UNITED STATES DEPARTMENT OF THE INTERIOR

Bureau of Ocean Energy Management, Office of Renewable Energy Programs

July 2, 2015

Guidelines for Providing Geophysical, Geotechnical, and Geohazard Information Pursuant to 30 CFR Part 585

Introduction

The U.S. Department of the Interior, Bureau of Ocean Energy Management (BOEM) requires developer to submit a Site Assessment Plan (SAP), Construction and Operations Plan (COP), or General Activities Plan (GAP), (collectively referred to as 'Plans' in these guidelines) for review and approval prior to the installation of any renewable energy facility, structure or cable proposed on the Outer Continental Shelf (OCS). BOEM regulations require a developer to include the results of site characterization surveys, with supporting data, as part of a Plan in order to evaluate the impact of seafloor and sub-seafloor conditions on the installation, operation, and structural integrity of a proposed project.

The following guidelines provide recommendations for acquiring the geophysical, geotechnical, and geohazard information necessary for BOEM to conduct a technical and environmental review of an applicant's Plan. Appendix B of these guidelines outlines BOEM's preferred format for receiving the results of the site characterization activities.

These guidelines have been and will continue to be updated periodically as new information or methodologies become available. This version replaces the guidance previously published November 9, 2012. The updates in these guidelines include purpose-driven recommendations for geophysical surveys and geotechnical investigations, additional recommendations for data acquisition instrumentation, and more detailed information about Site Characterization Report formatting, content, and deliverables.

The Archeological Survey Guidelines, previously included with the Geophysical, Geotechnical, and Geohazard Guidelines, have been separated into a standalone document named Guidelines for Providing Archaeological and Historic Property Information Pursuant to 30 CFR Part 585. Archeological survey data are high resolution than data collected to identify 1) historic period sites, such as shipwrecks and associated remains, sunken aircraft, and other maritime infrastructure; and (2) pre-contact archaeological sites once part of the terrestrial landscape and since inundated by global sea level rise during the late Pleistocene and Holocene. Archeological surveys may therefore necessitate different equipment choices or survey design to achieve their intended purpose of cultural resource identification.

Authority and Regulations

BOEM's renewable energy regulations for the submission of SAPs (30 CFR § 585.610(b)), COPs (30 CFR § 585.626(a)), and GAPs (30 CFR § 585.645(a)) require lessees and grantees to submit the results of geological and geotechnical surveys. It is also a requirement that Plans submitted to BOEM describe shallow hazards, geological conditions, geotechnical characteristics, and overall site investigation results, and information pertinent to archaeological resources that could be affected by the activities proposed in SAPs (30 CFR 585.611(a); 30 CFR § 585.611 (b)(1); 30 CFR § 585.611(b)(6)), COPs (30 CFR § 585.627(a)(1); 30 CFR § 585.627(a)(6)), and GAPs (30 CFR § 585.646(a); 30 CFR § 585.6.46(f)).

BOEM recommends following these guidelines to produce data of the quality necessary to characterize geotechnical and geological conditions and to identify hazardous features. Should BOEM determine that the results of the surveys provided in a Plan are insufficient, BOEM may request the applicant provide additional information. If an applicant fails to provide the requested information as required by 30 CFR Part 585, BOEM may disapprove a SAP (30 CFR § 585.613(d)), COP (30 CFR § 585.628(e)), or GAP (30 CFR § 585.648(d)).

Elements of these guidelines may be required under the terms and conditions of a specific lease. A lease may also have requirements different from those discussed in these guidelines. Lessees should note that while these guidelines and conditions in their lease(s) may be similar, lessees must comply with the terms of their lease(s).

I. Site Characterization Investigation Overview

Site characterization investigations should consist of a number of phases where the preceding phase informs the following phase. Site characterization should include the following activities: desktop studies, seabed exploration, laboratory testing of collected sediment samples, evaluation and assessment of geotechnical engineering properties, and documentation of the results in a written report.

BOEM strongly recommends that applicants undertake their geotechnical exploration efforts after the geophysical survey has been completed and the data has been analyzed because geotechnical investigation parameters should be influenced by the findings of the geophysical investigation.

The resulting site characterization report(s) should include site-specific information on: geohazards, anthropogenic hazards, slope stability, seabed topography and morphology, rock outcrops and boulders, subcropping rock and buried boulders, bedforms, scour, soil type, stratigraphy, sediment variability, soil strength, deformation and consolidation, and information of specific factors such as cyclic loading and soil sensitivity. Regional information on seismology, volcanic activity, slope stability, and the presence of shallow gas or gas hydrates should also be included in the site characterization report(s).

Applicants are encouraged to use the following documents for additional guidance in performing site characterization activities (see Section VIII):

- Geotechnical & Geophysical Investigations for Offshore and Nearshore Developments, International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE), September 2005
- Marine Soil Investigations, NORSOK Standard G-001, October 2004
- Recommended Practice DNV-RP-J301, Subsea Power Cables in Shallow Water Renewable Energy Application, DNV, 2014
- Standard for Geotechnical Site and Route Surveys, Minimum Requirements for the Foundation of Offshore Wind Turbines, BSH, 2003
- International Hydrographic Organization, IHO Standards for Hydrographic Surveys, Special Publication N° 44, 2008
- International Cable Protection Committee (ICPC) Recommendations 1 through 14
- ASTM D2488 Standard Practice for Description and Identification of Soils (Unified Soil Classification System), Book of Standards, v04.08
- ASTM D2487 Standard Practice for Classification of Soil for Engineering Purposes, Book of Standards, v04.08

The BOEM guidelines (presented here) take precedence over the above documents in case of conflict.

II. IV. Pre-Survey Coordination with BOEM

Lessees and applicants should coordinate with BOEM prior to the initiation of survey activities through both the preparation of a survey plan and a pre-survey meeting. This coordination assists in ensuring that surveys are designed and conducted in a manner that is likely to provide the information required for BOEM to review a plan. This coordination serves as an opportunity to address potential historic preservation issues or concerns well in advance of the date an applicant intends to mobilize for a survey.

Pre-Survey coordination may include, but is not limited to, discussions regarding:

- the scope and purpose of the survey
- survey logistics (proposed survey area, dates, times, etc.)
- data to be acquired
- field techniques and equipment (specifications of data acquisition systems)
- new types of technology or alternative survey methods
- data processing and analysis
- data and information to be submitted
- maximum expected extent of bottom-disturbing activities (horizontal and vertical extents, types of activities contributing to bottom-disturbance, etc.)
- site-specific considerations

III. High-Resolution Geophysical Survey

BOEM will review the results of High-Resolution Geophysical (HRG) survey for the information it provides on seafloor and sub-surface conditions as they pertain to the proposed projects' siting, design, construction, and operation. There are a number of factors to consider when planning a HRG survey, including but not limited to: water depths, coverage, seismic penetration depth, site conditions, resolution, and ground truthing techniques.

A. Survey Coverage

The area surveyed should be sufficient to encompass a full sea floor search of the project area that may be affected by the activities proposed in the Plan, including all seafloor-disturbing activities. These activities may include, but are not limited to geotechnical exploration (e.g., borings, vibracores, etc.), construction activities, installations (e.g., facilities, cable arrays, transmission cables, etc.), decommissioning, and any other associated anchoring mechanisms or appurtenances.

BOEM recommends that the survey area be as large as practical in cases where uncertainty exists regarding proposed project locations or methodologies. A larger survey area will give the applicant greater flexibility for placement of structures and methods of construction, operation, maintenance, and decommissioning in the future.

The applicant should conduct the HRG survey along a series of regularly spaced and parallel track lines. Tie-lines running perpendicular to the track lines should also be surveyed. The survey grid should be oriented with respect to the bathymetry, geologic structure, cable corridor, and proposed renewable energy structure locations, whenever possible.

Survey line spacing is dependent upon a variety of factors including water depth, equipment employed, and the desired resolution of the survey data. BOEM recommends different minimum line spacing based on the project area and goals of the survey. In some instances, tighter line spacing may be necessary to acquire the appropriate level of coverage and data quality.

1. *Project siting survey*

The project siting survey includes the area outside the transmission cable route, typically inside the leased area, that will experience bottom-disturbing activity related to the following activities:

- geotechnical exploration
- installation of data collection structures (e.g., meteorological towers or buoys or other site assessment equipment)
- the installation of renewable energy generators and any associated equipment and structures
- inter-array cable installation
- any other project-related activities that have the potential to impact the seafloor

The survey area should provide coverage of the entire area that could be physically disturbed by the proposed activity. The area of physical disturbance includes the installation site and sufficient surrounding area to account for anchors or any other equipment that may disturb the seafloor during activities.

Line spacing for hazard assessment and site characterization HRG surveys should not exceed a primary line spacing of 150 m throughout the project area. BOEM recommends a grid survey pattern in this area with a maximum tie line spacing of 500 m.

2. *Transmission Corridor Survey*

The transmission corridor runs within the project easement that connects the onshore facilities to the siting area. The survey should cover the entire area of physical disturbance, including areas where lay barge anchors may be placed during cable installation. These guidelines refer to the portion of the project easement located on the OCS, if a transmission corridor passes through state or territory waters it will be subject to the applicable state or territory regulations.

The survey pattern along the transmission route should consist of a survey line run along the proposed cable route centerline, and offset parallel lines on either side with a maximum line spacing of 150 m. A minimum of two offset parallel lines are recommended, however the ultimate number of offset parallel lines may be increased to provide sufficient coverage of the entire area that could be physically disturbed by installation activities.

The survey corridor width can vary with water depth, increasing in width as the seabed deepens. BOEM recommends a minimum corridor width of 25 m from 0 to 20 m water depth, 50 m from 20 to 50 m water depth, 100 m for 50 to 100 m water depth, and 200 m for water depth greater than 100 m. If hazards or obstructions are identified during survey operations, it may be necessary to increase the width of the survey corridor or adjust the corridor path to allow for safe passage of the transmission lines.

Perpendicular tie-lines along the cable route should not exceed a line spacing of 500 m and a minimum of at least three equidistant tie-lines should be surveyed.

B. Data Acquisition Instrumentation

The instrumentation should be deployed in a manner that minimizes interference between systems, results in the least environmental impact practicable, and records all data at the optimal sampling rate of the equipment for the depth and sweep rates. All data recorders should interface with the navigation system to ensure proper integration of positioning information. All instruments should perform to the manufacturer's specifications, and all recorded data should be readable, accurate, and contain sufficient metadata.

1. Navigation and Positioning

The navigation system should continuously determine the surface position of the survey vessel. Uncertainty of the navigation system and quality control methods should conform to the requirements of Special Order Surveys as defined by the International Hydrographic Organization (IHO), (IHO Standards for Hydrographic Surveys, 2005). For special order surveys, the total allowable horizontal uncertainty at a 95% confidence level is 2 m. Position fixes should be digitally logged continuously along the vessel track. Geodesy information should be clearly presented and consistent across all data types.

BOEM recommends the use of a vessel-mounted acoustic positioning system, such as ultra-short baseline (USBL) positioning, to improve the reliability of positioning towed sensors. If a vessel-mounted acoustic positioning system is not used, layback distances should be calculated, recorded, and cross-checked with feature matching techniques to provide accurate positioning of towed sensors. Total horizontal uncertainty for equipment positioning should be better than 10 m.

2. Bathymetry

BOEM encourages the use of swath bathymetry systems to obtain full bathymetric data coverage of the project area. The system should be set to record with a sweep appropriate to the range of water depths expected and in a manner that ensures a full sea floor search. Data should be consistent with the IHO Special Order survey standards from 0 to 40 m water depths and with 1a survey standards beyond 40 m water depth (IHO Standards for Hydrographic Surveys, 2008). Applicants should also follow IHO hydrographic survey guidelines for quality control and data processing (IHO Standards for Hydrographic Surveys, 2008).

BOEM recommends the use of a system that can produce gridded data with resolution of at least 0.5 m in water depths shallower than 50 m and 1 m or better than 2% of water depth resolution in water depths beyond 50 m. Backscatter values from the seabed returns should also be logged and processed as appropriate.

To improve bathymetric data accuracy, the system should be calibrated and appropriate corrections applied to the data. A heave compensator should be used in conjunction with the system to remove the effects of vessel movement from the data. Water column sound velocity should be measured at regular intervals using a conductivity temperature depth (CTD) sensor or velocity probe capable of recording the maximum water depth expected in the survey area. Water depths should be corrected for vessel draft and tidal level and appropriately referenced to mean lower low water (MLLW).

Bathymetric light detection and ranging (LIDAR) methods are often used in areas with complex and rugged shorelines and provide seamless coverage between the land and sea. These systems are typically aircraft mounted and use two different frequencies of laser pulses to determine water depths and shoreline morphology. Depending on water clarity, LIDAR systems can be cost effective in extensive areas of shallow water, typically less than 30 m deep, where traditional survey methods are difficult and labor intensive. LIDAR has been successfully used to depths of 50 m in very clear waters.

3. *Magnetometer*

For HRG surveys conducted in water depths of 100 m or less, a magnetometer should be employed to detect ferrous metals or other magnetically susceptible materials. The magnetometer should be towed as near as possible to the seafloor, no more than 6 m above the seafloor, and in a way that minimizes interference from the vessel hull and the other survey instruments. A depth sensor or altimeter should be used to ensure the proper height of the magnetometer.

Magnetometer sensitivity should be 1.0 gamma (γ), or one nanotesla (nT), or less, and the data sampling interval should not exceed one second. Background noise level should not exceed 3 γ peak-to-peak. Magnetometer data should be recorded on a digital medium in such a way that the data can be linked electronically to the positioning and depth data. Annotate time, position, altitude, and recorder speed on all output data.

All pipeline and in-service cable crossing locations should be identified. If the cables are not observed in the bathymetric, side-scan sonar, or sub-bottom profiler data then BOEM recommends the use of a magnetometer to determine the precise location of the proposed cable crossing and in-service cable.

4. *Side-Scan Sonar*

Side-scan sonars provide an acoustic picture of the seabed by measuring the amplitude of the backscattered return signals. This backscattered photo-like image shows regions of enhanced acoustic reflectivity and absorption as well as acoustic shadows from objects with both positive and negative relief. Because the changes in acoustic backscatter are relative, it is necessary to calibrate the data by ground truthing or by collecting sediment samples from regions of different acoustic character.

BOEM recommends the use of a towed, dual-channel dual-frequency side-scan sonar system to provide continuous planimetric imagery of the seafloor in order to characterize seabed habitats and sediment distribution, locate surficial boulders, and identify anthropogenic hazards and cultural resources. To provide sufficient definition of features, BOEM encourages the use of a system that operates at as high a frequency as practical based on the factors of line spacing, instrument range, and water depth. Systems with operational ranges of 200 to 600 kHz frequency range are generally recommended for site characterization.

The survey line spacing and instrument range should be designed to provide at least 100% overlapping coverage in a manner that is capable of providing resolution of small, discrete targets 0.5 m to 1.0 m in diameter at maximum range. The side-scan sonar sensor should be towed above the seafloor at a distance that is 10% to 20% of the range of the instrument (Table 1).

Table 1: Side-scan Sonar Coverage Area.

Instrument Range	Height of Instrument above Seafloor at 10% of Range	Height of Instrument above Seafloor at 20% of Range
30 m/channel	3 m	6 m
50 m/channel	5 m	10 m
60 m/channel	6 m	12 m
75 m/channel	7.5 m	15 m
100 m/channel	10 m	20 m
200 m/channel	20 m	40 m

The data should be digitally recorded and visually displayed to monitor data quality and identify targets of interest during acquisition.

The data should be post-processed to improve data quality for interpretation and mapping. For example, adjusting for slant range effects and variable speed along line is appropriate. Both individual lines and mosaics should be output as 0.5 m resolution or better georeferenced images.

5. Sub-bottom Profilers

BOEM recommends collection of sedimentary structure data 10 m beyond the depth of disturbance. For example, penetration depths should be 10 m greater than the maximum depth of disturbance from a meteorological tower or wind turbine foundation, the maximum expected anchor/spud penetration for an anchored rig or work barge, or the depth of cable burial. BOEM recommends the collection of 0.3 m-resolution data in the upper 10 m of sediments. Depending on the regional geology, contractor expertise, and project design, there are a number of equipment choices and methodologies that can provide sufficient subsurface stratigraphy information.

It is important to note these systems rely on the interpretation of reflections from acoustic impedance changes that may or may not correlate to geologic formation boundaries. Often the acoustic impedance changes because of sedimentary variations but other factors such as consolidation, pore water, biologic colonies, and gas presence can affect the acoustic character or severely reduce penetration. Because the information on sediment characteristics gathered from sub-bottom profiles is more qualitative than quantitative, the data requires ground truthing, or calibration, from subsurface sediment samples such as cores or borings.

When choosing sub-bottom profiler systems, the applicant should be aware that the National Marine Fisheries Service (NMFS) currently considers sound levels above 160 dB re 1 µPa (RMS) to constitute Level B harassment under the Marine Mammal Protection Act. Sounds above 180 dB re 1 µPa (RMS) are considered Level A harassment. Thus, BOEM recommends that, where practicable, sound be kept below these levels.

Note that marine mammal monitoring plans are required by NMFS for sound levels above these thresholds. The Record of Decision for the Atlantic OCS Proposed Geological and Geophysical Activities Mid Atlantic and South Atlantic Planning Areas, Final Programmatic Environmental Impact Statement requires BOEM include specific mitigation measures for HRG activities undertaken for renewable energy development in the leases covering planning areas in the Mid Atlantic and South Atlantic.

i. High Frequency CHIRP Systems

High-frequency acoustic sub-bottom profiler data is recommended to determine the shallow sediment distribution, assess cable burial feasibility, and identify subsurface features. CHIRP systems provide continuous and very high-resolution data on subsurface geological features within the uppermost 10 to 15 m of sediment. The sub-bottom profiler system should be capable of achieving a resolution of vertical bed separation of at least 0.3 m in the uppermost sediments, depending on the substrate.

In regions where traditional sub-bottom profiler frequency ranges (2 to 16 kHz) achieve less than 10 m of penetration, BOEM recommends either reducing the frequency range of the system and/or the use of a lower frequency (0.5 to 12 kHz) system.

The data should be digitally recorded, allow signal processing to improve data quality and should allow the export of data to a workstation for integrated interpretation and mapping.

ii. Medium Penetration Seismic Systems

A medium penetration seismic system, such as a boomer, bubble pulser, or other low frequency system, can be used to provide information on sedimentary structure that exceeds the depth limitations of CHIRP systems. The system should be capable of penetrating greater than 10 m beyond any potential disturbance depth with a vertical resolution of at least 3 m. The seismic source should deliver a simple, stable, and repeatable signature that is near to minimum phase output with usable frequency content.

Based on the results of previous surveys conducted in support of offshore renewable energy projects, BOEM has found that multi-channel streamer systems generally provide the highest resolution data when using a 16- to 48-channel streamer system positioned less than 1 m from the sea surface system and a dual or triple plate source. The data should be processed to improve image quality by suppressing or removing multiples and enhancing the signal to noise ratio.

Applicants should be aware that acquisition and processing of shallow water multi-channel seismic data is highly technical and complex. Therefore, the collection of multi-channel data may or may not hold a strong advantage over single-channel systems depending on the survey objective, contractor expertise, project design, and site conditions.

Medium penetration seismic data should contain minimal data artifacts and minimal over printing of seabed multiples to allow for the identification of laterally continuous horizons 10 m beyond the maximum depth of disturbance.

6. *Seabed Sampling*

Seabed samples are required for a variety of reasons including: ground-truthing interpreted geophysical data, geotechnical investigations, benthic analysis, and archaeological interpretation. It is important to collect the samples in a manner that will provide sufficient information for all appropriate uses. It is recommended that the most stringent sampling guidelines be followed to ensure the samples are of sufficient quality to be used for all intended purposes. For site characterization, BOEM recommends following American Society for Testing and Materials (ASTM) soil classification system standards D2487 and D2488.

A major component of the geologic interpretation includes the description of the surficial and sub-surface sediments, thickness of the various sediment deposits, and identification of distinct horizons. Therefore, BOEM recommends the collection of the borings or vibracores as part of the geophysical survey effort for ground truthing the geophysical data. Sampling intervals and methodologies detailed in Section V of this report recommend one vibracore at each turbine location and at 1.0 km intervals along the transmission route. Additional grab samples collected as part of the benthic habitat survey should also be included in the site characterization report and used for interpretation of surficial sediment conditions. See the *Guidelines for Providing Benthic Habitat Survey Information for Renewable Energy Development on the Atlantic Outer Continental Shelf Pursuant to 30 CFR Part 585* for sampling methodology and requirements.

IV. Geotechnical Investigations

The scope of the geotechnical investigation should be based on the results of geophysical surveys, other previous investigations, and the proposed scope of the project—specifically, the proposed type of structures and foundations that will disturb the seabed. The results of the exploration should allow for a thorough investigation of the stratigraphic and geoengineering properties of the sediment that may affect the foundations or anchoring systems of the structures. There also should be sufficient geological and geotechnical sampling and testing of foundation sediments to thoroughly categorize engineering conditions within any proposed transmission cable corridor. Together with the geophysical surveys, the geotechnical investigations should allow for a thorough assessment of potential geohazards, such as faulting, liquefaction, submarine landslides and slumping, erosion and scour, and other hazards.

BOEM strongly recommends the geotechnical efforts be undertaken after the geophysical survey has been completed and the data has been analyzed because the geophysical data should highly influences the scope of the geotechnical investigation. For example, if in the survey area there are numerous geohazards or extensive heterogeneity, the geotechnical investigation may warrant additional sampling and analyses to identify the vertical and horizontal extent of geohazards and to characterize site conditions. Conversely, if an area is relatively free of hazards and homogeneous, minimal geotechnical investigations may be sufficient to characterize the site.

Geotechnical investigations may be performed in phases to provide the appropriate level of geotechnical design parameters and recommendations for the project as it progresses from preliminary to final design stage.

A. Geotechnical Exploration

A geotechnical exploration program should consist of a combination of drilling and sampling of the sediments using boring methods and in-situ methods such as cone penetrometer probes. The type of exploration method should be based on the anticipated sediment types and characteristics, as well as the proposed foundation, anchorage, or other structure types and dimensions.

The principal purposes of the exploration activities are to: (1) assess the suitability of sediments to support the renewable energy structure or associated transmission cable under all operational and environmental conditions; and (2) document soil characteristics necessary for design and installation of all structures and transmission cables.

An HRG survey should be conducted before geotechnical investigations, and the results of the survey should be used in planning the geotechnical exploration program, selecting locations and depths of soil samples, and avoiding benthic habitats and potential archaeological resources.

Jack-up platforms or specialized vessels with heave compensating systems should be used, depending on the water depth, ocean conditions, and type of exploration method. Seabed founded sampling devices or remote operated vehicles may also be appropriate, especially in deeper waters.

Geotechnical explorations should provide for:

- Adequate in-situ testing, boring, or sampling (i.e., cone penetrometer test (CPT), drilled borings, vibracores, etc.) at each foundation location and at 1.0 km intervals along the proposed transmission cable route to shore, and examination of all important sediment and rock strata to determine their strength classification, deformation properties, and dynamic characteristics.

- A sufficient number of “deep” borings (with soil sampling and testing) within the project area to determine the vertical and lateral variation in seabed conditions and to provide the relevant geotechnical data required for facility design. To be considered a “deep boring,” the soil boring depth should be at least 10 m deeper than the design penetration of the foundation.

For areas with highly variable subsea soil conditions, it may be appropriate to obtain a higher number of deep borings, possibly one at each turbine foundation location, to adequately characterize the stratigraphic and geoengineering properties for each foundation design.

Depending on the sediment and geologic conditions, it may be appropriate to use CPT probes instead of deep borings at selected locations.

In some cases, the number of borings or probes may be reduced if relatively uniform conditions are present. The depth of deep borings or CPT probes may be reduced if very dense sediment or bedrock is encountered before reaching the recommended depth.

There may also be conditions such as very soft or unstable sediments that warrant greater depths than recommended.

Any variation from the recommended number of borings or drilling depth should be adequately justified by the conditions encountered.

B. Laboratory Testing

Selected samples obtained from the borings should be subjected to laboratory testing to aid in classification and to allow determination of the geotechnical properties necessary for design, such as unit weight, grain size distribution, specific gravity, compressibility, density, shear strength, and dynamic properties for assessment of seismic and cyclic loading conditions.

The laboratory tests should be performed in accordance with ASTM standards, and the laboratory should maintain accreditation from the US Army Corps of Engineers, the American Association of State Highway and Transportation Officials Materials Reference Laboratory, or equivalent.

C. Geotechnical Engineering Analyses

Geotechnical investigations should be able to:

- Provide analysis of in-situ and laboratory soil test data to estimate foundation soil response to anticipated static and dynamic loads.
- Determine foundation embedment depth and predict susceptibility of the foundation to liquefaction and other geohazards.
- Evaluate the potential for seafloor erosion and scour in the context of empirically derived current velocity data for the project area.
- Integrate the results of the geotechnical and geophysical investigations to provide a comprehensive analysis of geologic hazards that may affect the site.

In some cases, the information gathered during geotechnical investigation for engineering or siting purposes may provide information that informs the archaeological investigation, even if not explicitly designed to do so. BOEM encourages applicants to coordinate with their qualified marine archaeologist during the planning for geotechnical testing and, to the extent possible, to incorporate the relevant results of geotechnical investigation into the archaeological analysis. This may include visual inspection of vibracores for the presence of intact paleosols, subsampling of organic materials for paleoenvironmental analysis, radiometric dating, or other applicable analyses. (See the *Guidelines for Providing Archaeological and Historic Property Information Pursuant to 30 CFR Part 585* for further details).

V. Contact Information

For further information or inquiries regarding these guidelines please contact the Office of Renewable Energy Programs at (703) 787-1300 or renewable_reporting@boem.gov.

VI. References

American Society for Testing and Materials, ASTM D2488 Standard Practice for Description and Identification of Soils (Unified Soil Classification System), Book of Standards, v04.08.

American Society for Testing and Materials, ASTM D2487 Standard Practice for Classification of Soil for Engineering Purposes, Book of Standards, v04.08.

Guidelines for Providing Benthic Habitat Survey Information for Renewable Energy Development on the Atlantic Outer Continental Shelf Pursuant to 30 CFR Part 585.

Geotechnical & Geophysical Investigations for Offshore and Nearshore Developments, International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE), September 2005.

International Cable Protection Committee (ICPC) Recommendations 1 through 14 (http://www.iscpc.org/).

International Hydrographic Organization, IHO Standards for Hydrographic Surveys, Special Publication N° 44, 2008 .

Marine Soil Investigations, NORSOK Standard G-001, October 2004

Recommended Practice DNV-RP-J301, Subsea Power Cables in Shallow Water Renewable Energy Application, DNV, 2014.

Standard for Geotechnical Site and Route Surveys, Minimum Requirements for the Foundation of Offshore Wind Turbines, BSH, 2003.

Appendix A
Best Management Practices for Site Characterization

The offshore renewable energy industry is only beginning to take shape in the United States of America. Often, lessees do not have experience planning or assessing geophysical survey plans and marine geotechnical investigations. These efforts require a vast amount of technical knowledge concerning hydrography, oceanography, geophysics, geology, and marine engineering. To help facilitate successful investigations BOEM would like to offer some recommended Best Management Practices to lessees for their site characterization activities.

I. Site Characterization Overview

Site characterization investigations should consist of a number of phases where the preceding phase informs the following phase. Each subsequent phase generally resolves finer details about the site and provides more specific information. Site characterization investigations should include the following activities: desktop studies, seabed exploration, laboratory testing of collected sediment samples, evaluation and assessment of geotechnical engineering properties, and documentation of the results in a written report.

BOEM recommends applicants investigate the relevance of a desktop study at the beginning of their project planning. Desktop studies review available site-specific information about general conditions, seismic activity, existing geotechnical and geophysical data, meteorological and oceanographic data, anthropogenic hazards (such as fishing methods and areas, cables, pipelines, lease blocks, and shipwrecks), identify marine sanctuaries and protected areas. Desktop studies can also reveal local, state, and federal regulations and required permitting processes. Data collected during desktop studies may identify potential obstacles to project success, inform the applicant about regional site conditions, and help guide survey equipment choices and design.

Site reconnaissance surveys can be helpful between the desktop study and site characterization phase because they typically collect lower resolution data, at greater line spacing thus requiring less financial investment and provide information to assist planning the geophysical and geotechnical investigations.

The geophysical survey should be tailored to the site-specific conditions, risks, and hazards identified in the desktop study. When applicants design their survey and make equipment choices based on anticipated site conditions they can collect higher quality data, reduce redundancy, and more efficiently use vessel time. Such research may generate information that reduces data processing, interpretation, and analysis efforts.

BOEM strongly recommends that geotechnical exploration efforts are undertaken after the geophysical survey has been completed and the data has been analyzed because geotechnical investigation parameters should be heavily influenced by the findings of the geophysical investigation. Observed heterogeneity and anticipated sediment conditions combine with project specific requirements to determine the appropriate geotechnical exploration methodology and spatial distribution for adequate site characterization. The data from the desktop study, geophysical survey, and geotechnical investigations combine to inform the applicant and BOEM about site conditions and geohazards in the project area.

The resulting site characterization report should include site-specific information on: geohazards, anthropogenic hazards, slope stability, seabed topography and morphology, rock outcrops and boulders, subcropping rock and buried boulders, bedforms, scour, soil type, stratigraphy, sediment variability, soil strength, deformation and consolidation, and information of specific factors such as cyclic loading and soil sensitivity. Regional hazards information should also be presented in the site characterization report on topics such as: seismology, volcanic activity, slope stability, and the presence of shallow gas or gas hydrates.

Geophysical and geotechnical investigations are highly specailzed and each project and situation is different. Therefore, BOEM reviews survey plans on a case-by-case basis to ensure the highest likelihood of achieving the data quality recommendations.

Applicants are encouraged to use the following documents for additional guidance in performing site characterization surveys and activities (see Section VIII):

- Geotechnical & Geophysical Investigations for Offshore and Nearshore Developments, International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE), September 2005
- Marine Soil Investigations, NORSOK Standard G-001, October 2004
- Recommended Practice DNV-RP-J301, Subsea Power Cables in Shallow Water Renewable Energy Application, DNV, 2014
- Standard for Geotechnical Site and Route Surveys, Minimum Requirements for the Foundation of Offshore Wind Turbines, BSH, 2003
- International Hydrographic Organization, IHO Standards for Hydrographic Surveys, Special Publication N° 44, 2005
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II. HRG Surveys

BOEM recommends designing HRG surveys around the survey purpose and the proposed end use of collected data. The purpose of renewable energy HRG surveys can range from site reconnaissance, site characterization, environmental assessment, or cultural resource identification.

Although BOEM does not have any specific recommendations for site reconnaissance surveys, if an applicant would like to use data collected for site reconnaissance, as part of a phased survey approach, BOEM recommends following these guidelines regarding data quality:

1. Site reconnaissance surveys are typically performed with larger line spacing and less coverage than recommended in the guidelines therefore, depending on the data, infill is often necessary to provide sufficient information to generate an acceptable site characterization report.

2. Equipment choices appropriate for site reconnaissance typically provide broader coverage and less resolution. Therefore, the data generated may not provide resolutions discussed in these guidelines and may not be sufficient for site characterization.

3. The lessee should keep in mind the amount of time that occurs between the reconnaissance survey and the site characterization survey. The seabed is a dynamic environment, and if a long period of time passes between survey efforts, the resulting data set may not be sufficient to support a Plan.

Site characterization surveys typically include both a transmission route survey and a project siting survey. Depending on the project and site conditions, BOEM may have different recommendations regarding equipment and survey design for the project siting and transmission route surveys. Line spacing and survey design should be site specific and discussed as part of the pre-survey coordination. The information included in these guidelines only provides generalized, minimum recommendations.

BOEM also recommends that an applicant representative who is knowledgeable of survey operations, data acquisition techniques, installation requirements, and BOEM regulations be present during survey operations to oversee field activities, verify data quality, and provide real time assurance of adequate site conditions. Surface and subsurface hazards can require cable route or project siting changes, and it is often more efficient to make these determinations during survey operations to avoid additional survey and mobilization efforts.

III. Geotechnical Investigations

In order to meet the requirements for a COP, the geotechnical investigation needs to provide the required level of subsurface information for each planned structure that is founded in the seafloor. Therefore the location and approximate dimensions of the proposed structure foundations must be determined beforehand, typically based on the results of a desktop study and geophysical surveys. If these are insufficient, some preliminary borings may be helpful in determining the preliminary turbine layout and design.

For monopile foundations, there may be economic benefits to designing each monopile independently based on specific subsurface conditions rather than using designs for multiple locations based on worst case conditions. This should be considered in determining the number of deep borings.

The type of foundation will affect the scope of the geotechnical investigation. Monopiles are typically governed by lateral capacities and the damping characteristics of the sediments, while jacket or tripod foundations will be governed by vertical capacities. Anchors for floating structures are designed primarily on type and shear strength of the sediments. Limited on board laboratory tests and preliminary pile design calculations during exploration can help direct the final scope of the exploration to make sure it is sufficient.

Geotechnical investigations should include pile driving feasibility studies, especially in dense sandy or gravelly sediments. Noise mitigation requirements for large pile driving hammers are becoming more important as larger foundations require hammers with greater energy. Ongoing research on long term cyclic loading effects on foundations may result in revisions to current pile capacity analyses and should be closely followed and utilized when appropriate.

IV. Site Characterization Report and Deliverables

The lessee should present the overall site investigation and supporting data in a complete and comprehensive site characterization report. The overall site investigation results include the integration of surface and subsurface geophysical data, geotechnical investigation results, geohazards survey results, geological survey results, and any other relevant information used to characterize the area.

The lessee should make their best effort to avoid numerous revisions and supplemental data submittals. If additional data is collected for site characterization after the submittal of a site characterization report, the main body of the report should be updated to include new data and/or analysis, all affected figures and charts should be updated, and a new revised document should be submitted to BOEM.

One of the best methodologies for review and analysis of geophysical and geotechnical data is a 3-D geologic model. A 3-D geologic model brings together bathymetric data, surficial data imagery, sub-bottom data imagery, and sediment samples and provides the viewer with an opportunity to see all the data in a single space. This technique can improve understanding and reduce the time and effort to review site characterization conclusions and analysis.

Appendix B
Site Characterization Survey Report Guidance

The applicant must submit one paper copy and one electronic version of the plan or application (§ 585.607; § 585.622(a); § 585.642(a)). For the digital report, applicants should provide Adobe PDF versions of all large format map layouts. A digital version of the report should be submitted on a compact disc (CD), digital video disc (DVD), or external hard drive. All data submitted by the applicant is expected to contain comprehensive metadata compatible with IHO survey standards as appropriate.

Applicants are encouraged to provide the results of the overall site characterization activities in a report containing the following:

1. Description of Surveyed Area OCS lease number(s), block number(s), and lease area(s); and minimum and maximum water depths of the survey area.

2. Reproducible (photocopy) geographic area map (generally page size = 8.5” x 11” and/or 11” x 17” fold-out), showing proposed facility and any transmission cable route relative to nearby geographic features.

3. Personnel list noting functional responsibilities. A list of the individuals involved in survey planning, fieldwork, and report preparation, and a brief description of their duties.

4. A summary of field operations, including unusual incident

5. Technical specifications of survey equipment and procedures:

- A brief description of the navigation system with a statement of its estimated accuracy for the surveyed area.
- A brief description of survey instrumentation including scale and sensitivity settings, sampling rates, and tow heights above the seafloor for the magnetometer and side scan sonar sensors.
- A diagram of the survey vessel, including its size, sensor configuration, navigation antenna location, cable lengths, and all offsets in X, Y, and Z directions from sensors to navigation antenna and/or the central reference point.
- Vessel speed, course changes, sea state, and weather conditions.
- A complete copy of the daily survey operations log (for the entire duration of the mobilization(s) and for each system used in the survey(s)).
- A description of survey procedures, including a statement of survey and record quality, a comparison of data from survey line crossings, and a discussion of any problems that may have affected the ability of the geophysicist or geologist to identify and analyze hazards in the surveyed area.

- Interpreted sample of each instrument record.

6. Route Position List

Transmission cable route provided as a Route Position List (RPL) in tabular format and in GIS shapefile format. The RPL and GIS formats should include information regarding installation or changes along the route (cable armoring, burial depths, alter courses where the cable changes direction including turn angle, cable crossings, etc.).

Applicants should provide a copy of the post survey planned RPL in MS Excel compatible tabular format and in accordance with ICPC Recommendation 11. Typically the header will include the following: system name, segment names, cable owners, RPL owner, RPL status, version number, issue date, datum, ellipsoid, depth units, vertical datum, and burial depth units. The body of the RPL will include the following items:

- Event number
- Event label
- As laid date
- Latitude degrees
- Latitude minutes
- Latitude direction
- Longitude degrees
- Longitude minutes
- Longitude direction
- Water depth
- Route distance
- Cumulative route distance
- Slack
- Cable distance
- Cumulative cable distance
- Cable type
- Burial depth

Events can include the following:

- Beach man hole (BMH)
- Alter course positions (A/C)
- Proposed WTG locations
- Any changes in cable protection or engineering design
- All cable and pipeline crossings and crossing angles

- Entry and exit positions for United Nations Law of the Sea and United States of America federally recognized waters including State Waters, Territorial Waters, Contiguous Zones and Exclusive Economic Zones.
- Entry and exit positions for hazard areas including, but not limited to: military exercise area, dumping zones, explosive ordnance zones, fishing zones, anchorages, shipping lanes, cable areas and lease blocks.

7. Charts

Applicants should annotate all charts with linear bar-scales (feet and meters), geographic and planar coordinates (latitude and longitude, eastings and northings), lease boundaries, lease numbers, proposed facility site(s) and cable transmission routes. Please refer to the separate *Guidelines for Submission of Spatial Data for Atlantic Offshore Renewable Energy Development Site Characterization Surveys* for further information on providing digital spatial data to BOEM.

Applicants should submit the following set of charts at a standard scale (generally 1:10,000) and oriented to true north, except the Alignment Sheets, which are aligned with the cable route:

1. Navigation Post-Plot Chart(s) of the surveyed area, showing survey lines and directions, and navigational information at intervals of no more than 150 meters.
2. Bathymetry Chart(s) including imagery, contours, and slope gradients greater than 10 degrees. Contour intervals should be dependent on water depths and seafloor morphology and generally range from 0.3 m to 10 m.
3. Geologic Surface Features and Shallow Structure Chart(s) including: side scan sonar contacts, magnetic anomalies, seabed sediment classification, seabed features, shallow geologic structure interpreted from high frequency sub-bottom profiler (SBP) data, seabed sample locations and descriptions, and all identified hazards.
4. Subsurface Structure Chart(s) including subsurface structure of horizons identified in subsurface geologic investigations including relevant core, deep boring and CPT locations and results as practical.
5. Magnetic Contour Chart(s) Details on symbology are provided in *Guidelines for Providing Archaeological and Historic Property Information Pursuant to 30 CFR Part 585*.
6. Shallow Isopach Chart(s) showing thickness, in meters, of unconsolidated Holocene/late-Pleistocene sediments.
7. Subsurface Horizon Elevation Chart(s) showing elevation, in meters, of the horizons identified in the medium penetration seismic data.
8. Alignment Sheet(s) that have at least 3 panels: (1) geologic features and shallow geology, (2) bathymetry, and (3) seabed profile with digitized reflectors from the SBP data. All panels should be presented with the transmission route in the horizontal position and include the cable route, KPs, and survey extents. When the route changes direction, the panel view should rotate to keep the route horizontal and show sufficient overlap of data. All requirements listed for the geologic features maps are to be included in the geologic

features and shallow geology panel. The bathymetry panel should contain contours and any routing information relevant to the installation or provided on the route position list. The seabed profile panel should contain slope indicators at the steepest point along the profile and any locations where the slope is sufficiently large and considered a hazard to the cable (typically greater than 5 degrees). BOEM recommends presenting the sub-bottom profile imagery from the nearest line on the seabed profiler panel, if this is not practical, the applicant may present the digitized reflectors used for interpretation. Seabed sample results are necessary on both the geologic features and seabed profile panels.

A standardized legend, map key, chart name and number, total number of charts, survey information panel, and location maps should be presented on all charts.

In all sediment descriptions, the primary sediment type should be in all capital letters and minor sediment constituents should be in lower case. This formatting should be included in all charts, sample logs, and figures presenting sediment descriptions and interpretations.

BOEM expects submitted charts to contain the following symbology where applicable. If additional features to those listed below are observed, they should also be presented on charts and identified in the legend with appropriate symbology.

- Distinct hatch/color for the following surficial conditions where observed: coral, gas seepage, boulder field, clay, silt, sand, gravel, cobbles and boulders, subcropping rock (less than 0.5 m sediment over rock or hardground), rock, and hardground with very dense or consolidated sediments.
- Bathymetric and isopach contours with major and minor line styles and colors.
- Coverage boundaries.
- Annotated slope gradient symbols with direction where the seabed slope is greater than 10 degrees.
- Different line styles for sediment boundaries and inferred sediment boundaries.
- Isolated rock outcrop symbols annotated with height above seabed.
- Pockmark symbols annotated with diameter and depth.
- Seabed depression line style.
- Scarps annotated with height.
- Distinct line styles for channels and ridges.
- Bedform symbols annotated with wavelength and height.
- Subsurface faults with depth annotated along symbol/line style.
- Seabed scars.
- Feature descriptions with leaders pointing to features or areas.
- Distinguishable symbols for sediment samples and testing including cores, grab samples, deep borings, probes and CPTs; annotated with the sample ID.
- Magnetic anomalies annotated with ID.

- Sonar contacts annotated with contact ID.
- Linear sonar contacts, with distinctions for observed contacts and inferred locations.
- Wrecks, both charted and observed.
- Distinguishable symbols for in-service, out-of-service cables.
- Pipelines.
- Sample log that includes both illustrations and descriptions of all sediment samples collected.
- CPT log showing results and interpretation.

8. Site Conditions and Hazards Assessment

The site conditions and hazards assessment portion of the report presents the interpretation of geophysical data and geotechnical investigations. This section should include a description of the conditions and an assessment of the potential for hazards within the surveyed area. Topics of discussion should include, but not be limited to:

- General geological background/setting.
- Sediment type classification.
- Sediment thickness.
- Seabed features including but not limited to: scarps, channels, ridges, bedforms, exposed rocky areas, boulders (surface and buried), pockmarks and/or depressions, and seabed scars.
- Bedform symbols with wavelength and height and discussed in the following terms:

Name	Wavelength (meters)	Height (meters)
Sandwave	> 60	> 1.5
Megaripple	5 - 60	0.5 – 1.5
Ripple	< 5	< 0.5

- Slope gradients discussed as follows:

Classification	Gradient (Degrees)
Very Gentle	< 1
Gentle	1 to 4.9
Moderate	5 to 9.9
Steep	10 to 14.9
Very Steep	> 15

- Geologic interpretation of sub-bottom and medium penetration seismic data including but not limited to: buried channels, submarine canyons, river channels, exposed or buried hard bottom surfaces, shallow gas, gas hydrates, shallow-water flow, and karst areas.
- Fault activity, seismic shaking, and liquefaction potential.
- Bathymetry.

- Side scan sonar contacts or Remotely Operated Vehicle (ROV) video documentation.
- Magnetic anomalies.
- Unstable seafloor areas (e.g., slumping and sliding, areas of slope instability).
- Existing or planned cables and pipelines.
- Any other man-made potential obstruction or hazard including, but not limited to; disposal sites, dumping grounds, anchorage areas, shipwrecks, etc.

BOEM recommends providing examples of notable features observed in the data and discussion of how salient features are confirmed or refuted in different data streams.

9. Data

The applicant should provide digital copies of the data acquired for site characterization. All data should contain metadata identifying the vessel, collection dates and time, geocentric ellipsoid reference, projection information, and adequate information to identify the data. Applicants should provide the complete processed data sets in industry standard formats on CDs, DVDs or an external hard drive. A summary table of expected data deliverables is provided in Table B-1. Metadata should include the vessel name, dates, geocentric ellipsoid used as a reference, the associated projection system, and adequate information to identify each attribute.

The report should include data type specific descriptions of the processing sequences, an assessment of overall data quality, and discussion of identified notable features.

10. Geotechnical data/analysis

- Provide (in tabular format) latitude/longitude, easting/northing, sample ID, core length/non- recovery, sediment type description, water depth, and sample type if not indicated in naming conventions for all grab samples and cores.
- Photos of all cores and grab samples that include sample ID, latitude/longitude, easting/northing, date and time of collection, vessel name, and water depth information.
- A description of all seabed exploration and sampling methods used.
- Results of all exploration and laboratory testing, including boring logs, soil profiles, cone penetrometer plots, graphs and tables of all lab results.
- Results of all geotechnical analyses such as pile capacity charts, lateral pile analyses, finite element analyses

11. Results and conclusions

A summary of conclusions and recommendations supported by the survey data and analyses, including a discussion of known or potential hazards to avoid, or that may require further investigation.

Please include a comprehensive Hazards Report that lists, in tabular form, all possible obstructions and hazards to both cable and turbine installation. The Hazards Report should include sonar and magnetometer contacts, pipeline and cable crossings, anthropogenic hazards such as dump areas and anchorage zones, and geologic hazards. At a minimum, the report should include:

- Latitude/longitude.
- Easting/Northing.
- Water Depth.
- Hazard Type (contact ID, cable or pipeline name, geologic feature).
- Distance and direction from cable route or proposed WTG location.
- Additional hazard specific information such as crossing angle, sonar target dimension, magnetic anomaly strength, or contact description.

Table B-1
Digital Data Deliverable Summary Table

Data Type	Data format	Data Products
Bathymetric Data		
	XYZ Data	Contours (ESRI Compatible)
	Metadata detailing processing parameters, illumination angles and coordinate systems	Geo-referenced image file
	Navigation Data (XYZ or ESRI shapefile)	Arc ASCII Grid and Layer Files
Magnetometer Data		
	XYZ Data	Summary of the magnetic anomalies observed during the investigation and a list of all magnetic anomalies in tabular format including: latitude/longitude, eastings/northings, sensor height above seabed, size, and interpretation
	Navigation Data (XYZ or ESRI shapefile)	Magnetic contours (ESRI compatible), geo referenced image file, and/or Arc ASCII grid and layer files
	ESRI compatible data file attributed with information provided in tabular format (see data products)	
Side Scan Sonar Data		
	Raw XTF data	Summary of the sonar contacts identified in the investigations in tabular format including: latitude/longitude; eastings/northings; length, width, and height; and interpretation
	Navigation Data (XYZ or ESRI shapefile)	Processed geo-referenced data imagery (mosaics and individual lines)
Geotechnical Data		
	ESRI compatible data file for all sediment samples attributed with information provided	Sediment sample information in a tabular format including; latitude/longitude, easting/northing, sample ID, core

	in tabular format (see data products)	length/non-recovery, sediment type description, water depth, and sample type if not indicated in naming convention
	Results of all exploration and laboratory testing including; boring logs, soil profiles, cone penetrometer plots, and graphs/tables of all lab results	Results of all geotechnical analysis such as pile capacity, lateral pile analysis, and finite element analyses
	Sample photos of all cores and grab samples that include sample ID, latitude/longitude, easting/northing, date and time of collection, vessel name, and water depth information	
Geological and Hazards Assessment		
		Surface features, geologic interpretation, and hazards assessment (ESRI compatible)
		Near surface and surficial sediment descriptions and geologic interpretation (ESRI compatible)
Medium Penetration Seismic Data		
	SEG-Y data (final processed seismic data)	Reflectors/horizons, formatting options include XYZ data, CSF files compatible with Sonar Wiz Software, image plots, and/or other formats approved by BOEM
	SEG-Y byte positions	Digital image plots of interpreted data with SPs/CDPs
	List of lines, including SP and/or CDP ranges	Subsurface Horizon Elevation data as ESRI compatible contours and geo referenced image file/Arc ASCII grid file and layer files
	Navigation Data (XYZ, ESRI shapefile, or text file format) with line name and locations for the first, last and every tenth SP or CDP	Geologic structure interpretation as ESRI shapefiles, XYZ data, CSF files, or other formats approved by BOEM
	Digital image plots of uninterpreted data with shot points or CDP	

High Frequency CHIRP Data		
	SEG-Y data	Reflectors/horizons as XYZ data, CSF files compatible with Sonar Wiz, image plots, and/or other formats approved by BOEM
	SEG-Y byte positions	Digital image plots of interpreted data annotated with location information
	List of lines, including start and end of line times	Isopach data for sediment thickness of the unconsolidated Holocene/late Pleistocene sediments
	Navigation Data (XYZ, ESRI shapefile, or text file format) with line name	Geologic structure interpretation as ESRI shapefiles, XYZ data, CSF files, or other formats approved by BOEM
	Digital image plots of uninterrupted data annotated with location information	