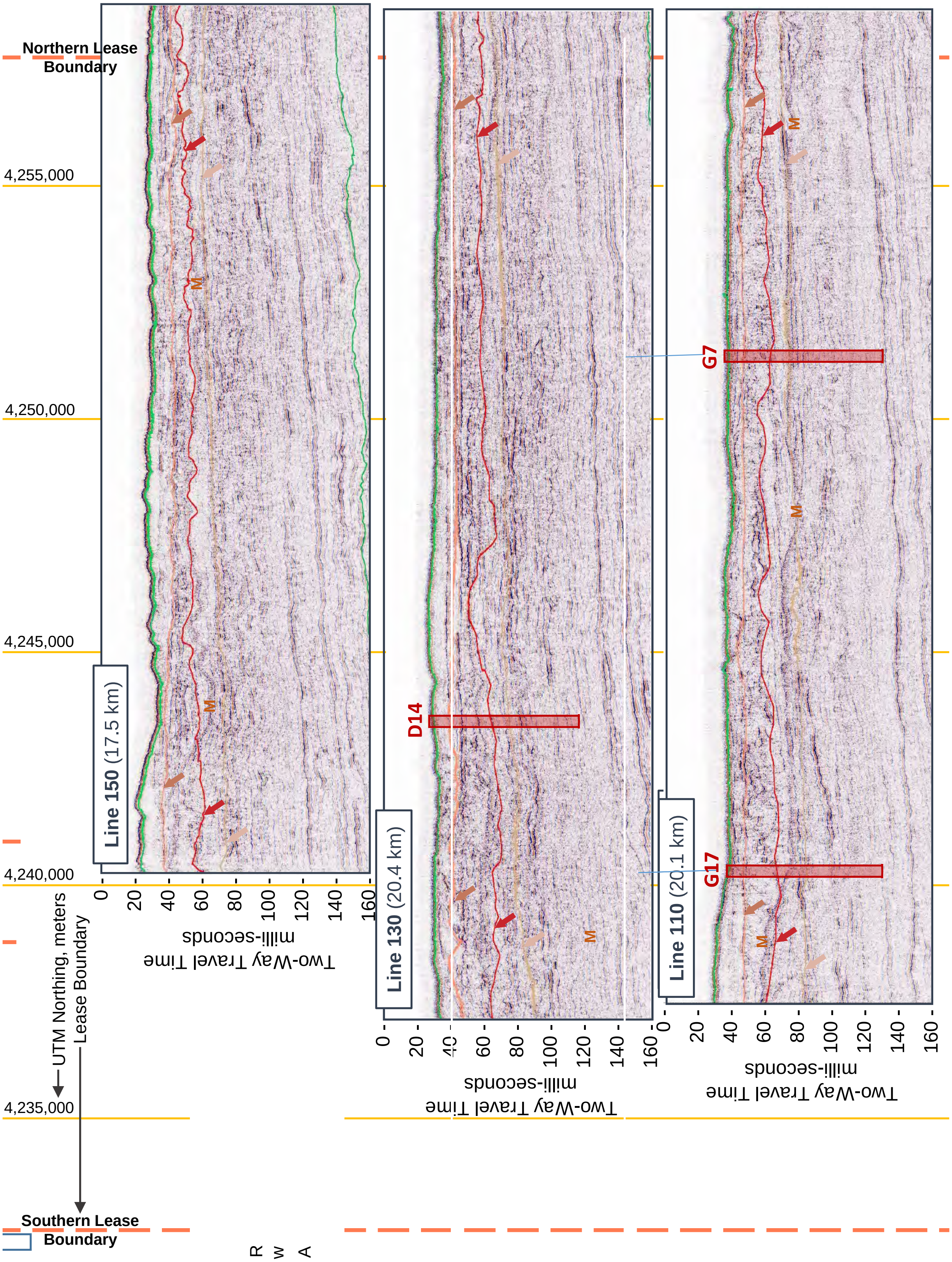


EAST – WEST MID-PENETRATION, SEISMIC REFLECTION RECORDS
Initial, Integrated G&G Site Characterization
US Wind – Maryland OCS Offshore Wind Energy Area

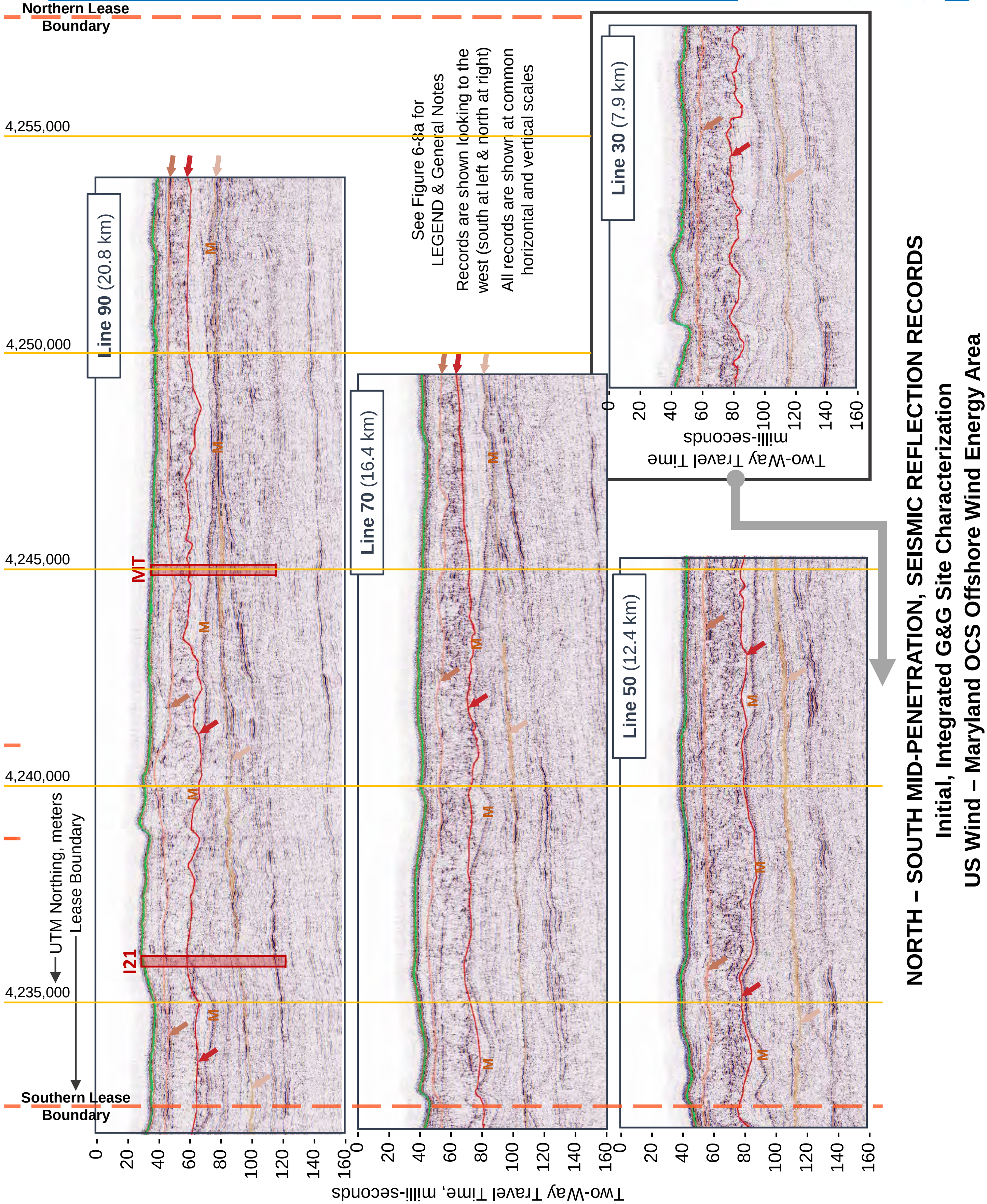
Figure 6-8a



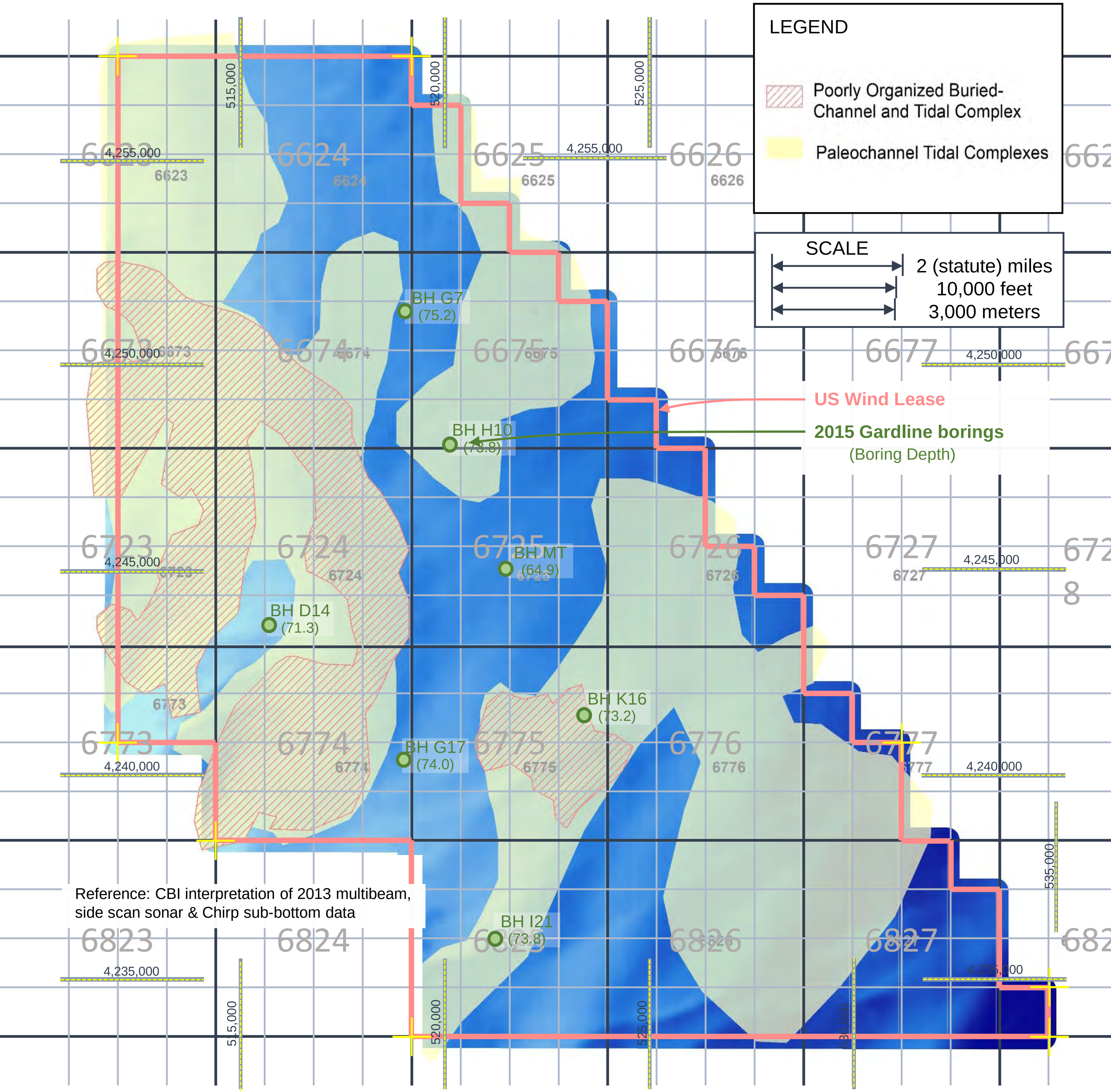
EAST – WEST MID-PENETRATION, SEISMIC REFLECTION RECORDS
Initial, Integrated G&G Site Characterization
US Wind – Maryland OCS Offshore Wind Energy Area



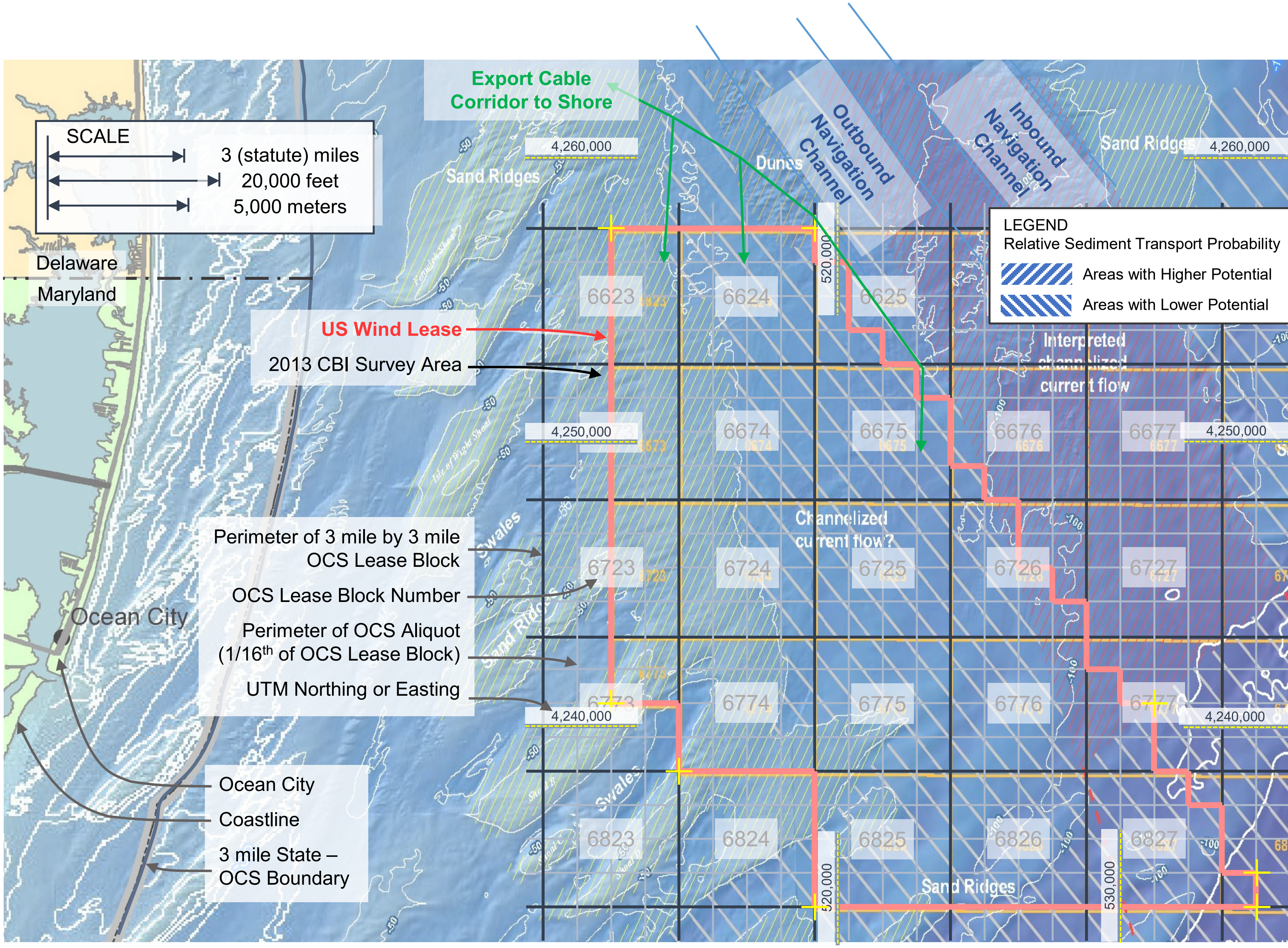
NORTH – SOUTH MID-PENETRATION, SEISMIC REFLECTION RECORDS
Initial, Integrated G&G Site Characterization
US Wind – Maryland OCS Offshore Wind Energy Area


NORTH – SOUTH MID-PENETRATION, SEISMIC REFLECTION RECORDS
Initial, Integrated G&G Site Characterization
US Wind – Maryland OCS Offshore Wind Energy Area
See Figure 6-8a for LEGEND & General Notes
Records are shown looking to the west (south at left & north at right)
All records are shown at common horizontal and vertical scales
Northern Lease Boundary
Southern Lease Boundary
UTM Northing, meters
Lease Boundary
4,255,000
4,250,000
4,245,000
4,240,000
4,235,000
Line 90 (20.8 km)
Line 70 (16.4 km)
Line 50 (12.4 km)
Line 30 (7.9 km)
MT
I21
M
Two-Way Travel Time, milli-seconds
Two-Way Travel Time milli-seconds
0
20
40
60
80
100
120
140
160

McNeilan & Associates

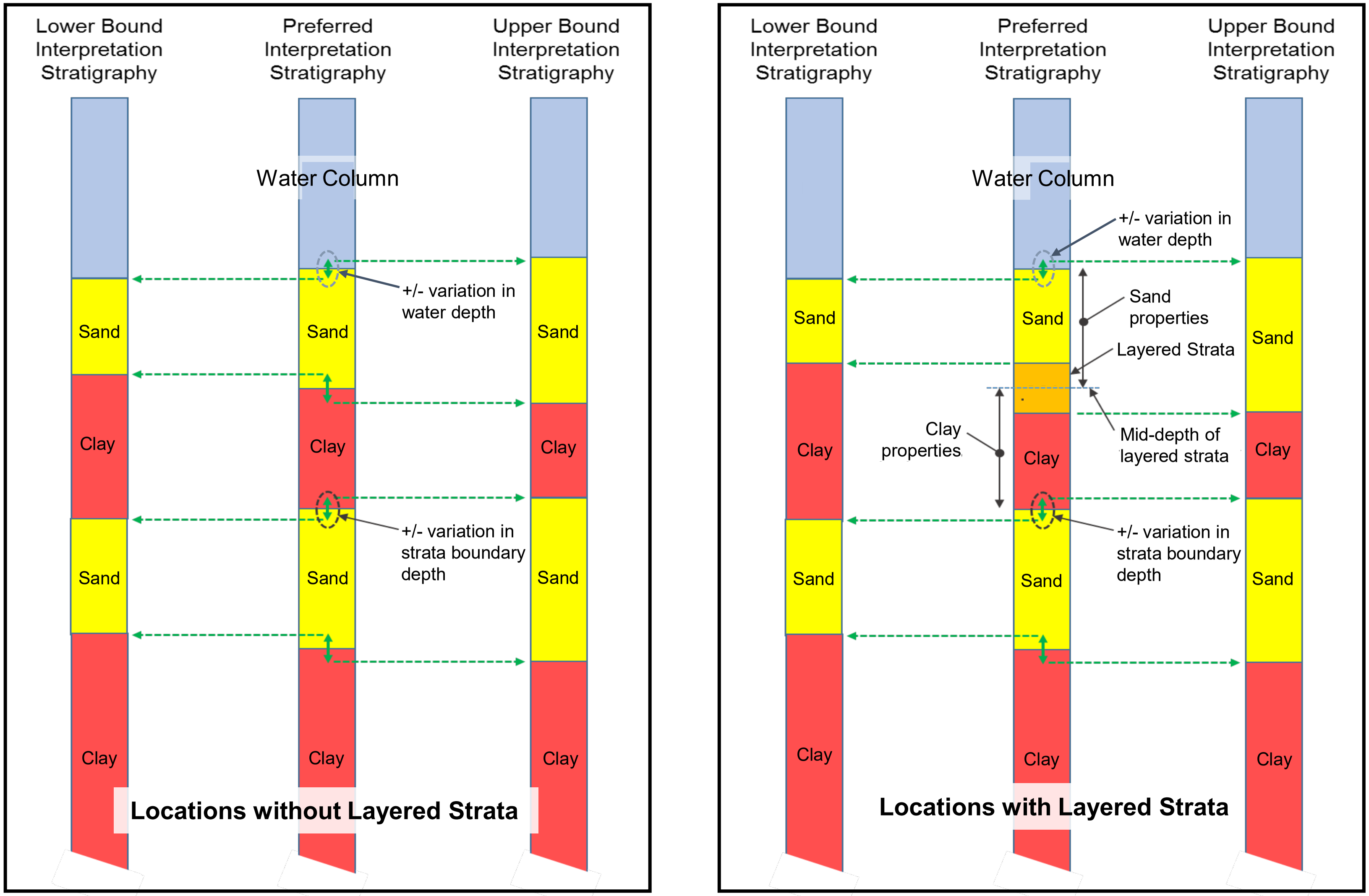


ORGANIZED & POORLY-ORGANIZED PALEOCHANNEL & TIDAL SEQUENCES
Initial, Integrated G&G Site Characterization
US Wind – Maryland OCS Offshore Wind Energy Area



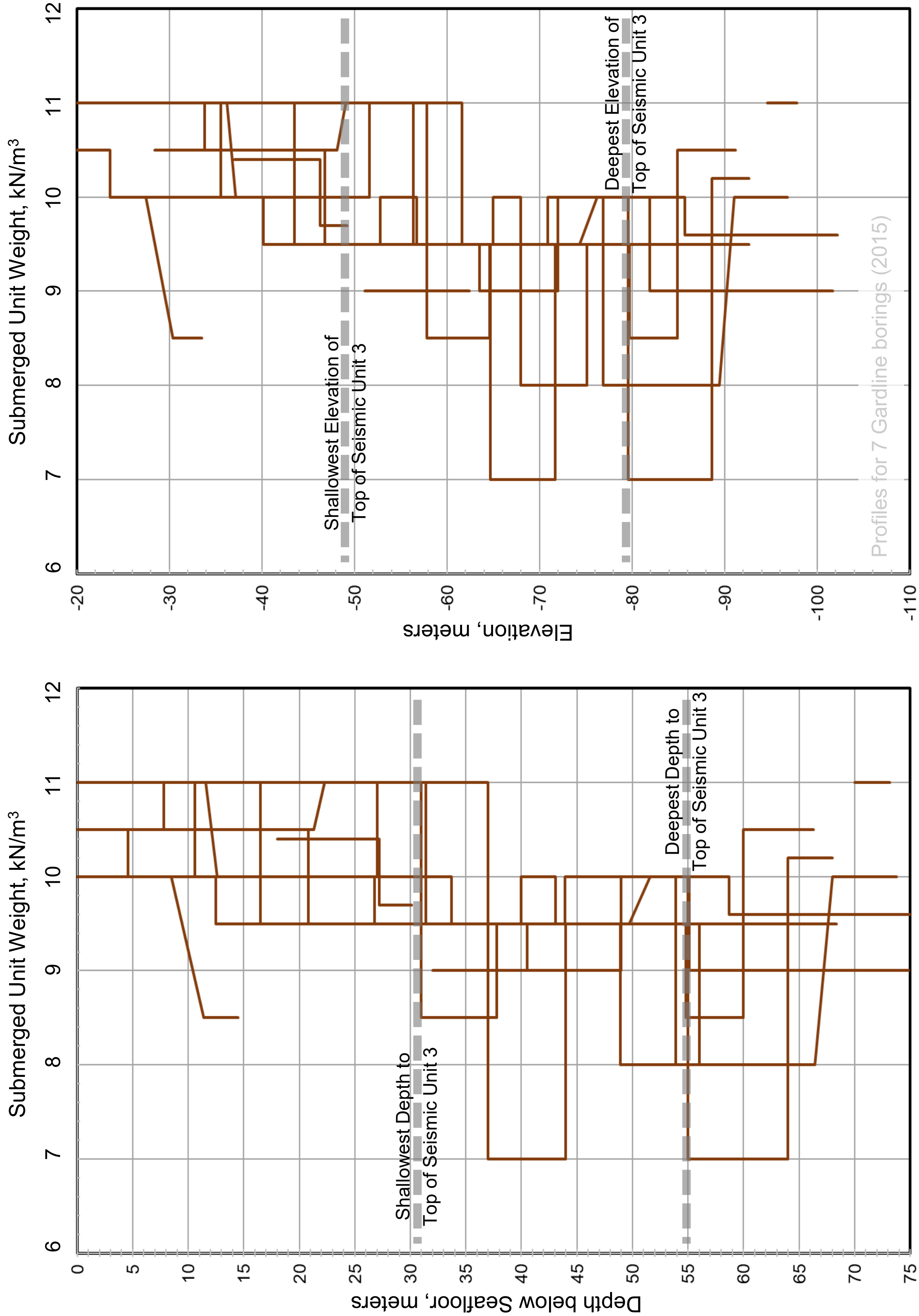
REGIONAL SEDIMENT MOBILITY HAZARD
Initial, Integrated G&G Site Characterization
US Wind – Maryland OCS Offshore Wind Development

Figure 7-1

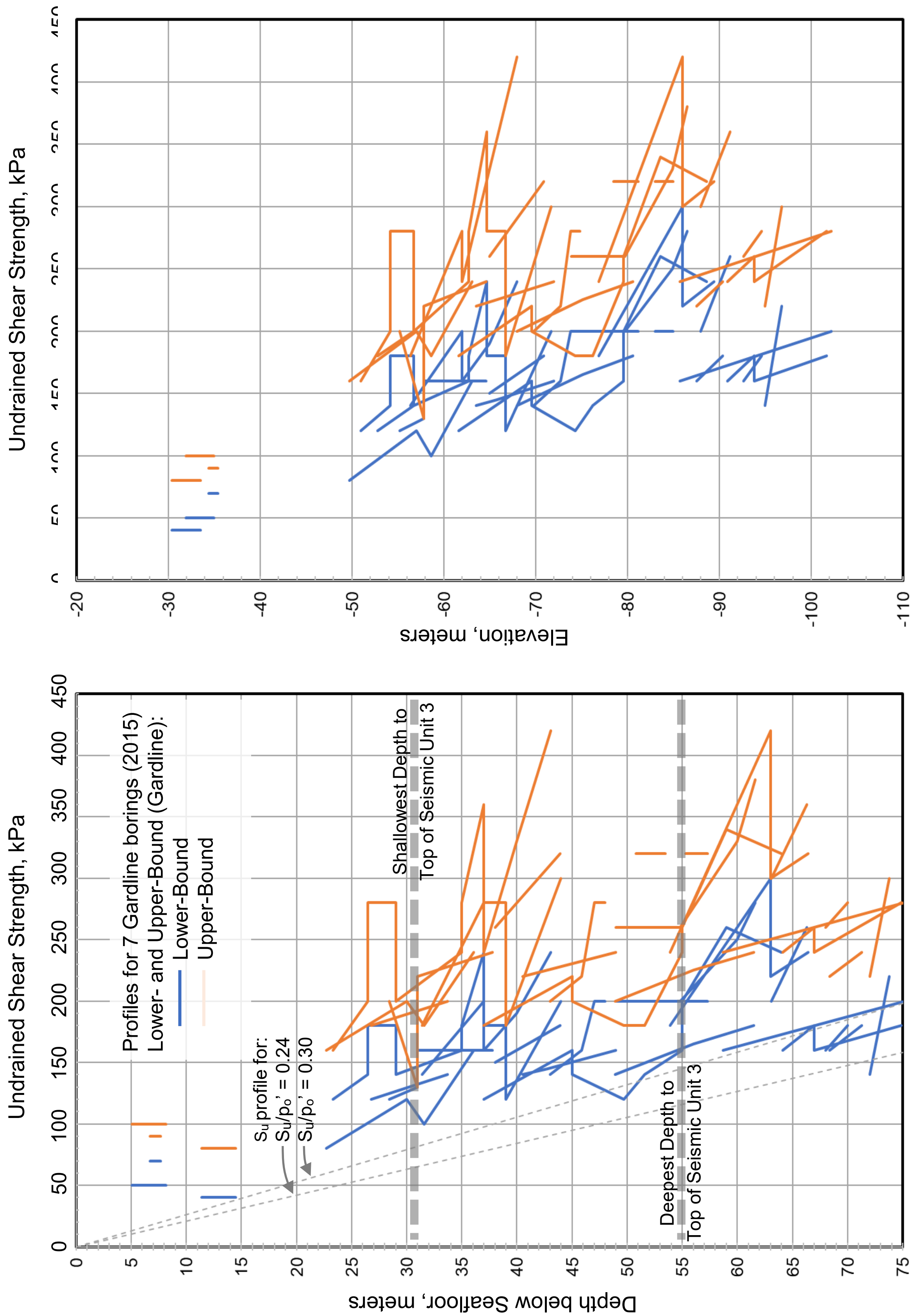


NOTE: Foundation Designer should verify that the different combinations of water depth, stratigraphy, and soil parameters as defined for the Lower & Upper Bound Conditions combine to produce weakest/softest or strongest/stiffest responses as intended for their design-specific analyses - particularly at low overburden (low stress) conditions.

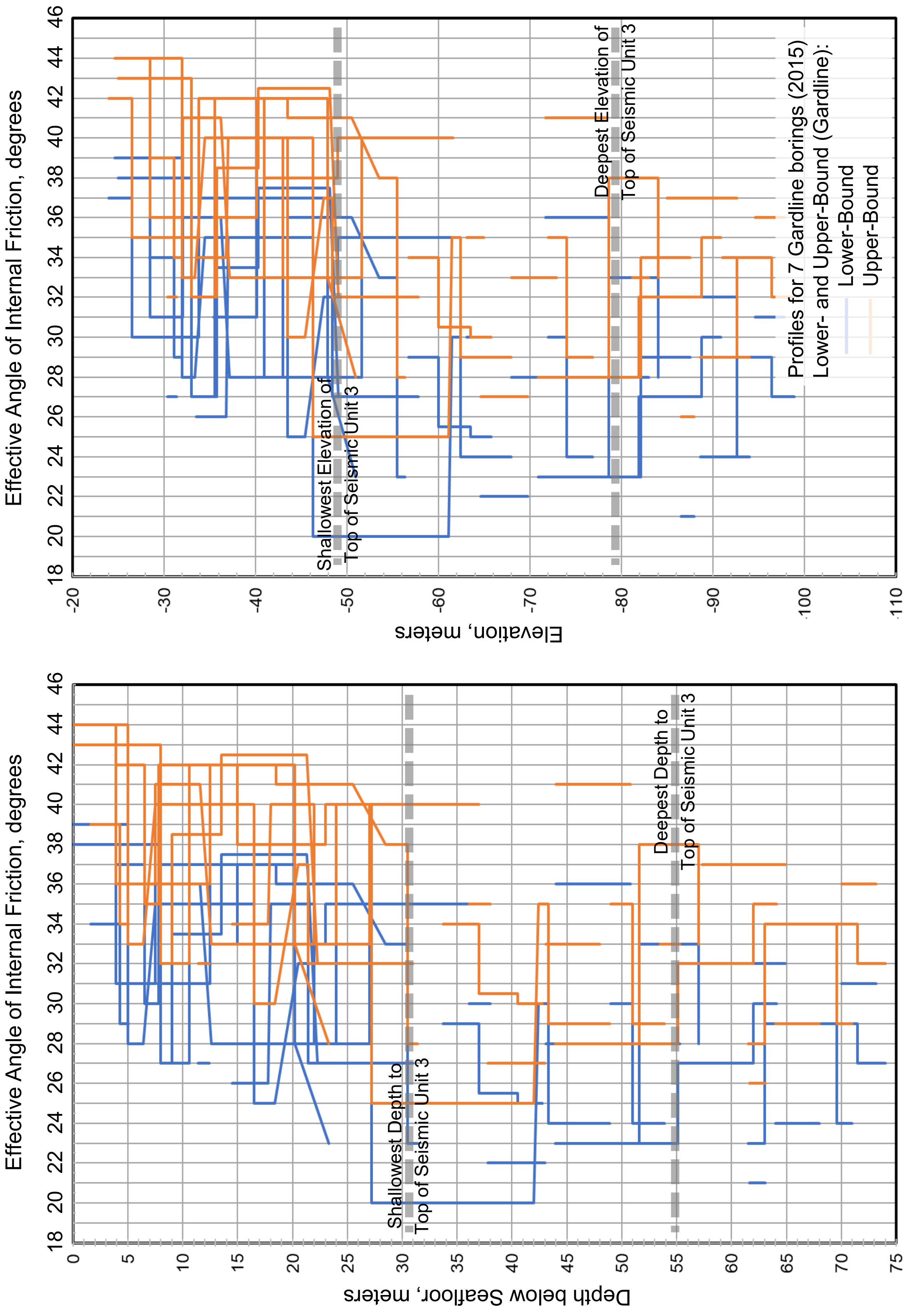
FORMULATION OF LOWER- AND UPPER-BOUND STRATA DEPTHS AND THICKNESSES
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Project



INTERPRETED SUBMERGED UNIT WEIGHT PROFILES
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Development



INTERPRETED UNDRAINDED SHEAR STRENGTH PROFILES
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Development



INTERPRETED EFFECTIVE ANGLE OF INTERNAL FRICTION PROFILES
Initial, Integrated G^G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Development

Global Pile Capacity - Stiffness Response Bounding Conditions
US Wind - Maryland OCS Offshore Wind Development

Upper Bound (Strongest and Stiffest) Stratigraphic Formulation
Option 1 Formulation - Assumes Location is on top of sand dune and outside of underlying Paleochannel

CBI-defined Unit	Pile Formulation Unit	Elevation	Depth	Material Type	Υ'	Su	ø	δ	β	Dr Range	fmax	Nq	qmax	p-y Formulation	
		meters	meters			kPA	degrees	degrees		%	kPa		MPa	Material Type	Reference
1	A	-18	0	Granular	11	-	35	30.0	0.46	65-85	96	40	10	dense sand	O'Neill (1983)
		-24	6			-									
Note - No Global or Local Scour is included in Upper Bound Stratigraphy															
2	B	-24	6	Granular	11	-	38	33.0	0.65	85-100	115	50	12	dense sand	O'Neill (1983)
		-38	20			-									
	C	-38	20	Cohesive	9.5	160	-				-	-	-	stiff clay	Reese et al. (1975)
		-46	28			200	-				-	-	-		
3	D	-46	28	Cohesive	9.5	240	-				-	-	-	stiff clay	Reese et al. (1975)
		-52	34			320	-				-	-	-		
	E	-52	34	Granular	10.5	-	35	30.0	0.46	65-85	96	40	10	dense sand	O'Neill (1983)
		-60	42			-									
	F	-60	42	Cohesive	9.5	240	-				-	-	-	stiff clay	Reese et al. (1975)
		-64	46			300	-				-	-	-		
	G	-64	46	Granular	10.5	-	35	30.0	0.46	65-85	96	40	10	dense sand	O'Neill (1983)
		-78	60			-									
	H	-78	60	Cohesive	9.5	300	-				-	-	-	stiff clay	Reese et al. (1975)
		-86	68			400	-				-	-	-		
	I	-86	68	Granular	10.5	-	35	30.0	0.46	65-85	96	40	10	dense sand	O'Neill (1983)
		-98	80			-									

NOTE: Upper Bound Stratigraphy is intended to represent the global best-case scenario representing the strongest and stiffest soil conditions.
The Upper Bound Stratigraphy is based on a location:
1) underlain by a sand ridge,
2) without an underlying paleochannel and
3) where the stratigraphic boundary between the paleochannel complex (Unit 2) and underlying semi-parallel, dipping strata (Unit 3) is relatively shallow.

UPPER-BOUND GLOBAL STRATIGRAPHY FORMULATION
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area

Figure 9-1

Global Pile Capacity - Stiffness Response Bounding Conditions
US Wind - Maryland OCS Offshore Wind Development

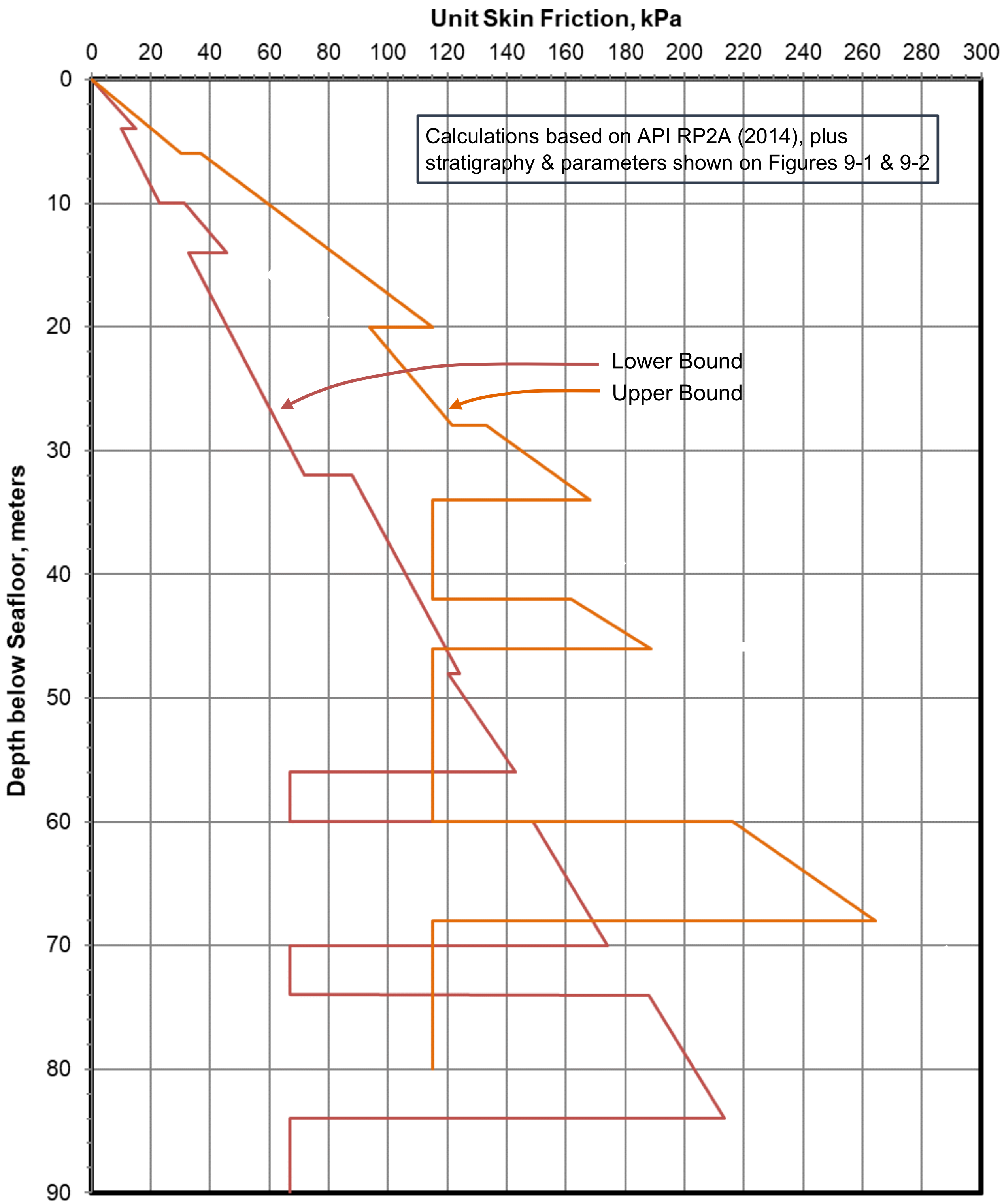
Lower Bound (Weakest and Softest) Stratigraphic Formulation
Option 1 Formulation - Assumes Location is in deepest water and overlies the center of a clay-filled paleochannel

CBI-defined Unit	Pile Formulati on Unit	Elevation	Depth	Material Type	ϒ'	Su	ø	δ	β	Dr Range	fmax	Nq	qmax	p-y Formulation	
		meters	meters		kN/m3	kPA	degrees	degrees		%	kPa		MPa	Material Type	Reference
1	A	-32	0	Granular	10	-	32	27.0	0.41	35-65	81	20	5	dense sand	O'Neill (1983)
		-33.5	1.5			-									
Note - Asssume 1.5-meters of local scour for Lower Bound Stratigraphy															
2	B	-33.5	1.5	Granular	10	-	30	25.0	0.37	35-65	81	20	5	dense sand	O'Neill (1983)
		-36	4			-									
	C	-36	4	Cohesive	7.5	10	-				-	-	-	soft clay	Jean Jean (2009)
		-42	10			25	-				-	-	-		
	D	-42	10	Granular	9.5	-	30	25.0	0.37	35-65	81	20	5	dense sand	O'Neill (1983)
		-46	14			-									
	E	-46	14	Cohesive	7.5	35					-	-	-	soft clay	Jean Jean (2009)
		-74	32			80					-	-	-		
	F	-74	32	Cohesive	8	120					-	-	-	stiff clay	Reese et al. (1975)
		-90	48			160					-	-	-		
3	G	-80	48	Cohesive	8.5	150	-				-	-	-	stiff clay	Reese et al. (1975)
		-88	56			180	-				-	-	-		
	H	-88	56	Granular	9.5	-	30	25.0	0.29	35-65	67	12	3	dense sand	O'Neill (1983)
		-92	60			-									
	I	-92	60	Cohesive	8.5	180	-				-	-	-	stiff clay	Reese et al. (1975)
		-102	70			210	-				-	-	-		
	J	-102	70	Granular	9.5	-	30	25.0	0.29	35-65	67	12	3	dense sand	O'Neill (1983)
		-106	74			-									
	K	-106	74	Cohesive	8.5	230	-				-	-	-	stiff clay	Reese et al. (1975)
		-116	84			260	-				-	-	-		
	L	-116	84	Granular	9.5	-	30	25.0	0.29	35-65	67	12	3	dense sand	O'Neill (1983)
		-122	90			-									

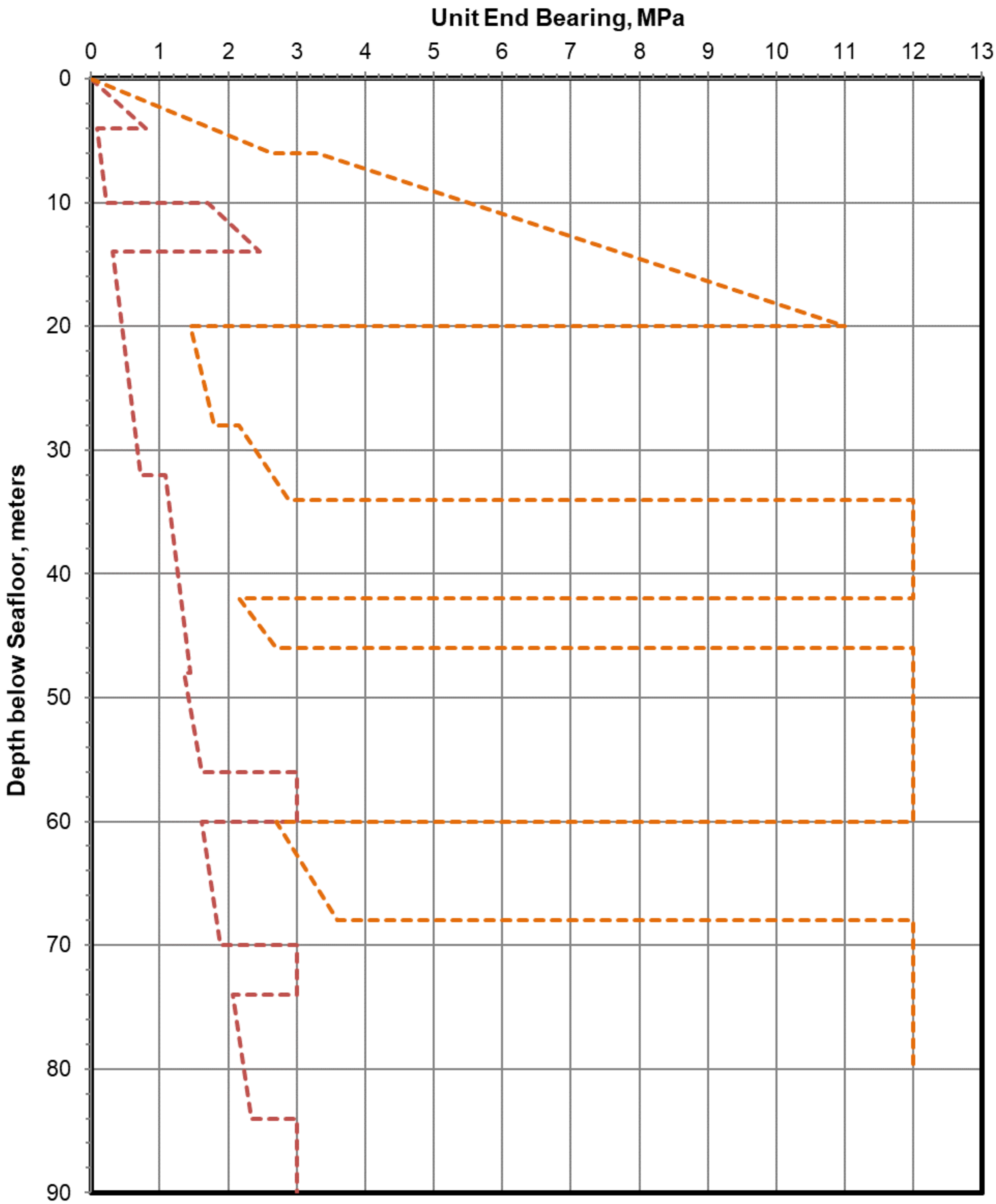
NOTE: Lower Bound Stratigraphy is intended to represent the global worst-case scenario representing the weakest and softest soil conditions.
The Lower Bound Stratigraphy is based on a location:

1) not underlain by a sand ridge,
2) with a thick, underlying paleochannel and
3) where the stratigraphic boundary between the paleochannel complex (Unit 2) and underlying semi-parallel, dipping strata (Unit 3) is relatively deep.

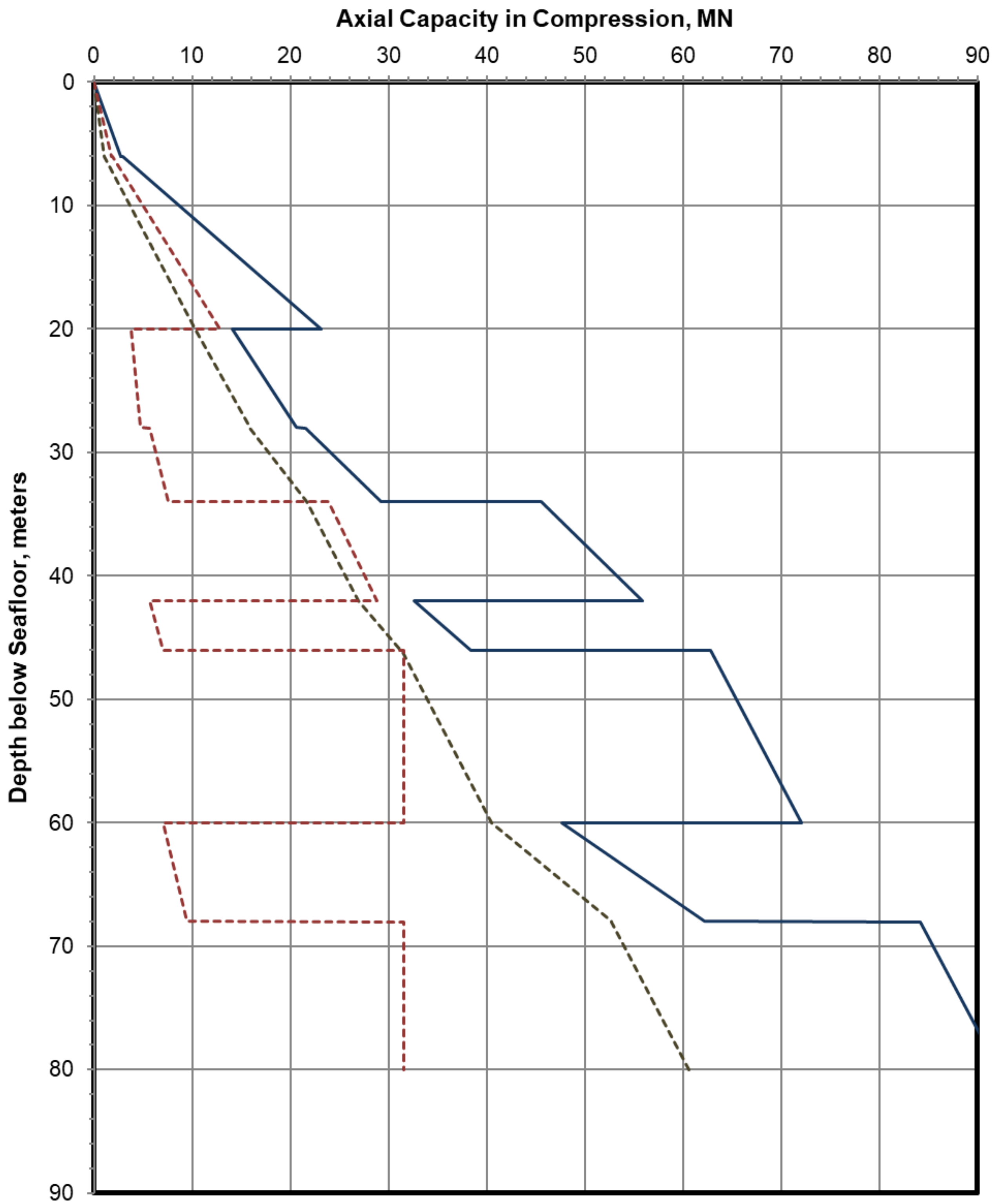
LOWER-BOUND GLOBAL STRATIGRAPHY FORMULATION
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area



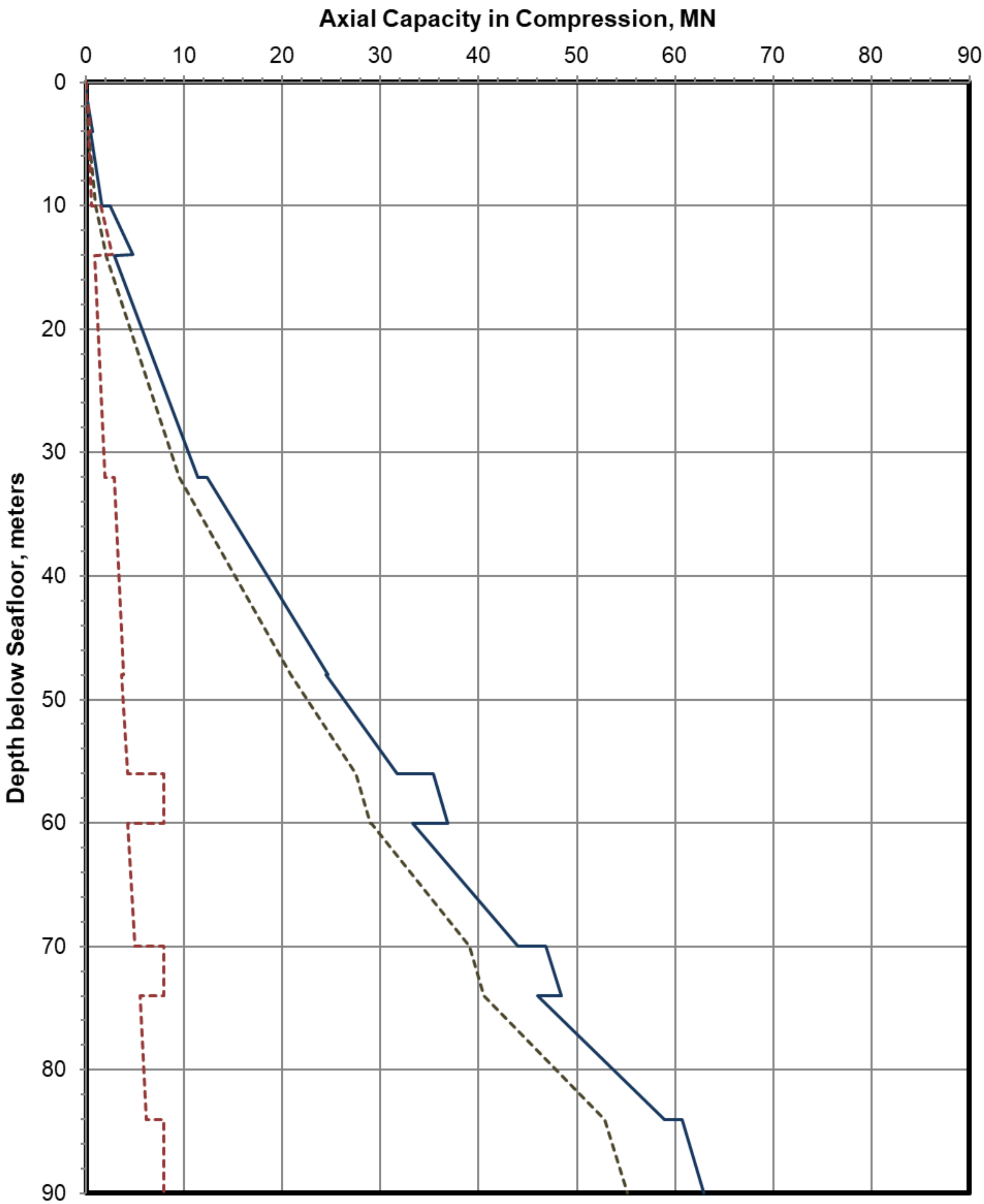
ULTIMATE AXIAL PILE CAPACITY – UNIT SKIN FRICTION
Global Upper- & Lower-Bound Conditions
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area



ULTIMATE AXIAL PILE CAPACITY – UNIT END BEARING
Global Upper- & Lower-Bound Conditions
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area

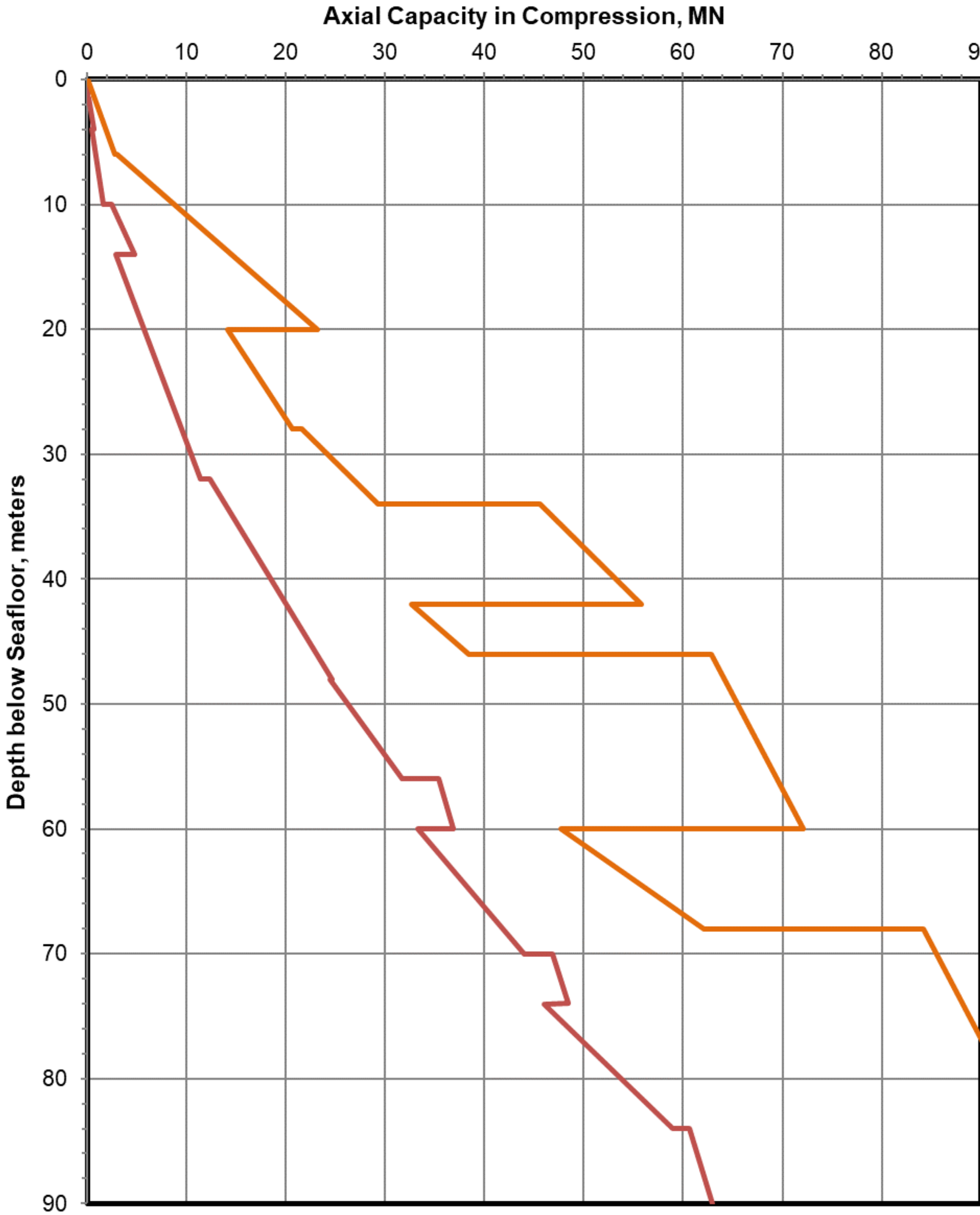


ULTIMATE AXIAL PILE CAPACITY – GLOBAL UPPER-BOUND CONDITIONS
1.83-meter-diameter, Driven, Steel-Pipe Pile
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area



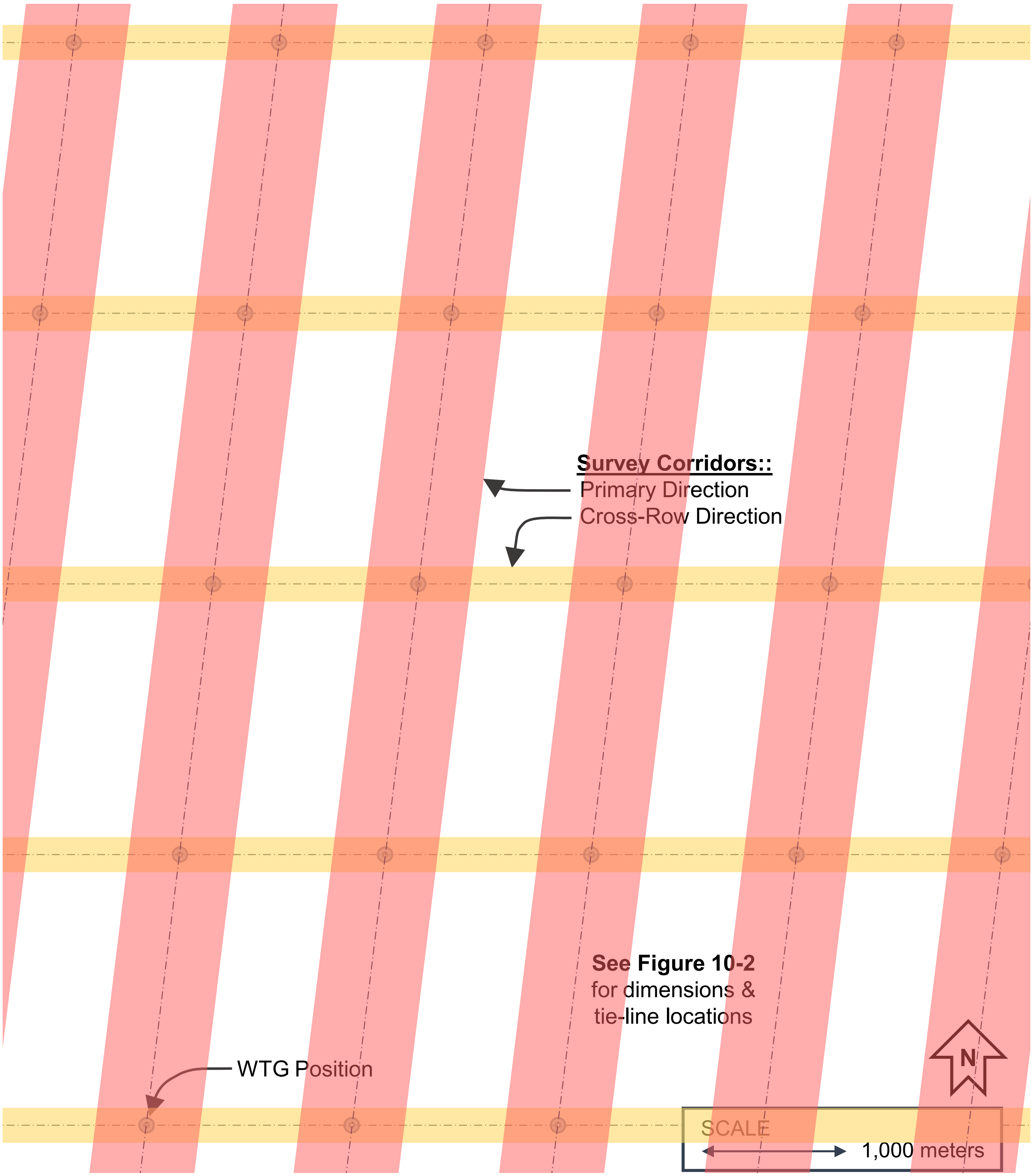
ULTIMATE AXIAL PILE CAPACITY – GLOBAL LOWER-BOUND CONDITIONS
1.83-meter-diameter, Driven, Steel-Pipe Pile
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area

Figure 9-6

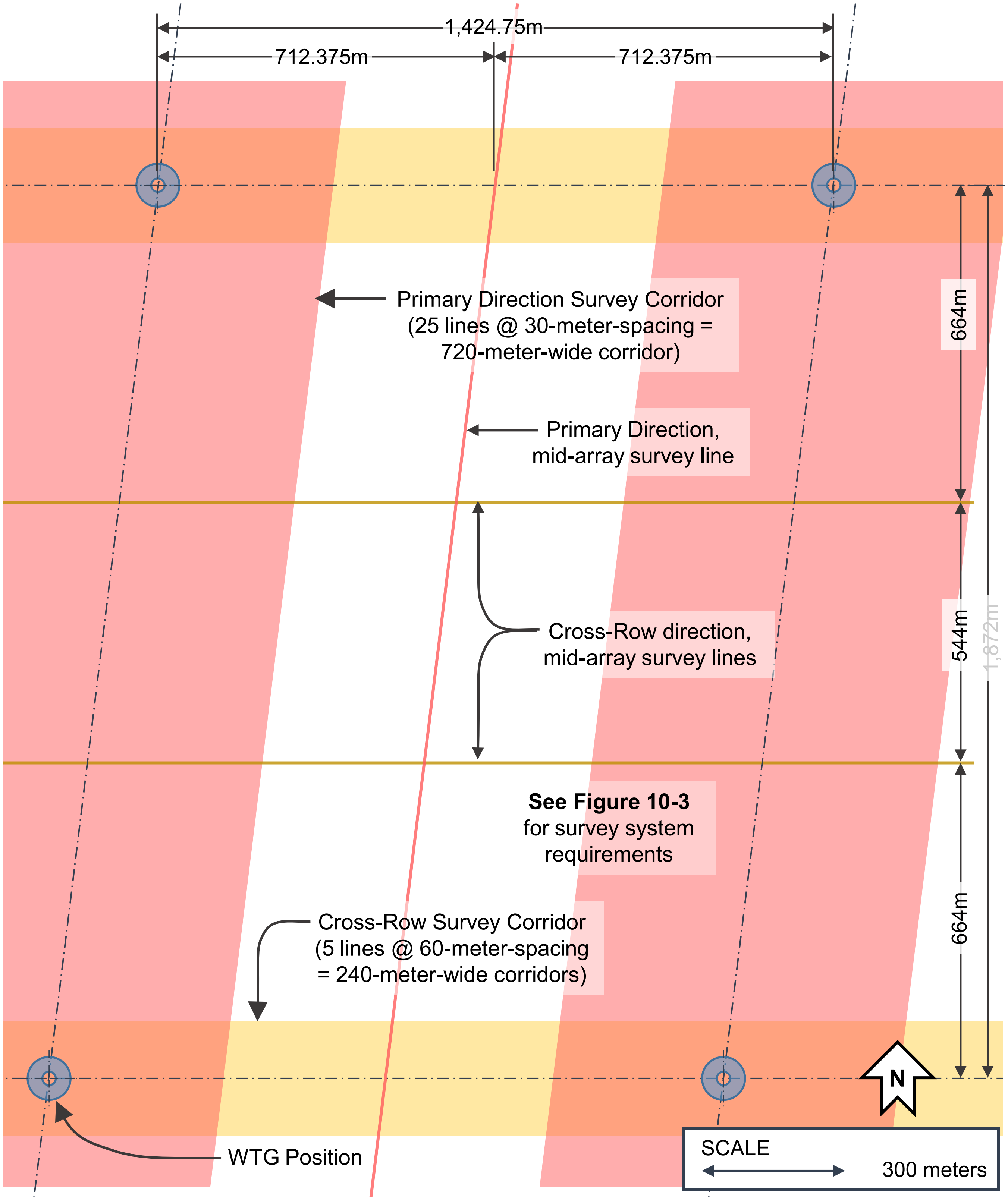


COMPARISON OF GLOBAL LOWER- & UPPER-BOUND AXAL PILE CAPACITY
1.83-meter-diameter, Driven, Steel-Pipe Pile
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area

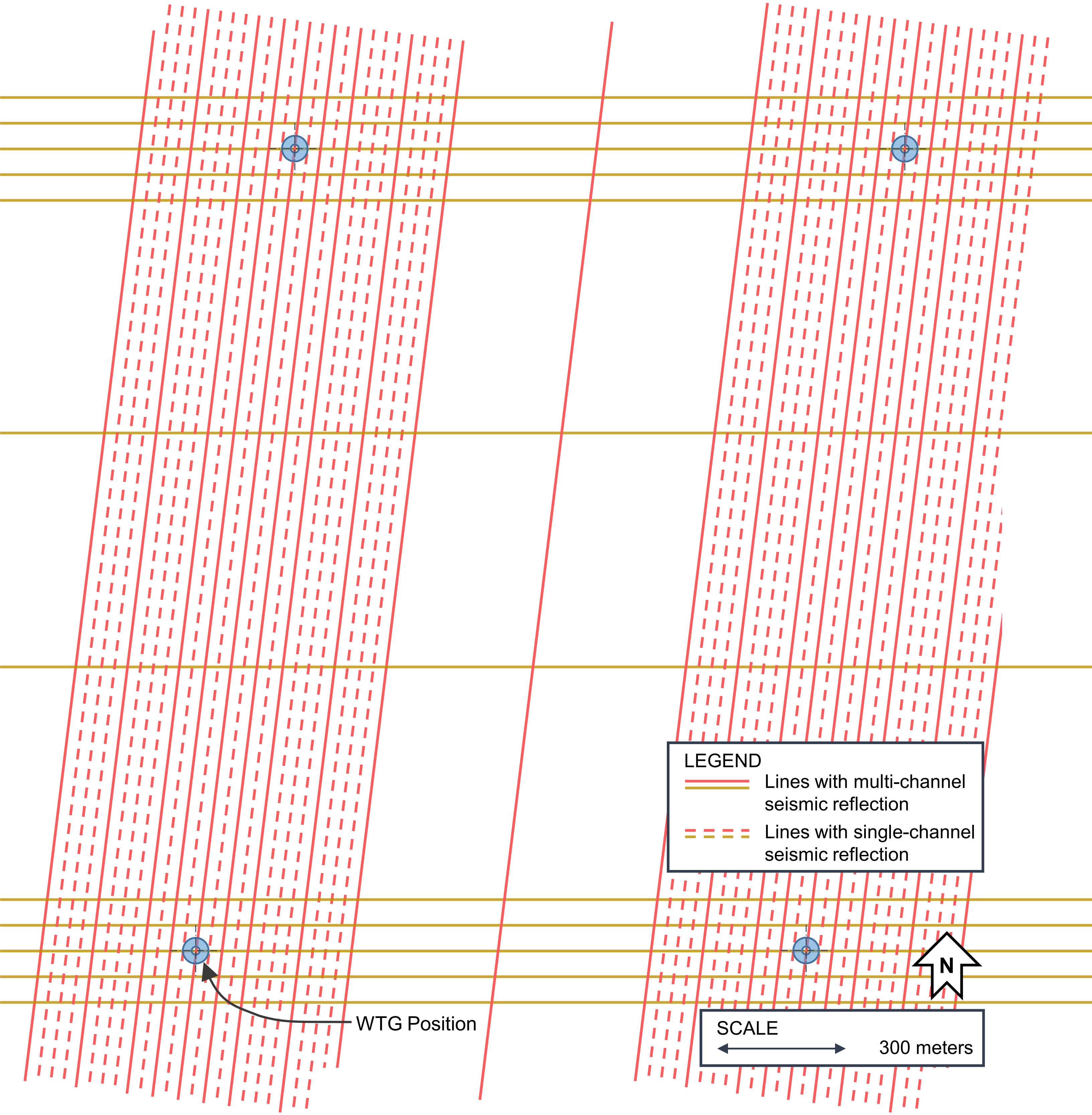
Figure 9-7



Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area



COP-PHASE HRG SURVEY TARTAN SURVEY CORRIDOR DETAIL
Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area



Initial, Integrated G&G Site Characterization Report
US Wind – Maryland OCS Offshore Wind Energy Area

Figure 10-3