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VINEYARD WIND

Draft
Construction and Operations Plan

Volume I

Vineyard Wind Project

September 30, 2020

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Submitted to
Bureau of Ocean Energy Management
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Sterling, Virginia 20166

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Public Archaeology Laboratory, Inc.
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Swanson Environmental Associates
Wood Thilsted Partners Ltd
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September 30, 2020

Section 3.0

Project Structures and Facilities – General Structural and Project Design, Fabrication and Installation

3.0 PROJECT STRUCTURES AND FACILITIES - GENERAL STRUCTURAL AND PROJECT DESIGN, FABRICATION AND INSTALLATION

3.1 Offshore Facilities

The Project's offshore elements include the Wind Turbine Generators ("WTGs") and their foundations, the electrical service platforms ("ESPs") and their foundations, scour protection for all foundations, the inter-array cables, the inter-link cable that connects the ESPs, and the offshore export cables. The WTGs, the ESPs, the inter-array cables, the inter-link cable, and portions of the offshore export cables are located in federal waters. The balance of the export cable run is located in Massachusetts waters.

Lightning protection will be installed on the electrical systems, including the WTGs and ESPs.

Table 3.1-1 lists the Project Envelope and highlights the maximum number of structures or maximum dimensions (referred to as the "maximum design scenario").

Table 3.1-1 Vineyard Wind Project Envelope with Maximum Design Scenario

CAPACITY	Maximum	
Wind Farm Capacity	800 megawatt ("MW")	
WIND TURBINE GENERATORS	**Minimum**	**Maximum**
Turbine Size	8 MW	~14 MW
Total Tip Height above Mean Lower Low Water ("MLLW")[1]	191 meters ("m") (627 feet ["ft"])	255 m (837 ft)
Number of Positions (up to)[2]	106	
Number of WTGs (up to)	100	
WTG FOUNDATIONS		
Foundation Envelope	-100% monopiles or -Up to 10 jackets, remainder monopiles	
Foundation Type	Jackets (Pin Piles)	Monopiles
Number of Piles/Foundation	3-4	1
Maximum Area of Scour Protection at each Foundation	up to 1,800 square meters ("m^2") (19,375 square feet ["ft^2"])	up to 2,100 m^2 (22,600 ft^2)
Maximum Number of Foundations Installed per Day (24 hours)	1 (up to 4 pin piles)	2
ELECTRICAL SERVICE PLATFORMS		
ESP Type	400 MW Conventional ESP	800 MW Conventional ESP
Number of ESPs	2	1

Table 3.1-1 Vineyard Wind Project Envelope with Maximum Design Scenario Highlighted (Continued)

ESP FOUNDATIONS		
Foundation Types for Conventional ESP	Monopiles	Jackets
Number of Piles/Foundation	1	3-4
Maximum Area of Scour Protection at each Foundation	up to 2,100 m^2 (22,600 ft^2)	up to 2,500 m^2 (26,900 ft^2)
Maximum Height above MLLW	65.5 m (215 ft)	**66.5 m (218 ft)**
INTER-ARRAY CABLES		
Inter-array Cable Voltage	66 kilovolts ("kV")	
Maximum Length of Inter-array Cables	**275 kilometers ("km") (171 miles ["mi"])**	
EXPORT AND INTER-LINK CABLES		
Export and Inter-link Cable Voltage	220 kV	
Maximum Length of Inter-link Cable	**10 km (6.2 mi)**	
Maximum Number of Export Cables	2	
Maximum Length of Offshore Export Cables (for two export cables)	**158 km (98 mi)**	

Notes:

Maximum Design Scenario indicated by double lined box and bold text.

1. Turbine output is not necessarily proportionately linked to size, so smallest turbine size may not be an eight MW turbine.
2. Additional WTG positions are included to account for spare positions in the event of environmental or engineering challenges.

3.1.1 Wind Turbine Generators

The Project will utilize WTGs specially designed for offshore use (see Figure 3.1-1). The WTGs consists of two main components: the Rotor Nacelle Assembly ("RNA") and the tower. The WTGs will have a three-bladed rotor with a rotor diameter as listed in Table 3.1-1 below. The nacelle houses the power generating components of the turbine, including the gear box, generator, transformer, converter and other auxiliary systems. A pitch and yaw system will allow the wind turbine to optimize its performance by positioning the direction of the rotor and the angle of the blades. The brake, pitch, and yaw systems may be controlled using hydraulics. The RNA is mounted on the tower, which is mounted on a foundation and/or transition piece via a bolted connection; the foundation is further described in Section 3.1.2. The tower is typically constructed in two or three sections for offshore wind projects. Both the nacelle and the tower are steel structures coated to protect against corrosion.

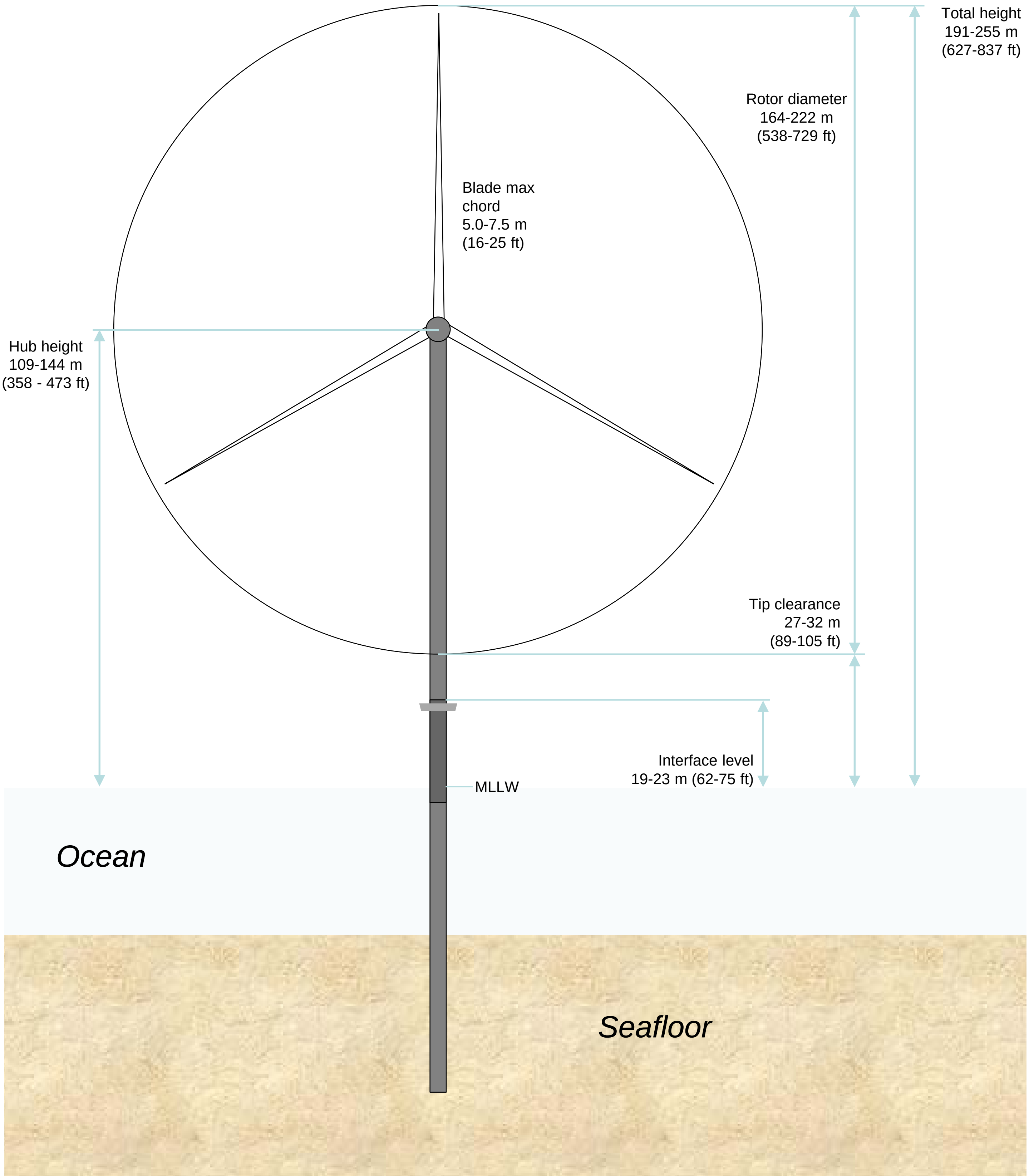

Figure 3.1-1
WTG Dimensions

For service purposes, the WTGs will have cranes in the nacelle and on the external working platform (which is mounted on the foundation and/or transition piece), that are able to lift spare parts to their proper location in accordance with operations and maintenance procedures. The WTGs will also include access ways for personnel inside the tower. An elevator will serve as the main access route. The elevator will be designed to carry personnel, tools, small equipment, and small spare parts. Ladders will serve as a secondary access route. All access routes will be designed to ensure and will comply with all relevant standards and regulations.

The wind turbine design will be verified for the specific site conditions during the Certified Verification Agent ("CVA") review process, where the design will be able to withstand wind speeds and gusts in the range of 180 kilometers per hour ("kph") (112 miles per hour [mph]) and 253 kph (157 mph), respectively. The offshore wind turbines will be designed to automatically stop power production when wind speeds exceed a maximum of 111 kph (69 mph), after which the rotor will normally idle. The exact speed at which power production will cease depends on the manufacturer's specifications. The structures will be designed for the extreme environmental conditions (including wind speed and wave height) verified by the CVA. Design wave heights are expected to be in the range of 18.3 m (60 feet).

Table 3.1-2 Envelope of WTG Parameters

WTG Parameter	Envelope
Tip height	191-255 m (627-837 ft) MLLW
Hub height	109-144 m (358-473 ft) MLLW
Rotor diameter	164-222 m (538-729 ft)
Platform level and expected interface level towards foundations	19-23 m (62-75 feet) MLLW
Tip clearance	27-32 m (89-105 ft) MLLW

Note: Elevations relative to MHHW are approximately 1 m (3 ft) lower than those relative to MLLW.

The WTGs will have maximum rotor tip height of 255 m (837 ft) above Mean Lower Low Water ("MLLW") and will include a nighttime wind turbine obstruction lighting system in compliance with Federal Aviation Administration ("FAA") and/or BOEM requirements. The obstruction lighting system will consist of two synchronized FAA "L-864" aviation red flashing obstruction lights placed on the nacelle of each WTG. If the WTGs' total tip height is 699 ft or higher, there will be at least three additional low intensity L-810 flashing red lights at a point approximately midway between the top of the nacelle and sea level. If approved by BOEM and the FAA, 30 flashes per minute will be utilized for air navigation lighting. Other temporary lighting (e.g. helicopter hoist status lights) may be utilized for safety purposes when necessary.

Vineyard Wind is working to reduce the lighting to lessen the potential impacts of nighttime light on migratory birds and to address aesthetic concerns. The Project expects to use an Aircraft Detection Lighting System (ADLS) that automatically activates all aviation obstruction lights (FAA lights on both the nacelle and tower) when aircraft approach the Project. Alternatively, the Project may use a system that automatically adjusts lighting intensity in response to visibility conditions. The use of either of these systems is subject to commercial availability by turbine manufacturers, and approval by BOEM and the FAA, if applicable. A report on how often the ADLS system would be activated is included in Appendix III-N for informational purposes. If the use of ADLS is not feasible, reduced lighting for the interior will be reviewed and discussed with BOEM and the FAA. Turbines will be no lighter than RAL 9010 Pure White and no darker than RAL 7035 Light Grey in color; Vineyard Wind anticipates that the WTGs will be painted off-white/light grey to reduce their visibility from against the horizon. Aviation concerns are further discussed in Section 7.9 of Volume III.

Marine navigation lighting will consist of multiple yellow flashing lights at each turbine and on the corners of the ESPs. Yellow lights will be visible at five nautical miles ("nm") and/or two nm in accordance with consultation with the US Coast Guard ("USCG"). Lighting on the turbines will be located on top of the work platform design level at a height of 19-30 m (62-98 ft) above MLLW. Lighting on top of the substations will be placed at a similar height above MLLW. Daytime marking schemes will generally follow International Association of Lighthouse Authorities guidance, which involves marking each structure in the Project Area with high visibility yellow paint. Alphanumeric identification in black lettering will identify each WTG. Each turbine will also be clearly identified on National Oceanic and Atmospheric Administration charts. The high visibility yellow paint shall begin at the waterline (at all tidal conditions) and cover the WTG foundation to a height of at least 15 m (50 ft) above the waterline. Sound signals and AIS transponders are included in the Project design to enhance marine navigation safety. Further information on marine navigation, including figures showing the marking and lighting, can be found in the Navigation Risk Assessment (see Appendix III-I).[7]

3.1.1.1 Site Layout

As described in Section 1.5, the Project is being permitted using an Envelope concept. Up to 106 turbine locations are being permitted to allow for spare positions (in the event of environmental or engineering challenges). Although the Project is including 106 WTG positions in the Project Envelope, only up to 100 positions will be occupied by a WTG. The site layout for up to 106 turbine locations is shown on Figure 3.1-2. The WTGs are laid out in a grid-like pattern with spacing of 1.4-1.8 km (0.76-1.0 nm) between turbines.[8]

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[7] The Project's lighting and marking scheme is being refined through ongoing consultations with USCG.

[8] The listed dimensions describe the typical grid spacing. The minimum distance between nearest turbines is no less than 1.2 km (0.65 nm) and the maximum distance between nearest turbines is no more than 2.1 km (1.1 nm). The average spacing between turbines is 1.6 km (0.86 nm).

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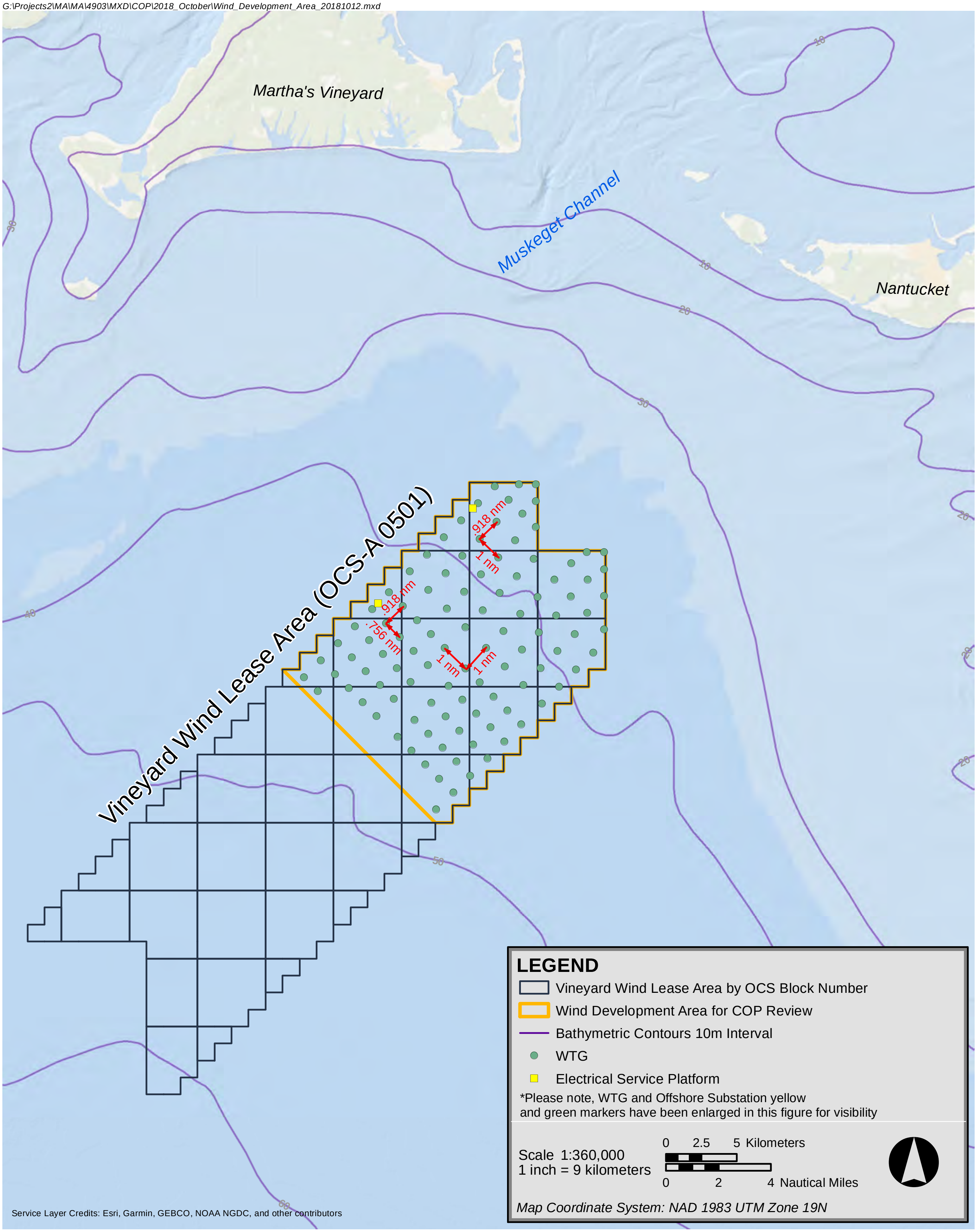

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Figure 3.1-2a

Wind Development Area for COP Review

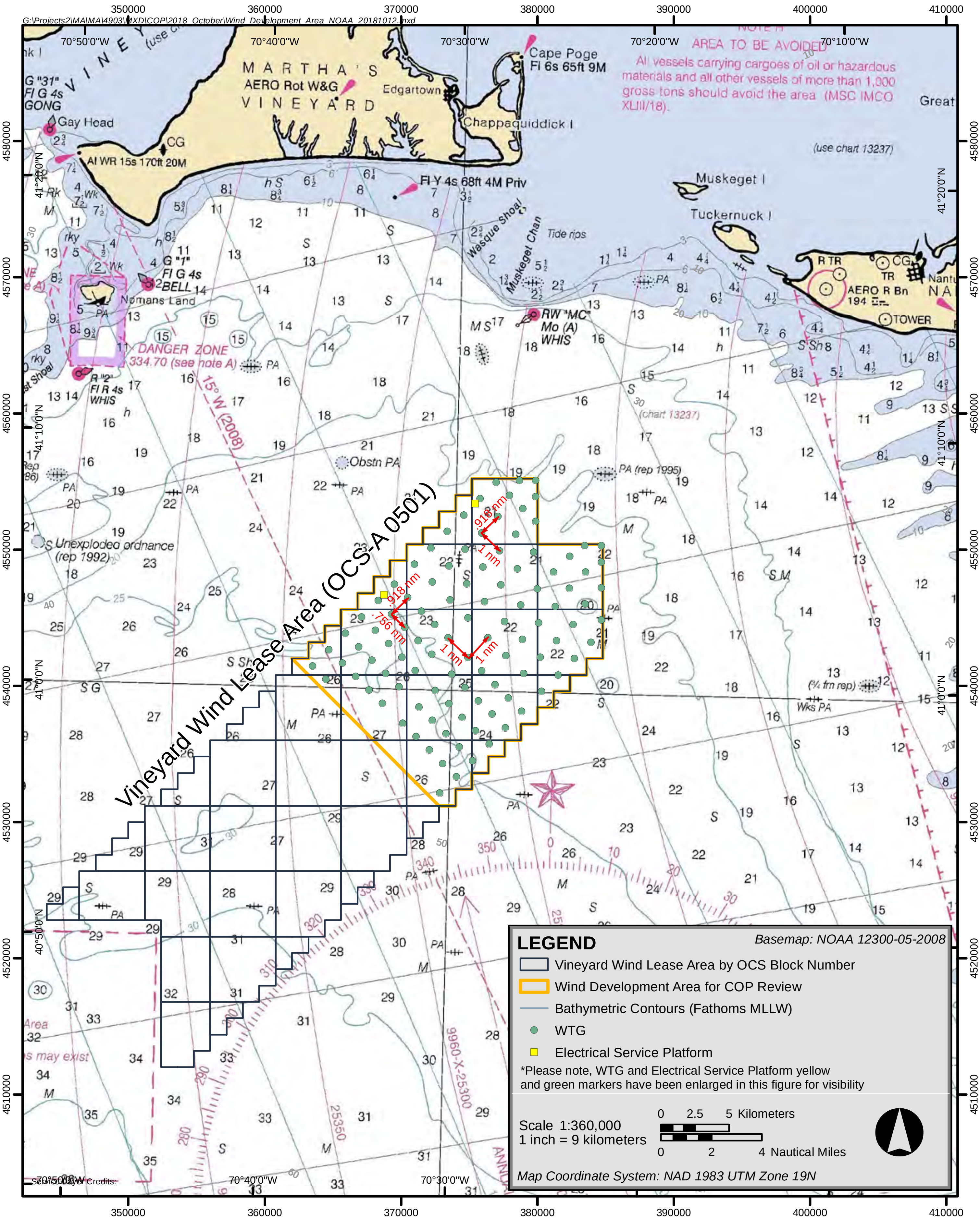

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Figure 3.1-2b

Wind Development Area for COP Review

In consultation with fishermen and the USCG, corridors in a northwest/southeast and northeast/southwest direction have been maintained.

3.1.2 WTG Foundations

The foundations supporting the WTGs will include one of the following two concepts:

- Monopiles and transition piece ("TP") (or extended monopile); and
- Jackets

As described in Section 1.5, both concepts are contained in the Project Envelope. The Maximum Design scenario considers either the installation of monopiles for all WTG foundations or the installation of up to ten jackets, with the remainder monopiles. Jackets are expected to be used in deeper water locations.

3.1.2.1 Monopiles

A monopile is a single, hollow cylinder fabricated from steel that is secured in the seabed. Monopile dimensions are shown on Figure 3.1-3 and are included in Table 3.1-3, below. Monopiles are a proven concept that has been used successfully at many offshore wind farms. As of December 2017, monopiles accounted for more than 80% of the installed foundations in Europe, with more than 3,350 units installed (Wind Europe, 2017).

A TP is typically installed between the monopile and WTG tower (see Figures 3.1-3 and 3.1-4). The TP features a connecting flange enabling the WTG tower section to be bolted/mounted on top of the TP; it also contains secondary structures, such as tower flange for mounting the WTG, boat landing, internal and external platform, and various electrical equipment needed during installation and operation (see Figure 3.1-3). In a variation of the concept, the monopile is extended to include the TP (this is referred to as an "extended monopile"; see Figure 3.1-5). In this case, secondary structures are attached after installation of the pile.

The monopile foundations for the Project will be equipped with a corrosion protection system designed in accordance with relevant standards. The monopiles will likely require the use of an anode cage to ensure sufficient corrosion protection closer to the seabed. An anode cage is a steel structure that has anodes attached to it.

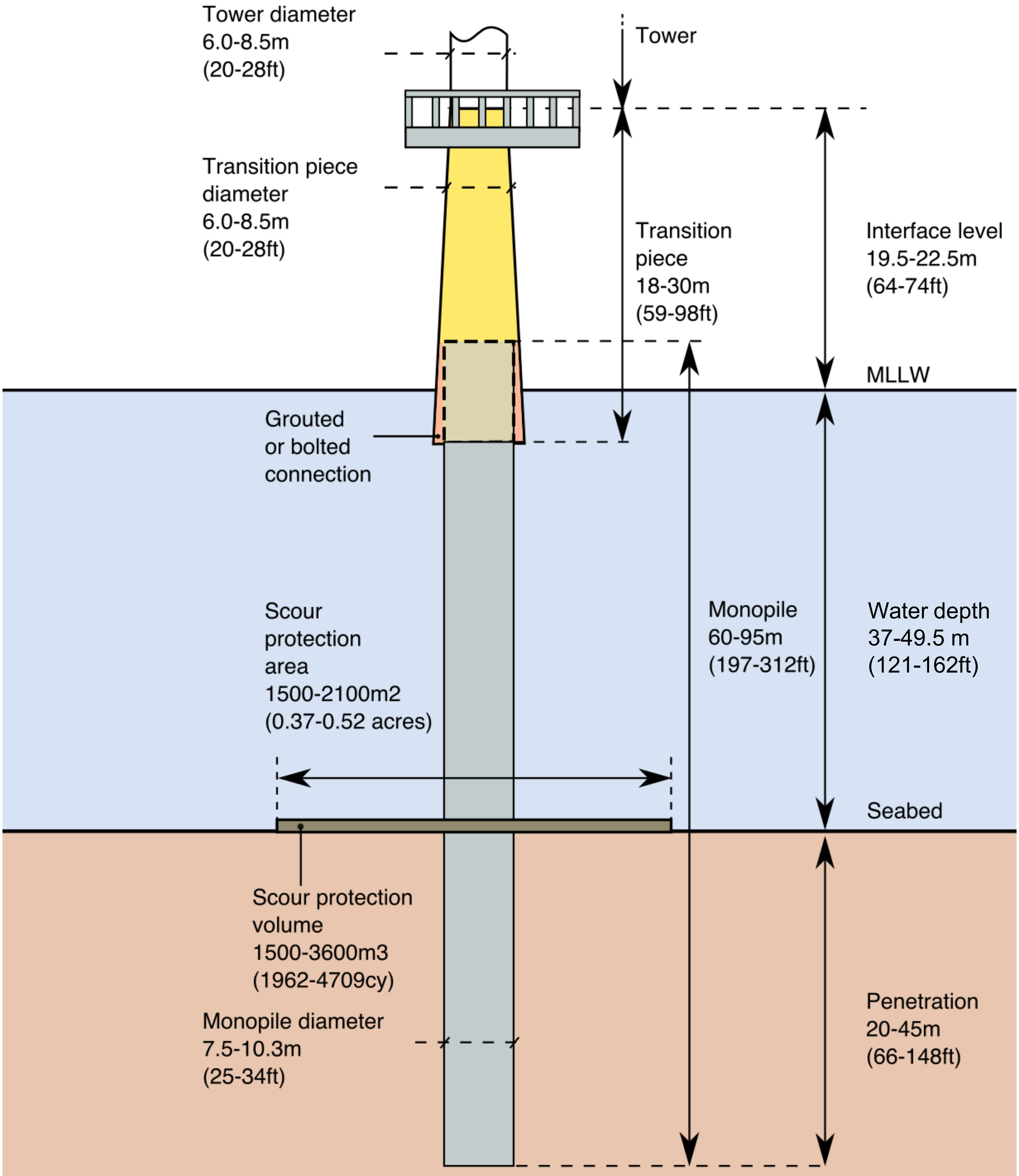

Figure 3.1-3
WTG Monopile Foundations

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Figure 3.1-4

Photographs of Monopiles and Transition Pieces

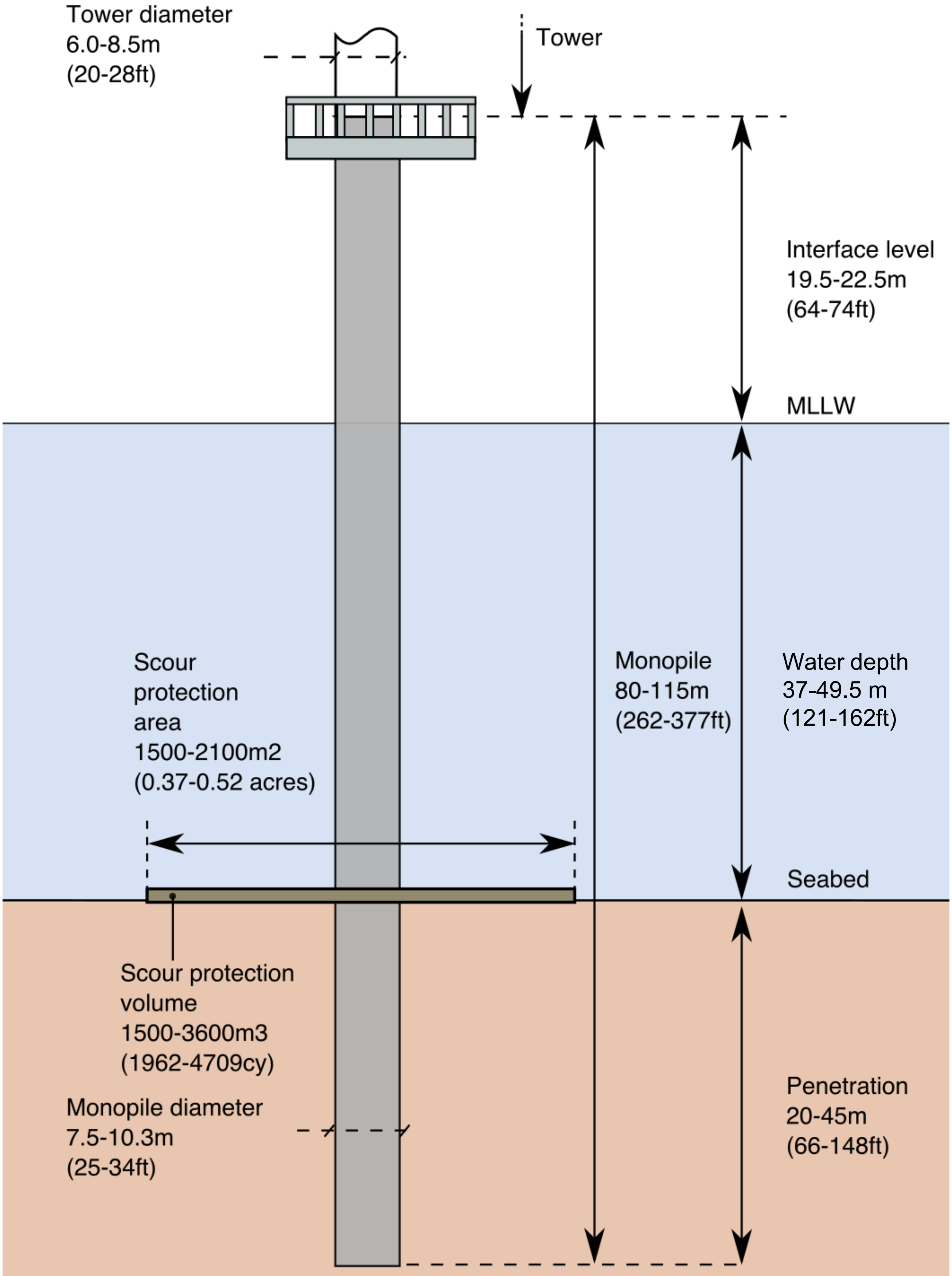

Figure 3.1-5

WTG Extended Monopile Foundation

3.1.2.2 Jackets

The jacket design concept consists of three to four piles, a large lattice jacket structure and a TP (see Figures 3.1-6 through 3.1-8). The jacket structure is supported/secured by pre-installed driven piles (one per leg). Alternatively, the jacket is secured to the sea floor via slender piles which are driven through "sleeves" or guides mounted to the base of each leg of the jacket structure.

The jacket will also contain secondary structures, such as boat landings and cable tubes. Jackets account for 12% of the number of foundations installed in 2016 in Europe, which brings their total market share to 6.6% (Wind Europe, 2017). Jackets are also widely used for other offshore applications, including in the oil and gas sectors. Further, as described for the monopiles (see Section 3.1.2.1, above), the jacket will be equipped with a corrosion protection system design in accordance with relevant standards.

The jacket is fixed to the piles and a TP is fitted to obtain the turbine loads and transfer them to the jacket structure. The TP will contain secondary structures, such as tower flange for mounting the WTG, internal and external platforms, and various types of electrical equipment needed during installation and operation.

3.1.3 Scour Protection

Scour protection is included to protect the foundation from scour development, which is the removal of the sediments near structures by hydrodynamic forces. Scour protection consists of the placement of stone or rock material around the foundation so that it can withstand the increased seabed drag created by the presence of the foundation. One of the benefits of scour protection is that it allows foundation penetration to be minimized, as the design does not have to account for significant scour development.

As shown on Figure 3.1-9, the scour protection will be one to two meters high (3-6 ft), with stone or rock sizes of approximately 10-30 centimeters (4-12 inches).

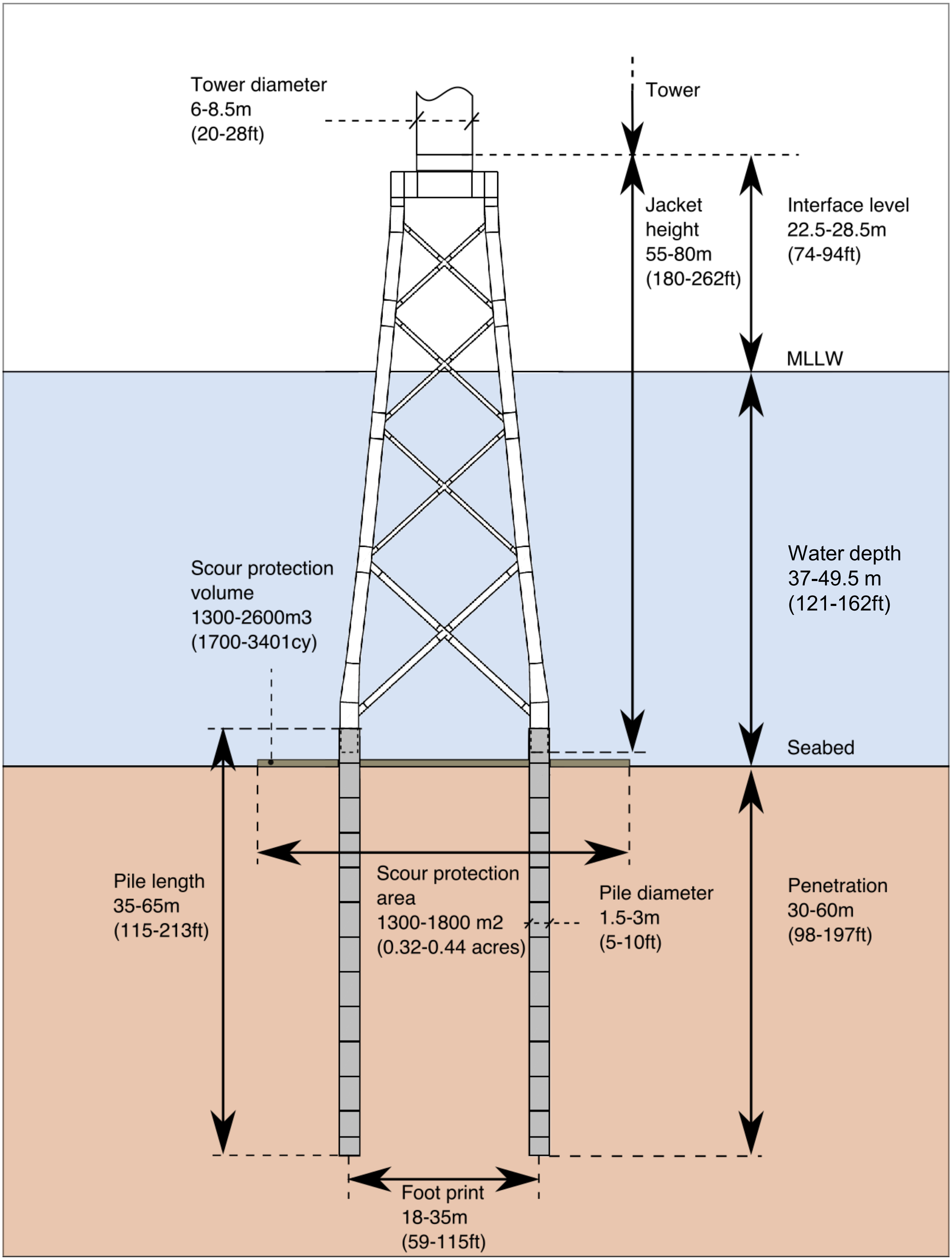

Figure 3.1-6
WTG Jacket Foundation

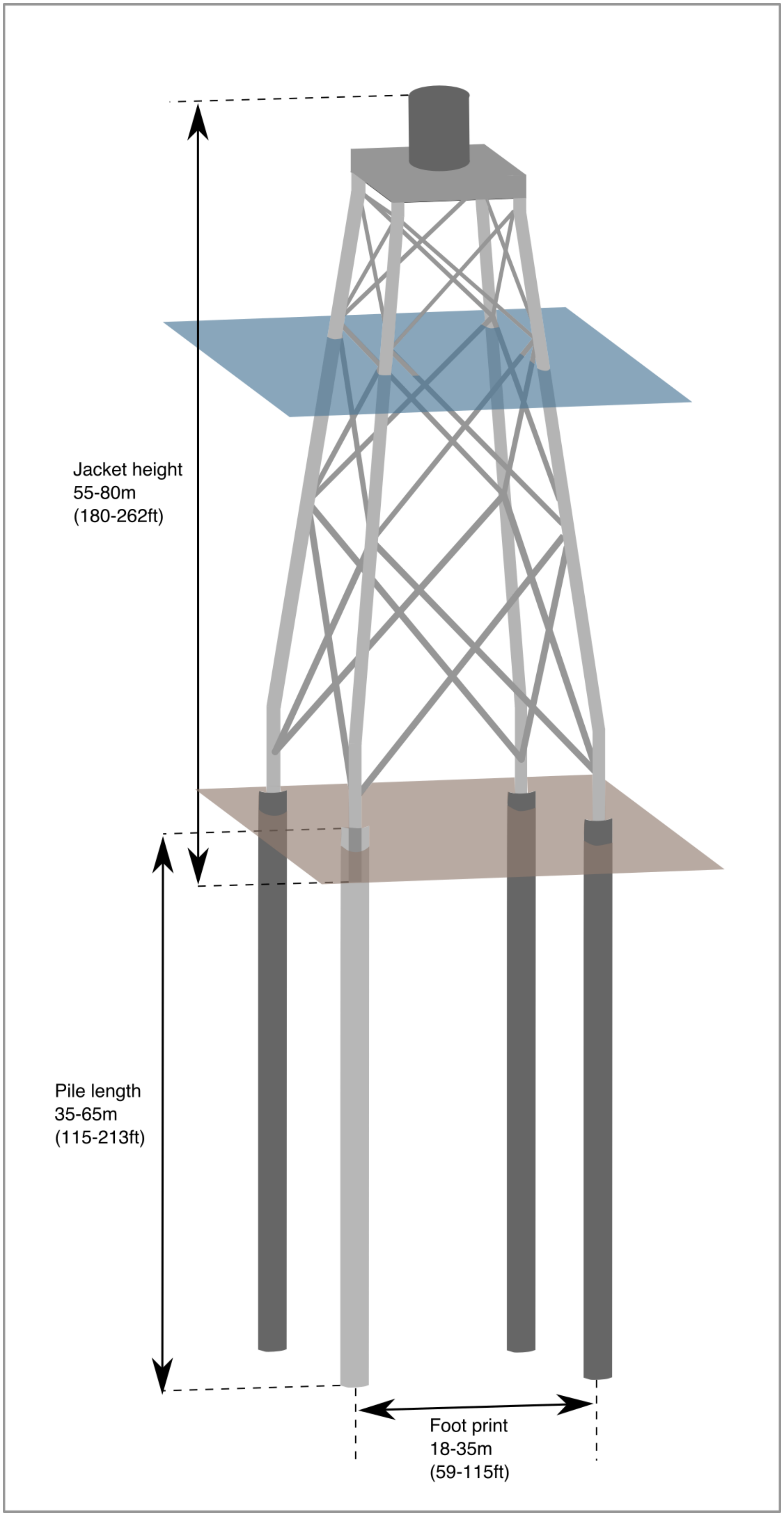

Figure 3.1-7
WTG Jacket Foundation 3D Rendering

Figure 3.1-8

Photographs of Jacket Foundations

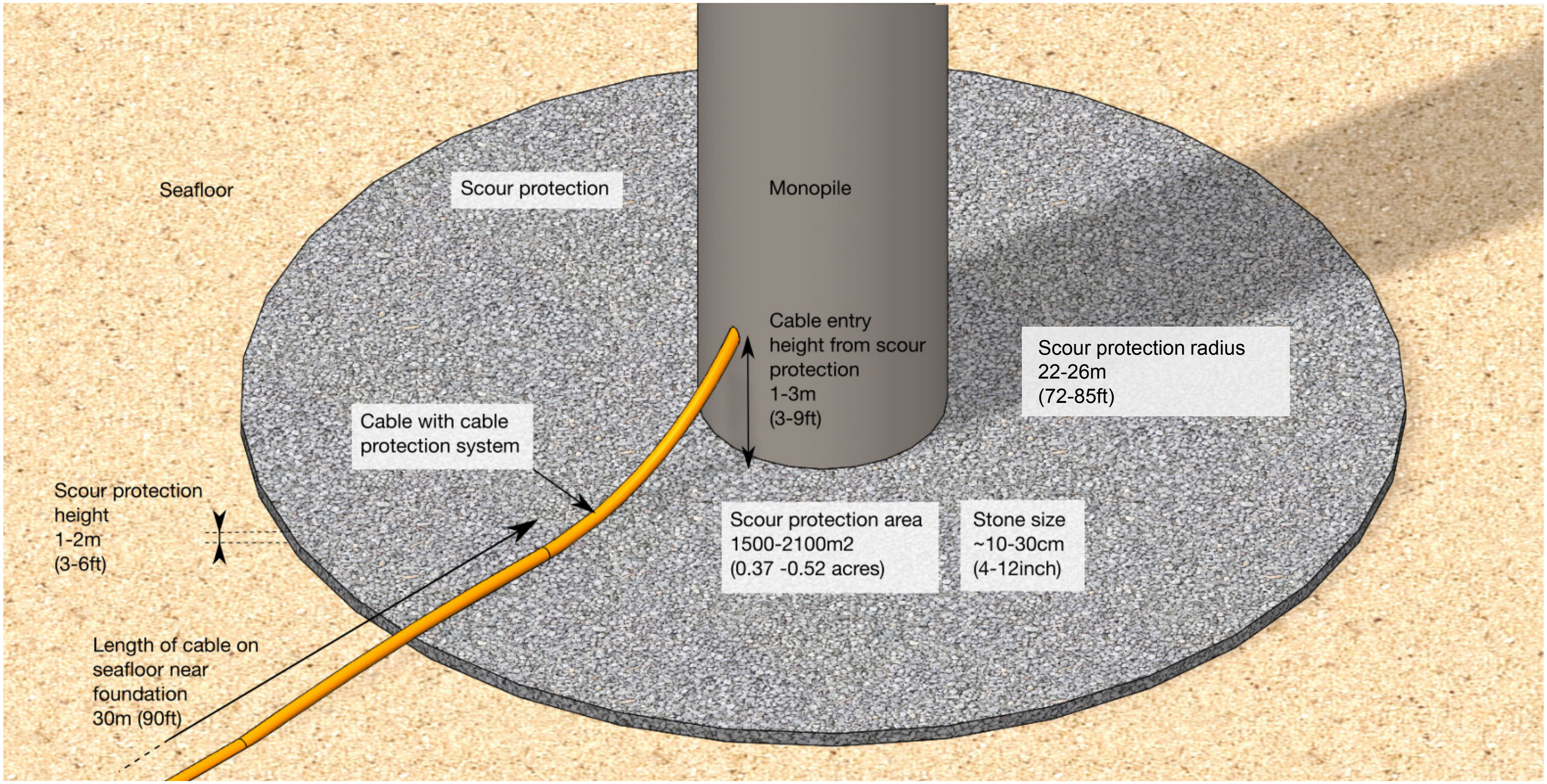

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Figure 3.1-9

Typical Scour Protection For Monopile Foundation

Table 3.1-3, below, shows the Project Envelope for the two foundation concepts and associated scour protection.

Table 3.1-3 Envelope of WTG Foundation Dimensions

Concept	Monopile		Jackets
	Monopile	**Extended Monopile**	**Piles (3-4 piles)**
Length	60-95m (197-312 ft)	80-115 m (262-377 ft)	35-65 m (115-213 ft)
Diameter (maximum)	7.5-10.3 m (25-34 ft)	7.5-10.3 m (25-34 ft)	1.5-3.0 m (5-10 ft)
Penetration	20-45 m (66-148 ft)	20-45 m (66-148 ft)	30-60 m (98-197 feet)
Bottom Pile Wall Thickness	70-100 millimeters ("mm") (2.8-3.9 inches)	70-100 mm (2.8-3.9 inches)	40-55 mm (1.6-2.2 inches)
	Transition Piece	**Transition Piece**	**Jacket Structure (including Transition Piece)**
Length	18*-30 m (59-98 ft)	(N/A)	55-80 m (180-262 ft)
Diameter	6.0-8.5 m (20-28 ft)	(N/A)	18-35 m (59-115 ft)
Interface elevation	19-23 m MLLW (62-75 ft MLLW)	(N/A)	22.5-28.5** m MLLW (74-94 ft MLLW)
	Scour Protection	**Scour Protection**	**Scour Protection**
Scour protection volume	1,500-3,600 m^3/mT (1,962-4,709 cubic yards ["cy"])	1,500-3,600 m^3/mT (1,962 – 4,709 cy)	1,300-2,600 m^3/mT (1,700-3,401 cy)
Scour protection area	1,500-2,100 m^2 (0.37 -0.52 acres)	1,500-2,100 m^2 (0.37 -0.52 acres)	1,300-1,800 m^2 (0.32-0.44 acres)

* Length to account for the possibility of a bolted connection.

** Interface elevation is set up to account for the possibility of an interface placed above the tower access door.

3.1.4 Electrical Service Platforms

For the 800 MW Project, there will be one 800 MW conventional ESP or two 400 MW conventional ESPs. The potential locations for the ESPs are shown on Figure 3.1-2. Similar to the WTG foundations, two options are considered for the ESP foundations: monopile or jacket (Figures 3.1-10 through 3.1-13).

The ESPs will serve as the common interconnection point for the WTGs within the array. Each WTG will interconnect with an ESP via a 66 kV submarine cable system. These cable systems will interconnect with circuit breakers and transformers (66 kV to 220 kV) located on the ESPs to increase the voltage level and transmit electricity through the offshore cable system to the final connection point to the bulk power grid. Additional information about the offshore cable systems is included in Sections 3.1.5 and 3.1.6.

Additional equipment on the ESPs is subject to final design but is anticipated to include the following: 220 kV AC switchgear for connection to the onshore substation, switchgear for connection with the wind turbines, transformer oil spill tanks, shunt reactors, auxiliary systems, cooling systems, fire pumps, seawater utility pumps for systems such as fresh water and cooling, fire detection and firefighting equipment, cranes (as required), rescue and evacuation facilities and equipment (such as life rafts or boats, lifejackets), supervisory control and data acquisition ("SCADA") equipment, and communications and navigation systems.

An HVAC system may be installed in the ESPs to protect the equipment and personnel from extreme temperatures. In addition, an emergency generator and/or battery may also be installed on the ESPs to provide emergency power.

Figures 3.1-10 through 3.1-13 provide illustrative dimensions for conventional ESPs on a standard monopile/transition piece foundation, an extended monopile foundation, and a jacket foundation (2D and 3D versions), respectively. Photographs of ESPs can be found in Figure 3.1-14. ESPs may also include a helipad for maintenance work and are anticipated to include at least one boat landing. Project Envelope dimensions for the ESPs are shown in Table 3.1-4 below.

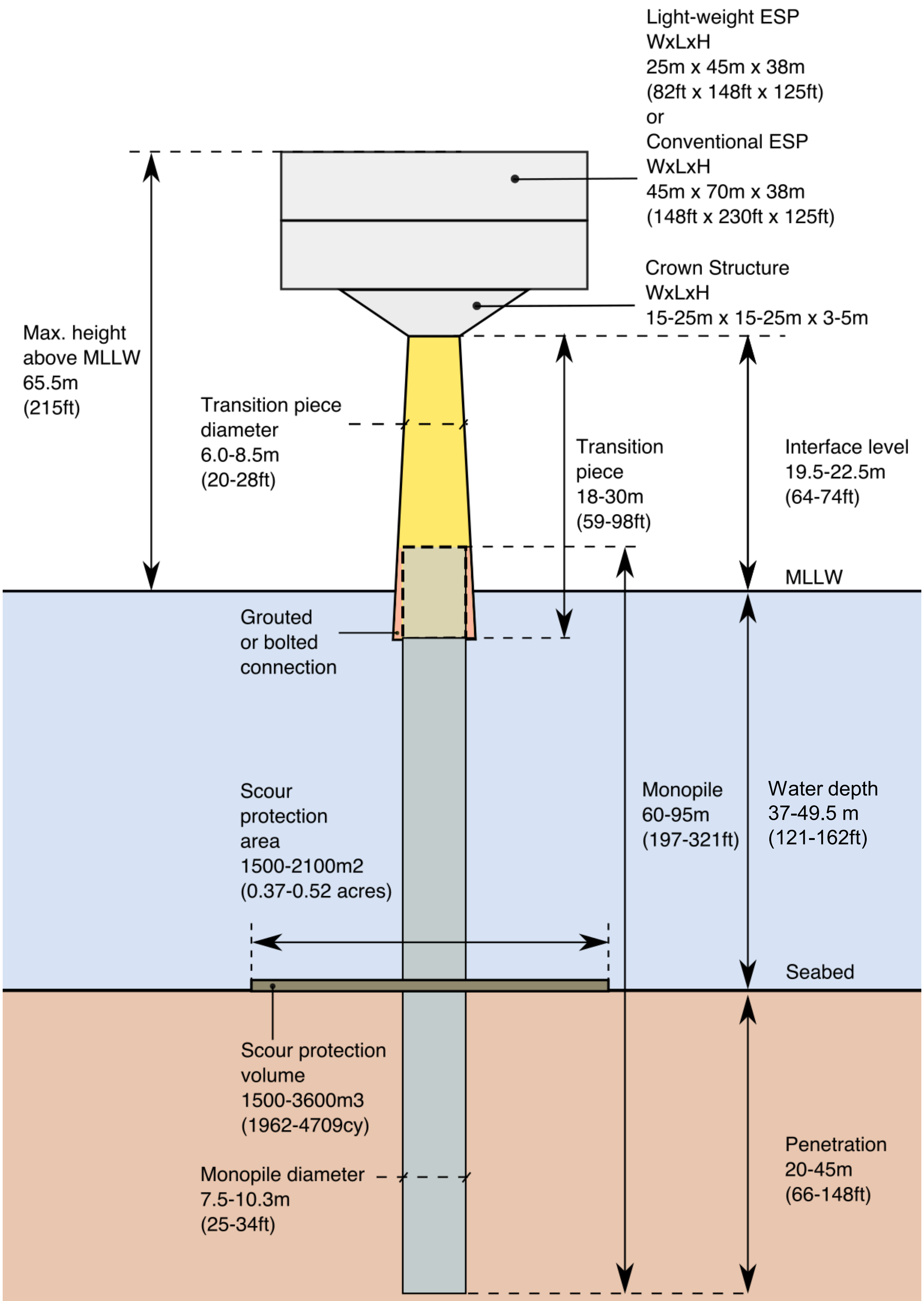

Figure 3.1-10
ESP Monopile Foundation

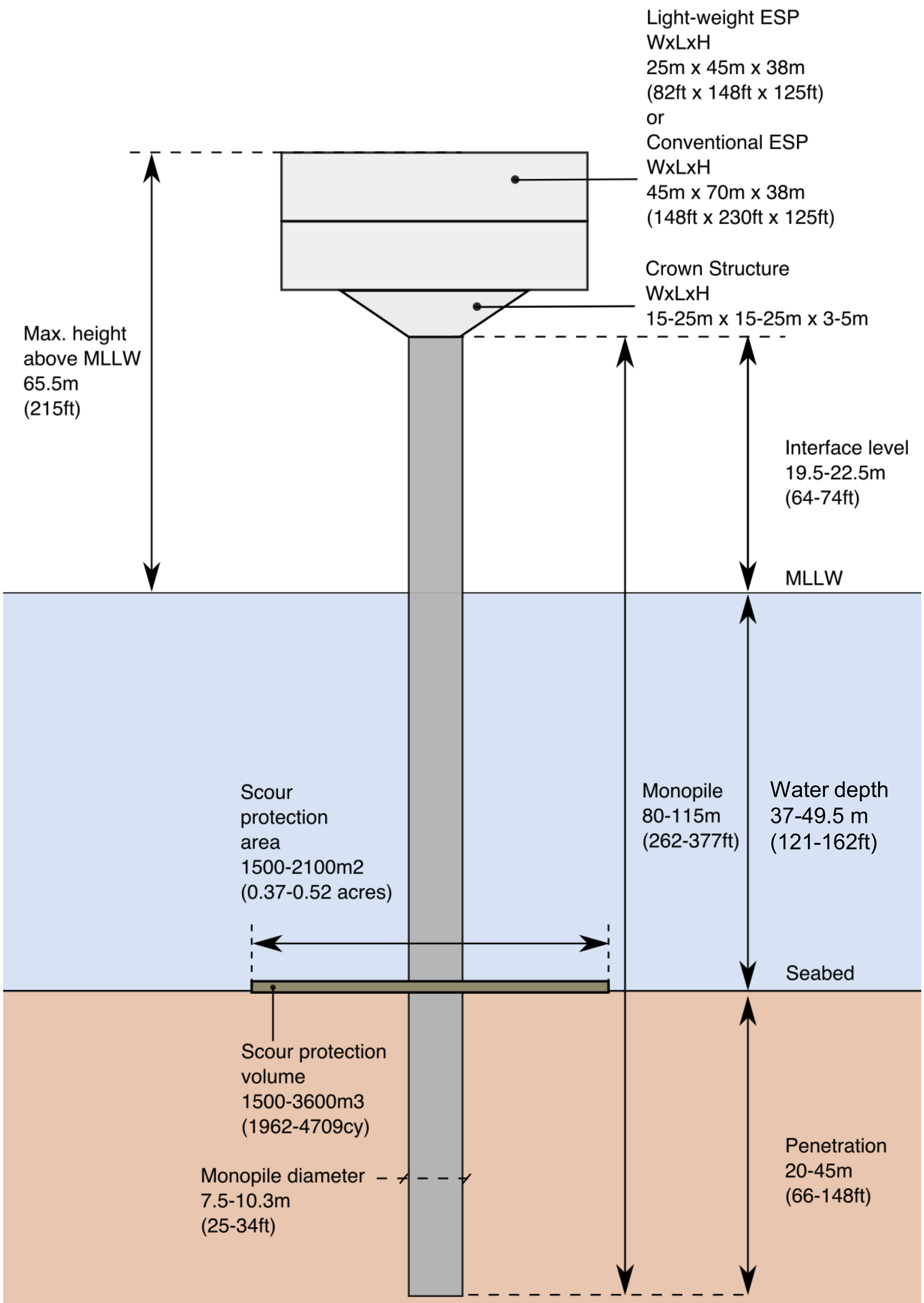

Figure 3.1-11
ESP Extended Monopile Foundation

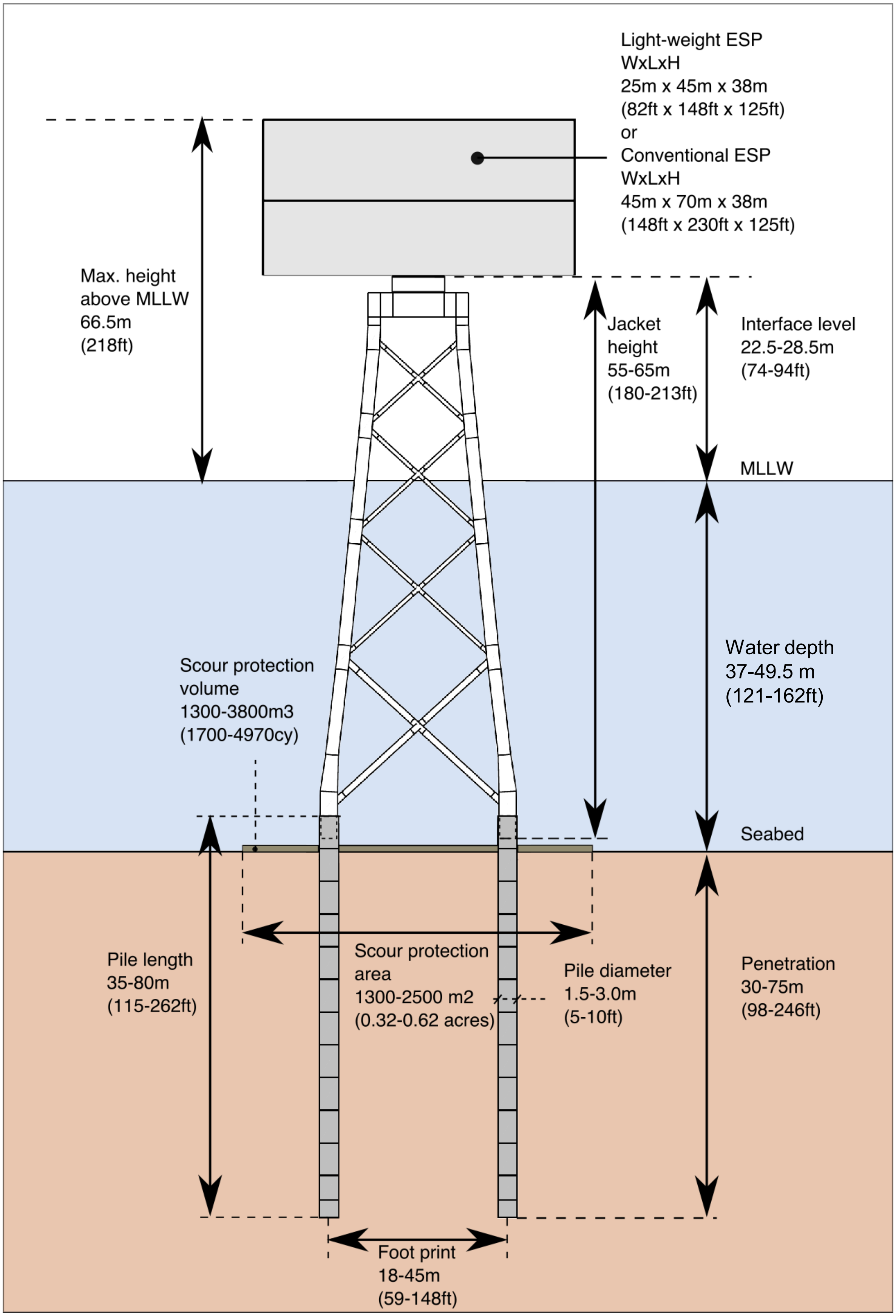

Figure 3.1-12
ESP Jacket Foundation

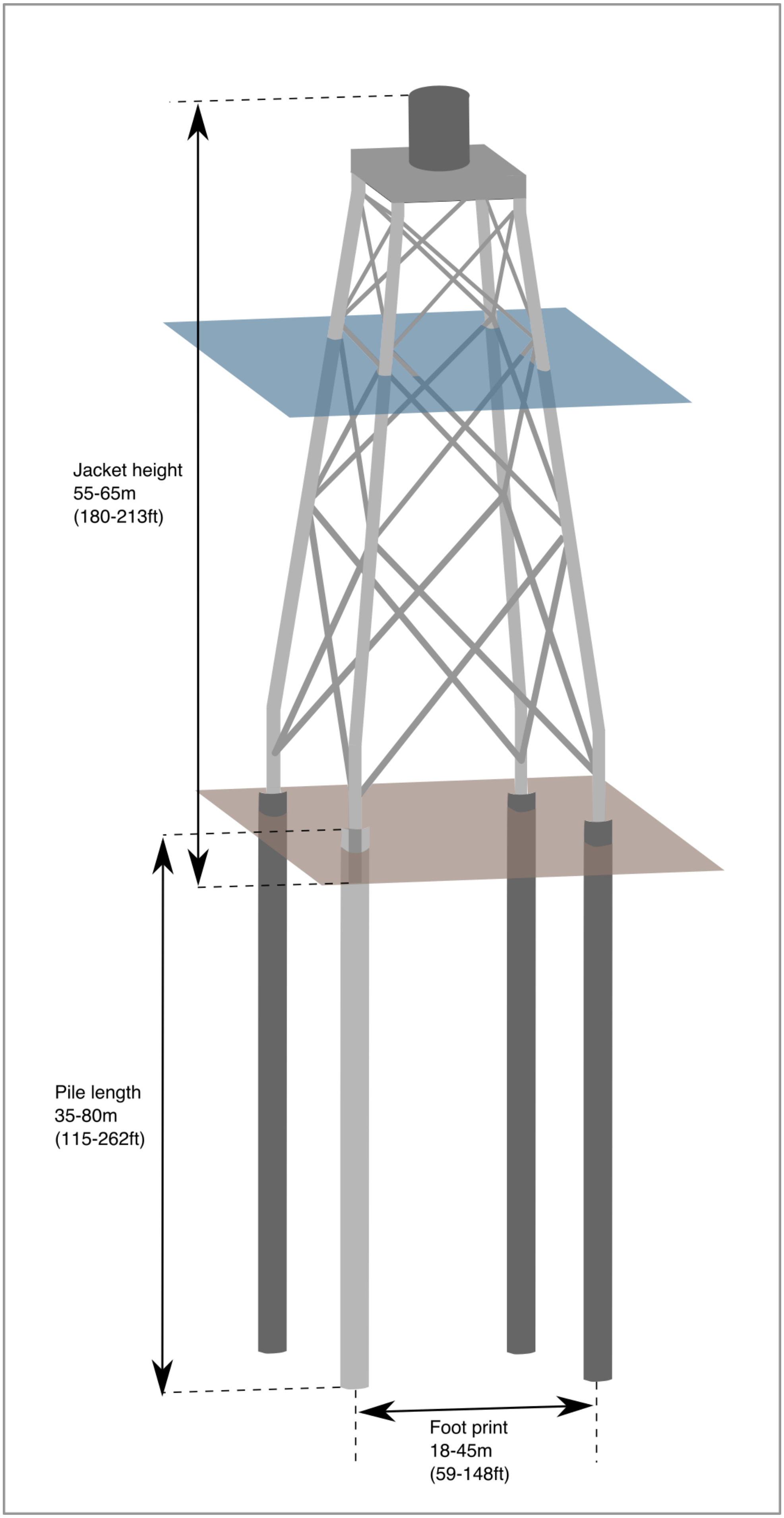

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Figure 3.1-13

ESP Jacket Foundation 3D Rendering

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Figure 3.1-14

Photographs of Electrical Service Platforms

Table 3.1-4 ESP Dimensions

Foundation Concept	Monopile		Jackets
	Monopile	Extended Monopile	Piles (3-4 piles)
Length	60-95m (197-312 ft)	80-115 m (262-377 ft)	35-80 m (115-262 ft)
Diameter (maximum)	7.5-10.3 m (25-34 ft)	7.5-10.3 m (25-34 ft)	1.5-3.0 m (5-10 ft)
Penetration	20-45 m (66-148 ft)	20-45 m (66-148 ft)	30-75 m (98-246 feet)
Bottom Pile Wall Thickness	70-100 mm (2.8-3.9 inches)	70-100 mm (2.8-3.9 inches)	60-80 mm (2.4-3.1 inches)
	Transition Piece	Transition Piece	Jacket Structure (including Transition Piece)
Length	18*-30 m (59-98 ft)	(N/A)	55-65 m (180-213 ft)
Diameter	6.0-8.5 m (20-28 ft)	(N/A)	18-45 m (59-148 ft)
Interface elevation	19.5-22.5 m MLLW (64-74 ft MLLW)	(N/A)	22.5-28.5** m MLLW (74-94 ft MLLW)
	Scour Protection	Scour Protection	Scour Protection
Scour protection volume	1,500-3,600 m^3 (1,962-4,709 cy)	1,500-3,600 m^3 (1,962 – 4,709 cy)	1,300-3,800 m^3 (1,700-4,970 cy)
Scour protection area	1,500-2,100 m^2 (0.37 -0.52 acres)	1,500-2,100 m^2 (0.37 -0.52 acres)	1,300-2,500 m^2 (0.32-0.62 acres)
	Crown Structure	Crown Structure	
Dimension (WxLxH)	15-25m x 15-25m x 3-5m (49-82 ft x 49-82 ft x 10-16.4 ft)	15-25m x 15-25m x 3-5m (49-82 ft x 49-82 ft x 10-16.4 ft)	(N/A)
Topside Component			
Dimensions for ESP (WxLxH)***	45m x70m x 38m (148ft x 230ft x 125ft)		
Complete ESP	Monopile /Extended Monopile		Jackets
Max Height above MLLW	65.5 m MLLW (215 ft MLLW)		66.5 m MLLW (218 ft MLLW)

* Length to account for the possibility of a bolted connection.

** Interface elevation is setup to account for the possibility of an interface placed above the tower access door.

***Dimensions for a conventional ESP are applicable to a 400 MW or an 800 MW ESP. Dimensions include possible helideck but do not include antennae.

3.1.5 Export Cables and Inter-Link Cables

3.1.5.1 Offshore Export Cable Corridor

The wind farm will connect to the onshore electrical grid via two offshore export cables that will travel north from the Offshore Project Area and make landfall onshore. Utilizing the Envelope concept for this part of the Project, there is one primary Offshore Export Cable Corridor ("OECC") with two route options through Muskeget Channel (see Figure 3.1-15). The OECC will pass through Muskeget Channel, turn west, and make landfall at the Covell's Beach Landfall Site in Barnstable (see Figure 3.1-15). The maximum length per cable is approximately 70-80 km (43-50 mi), which gives a total maximum length of export cables, assuming two cables, of 158 km[9] (98 mi).

3.1.5.2 Export Cable Separation Distances

A typical separation distance of 100 m (330 ft) will be maintained between the two cables to allow room for repairs, if needed (Figure 3.1-16). A total corridor width of 810 m (2,657 ft) will be maintained to allow for optimal routing of the cables. In some areas where more maneuverability may be required during construction, a corridor width of 1,000 m (3,280 ft) is planned. For sections where the cable crosses sensitive habitat areas or where a narrower corridor is needed for other reasons (e.g. where shoreline constrictions do not allow access), the recommended cable spacing may be decreased. Figure 3.1-15 shows the OECC.

3.1.5.3 Export Cable Design

Cable Design

Each offshore export cable will be comprised of a three-core 220 kV alternating current ("AC") cable for power transmission and one or two fiber optic cables for communication, temperature measurement, and protection of the high-voltage system (see Figure 3.1-17). The offshore export cables will be buried beneath the seafloor at a target depth of 1.5-2.5 m (5-8 ft); the minimum target burial depth is 1.5 m (5 ft) (see Section 4.2.3.3 for a description of cable installation techniques). The three copper or aluminum conductors will each be encapsulated by cross-linked polyethylene insulation. Waterproof sheathing will prevent the infiltration of water.

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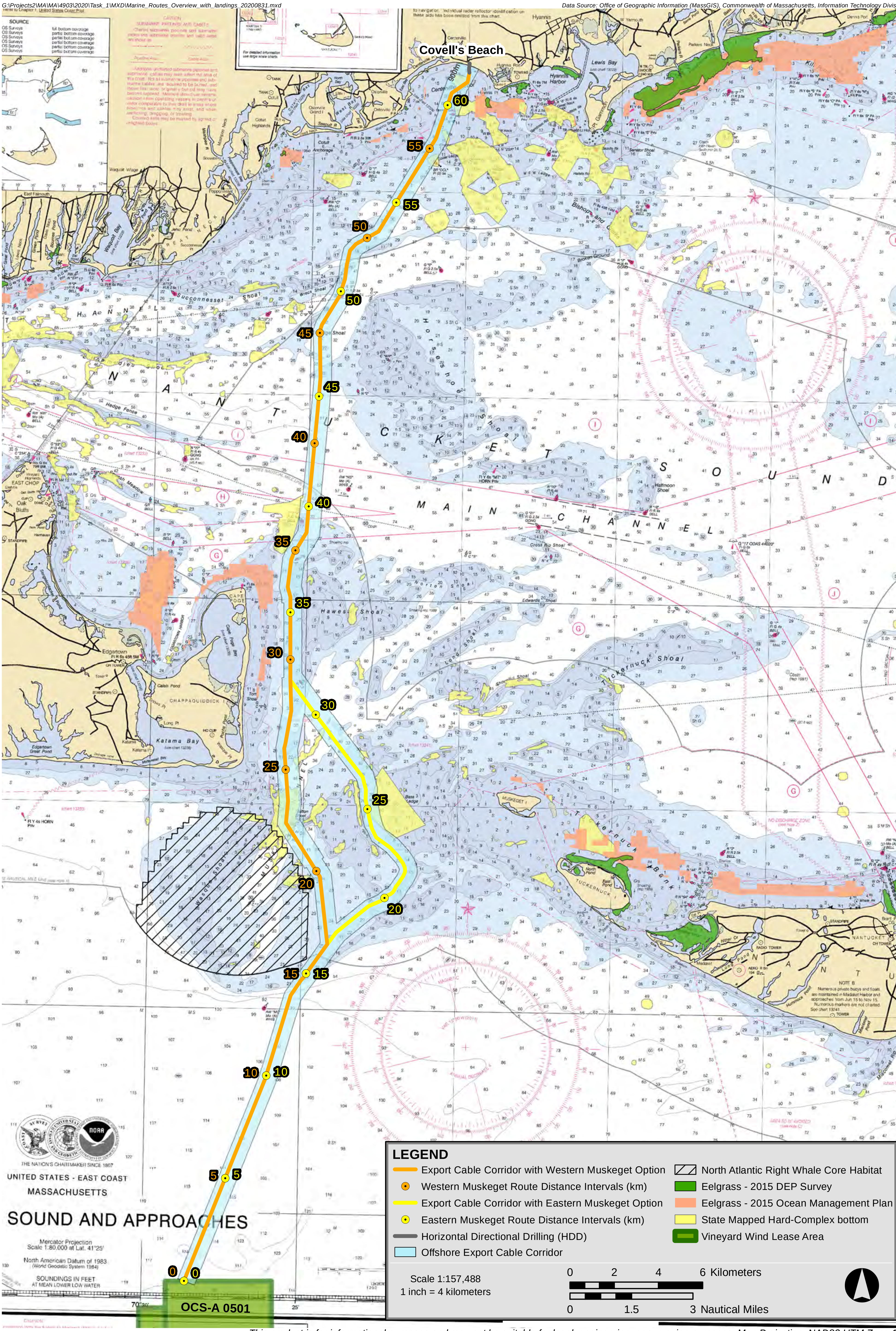
[9] Cable length is measured from the Landfall Site to one of the two potential ESP locations and includes an additional allowance for micro-siting.



This product is for informational purposes and may not be suitable for legal, engineering, or surveying purposes. Map Projection: NAD83 UTM Zone 19

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Figure 3.1-15a

Offshore Export Cable Corridor

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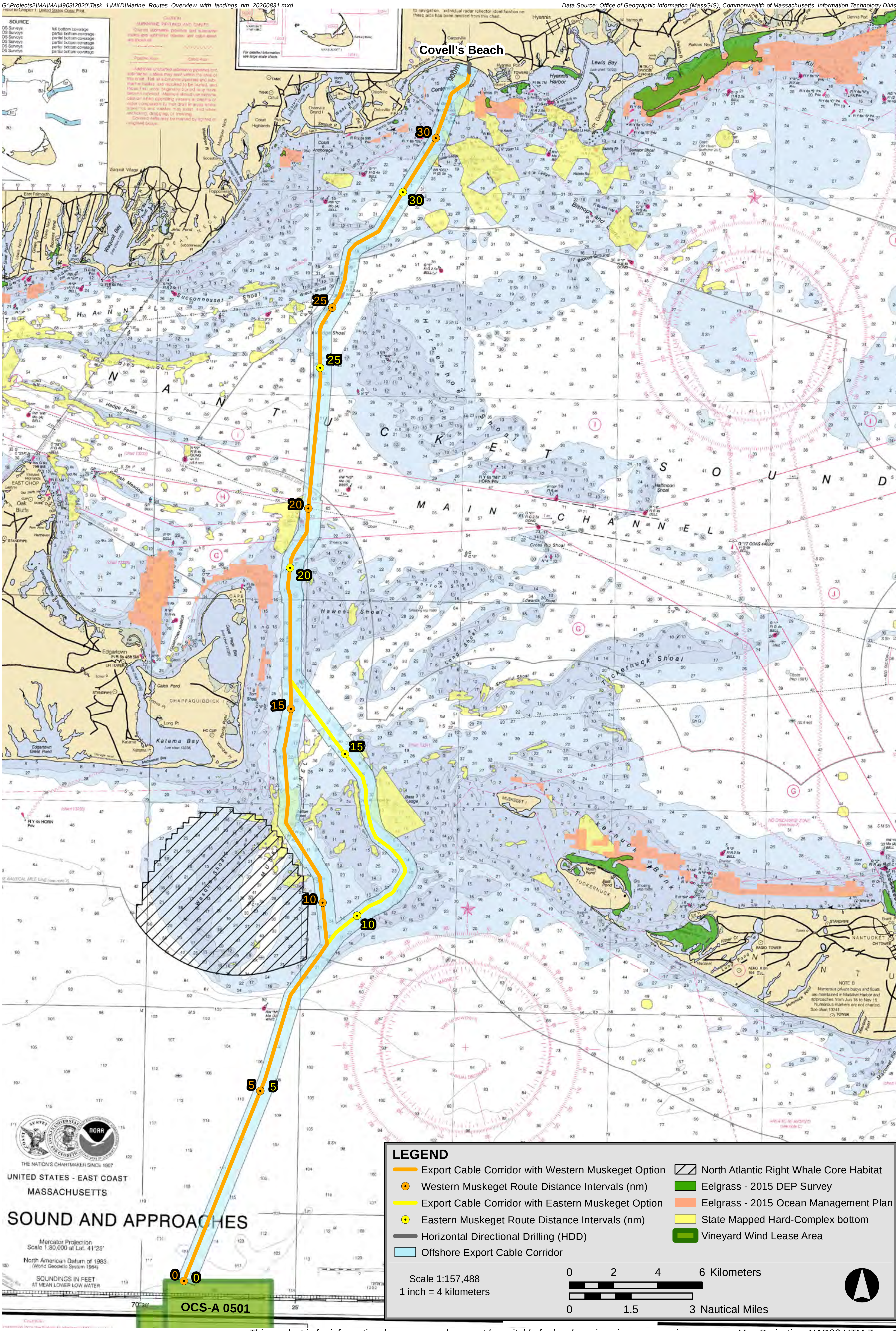
Data Source: Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, Information Technology Division



This product is for informational purposes and may not be suitable for legal, engineering, or surveying purposes. Map Projection: NAD83 UTM Zone 19

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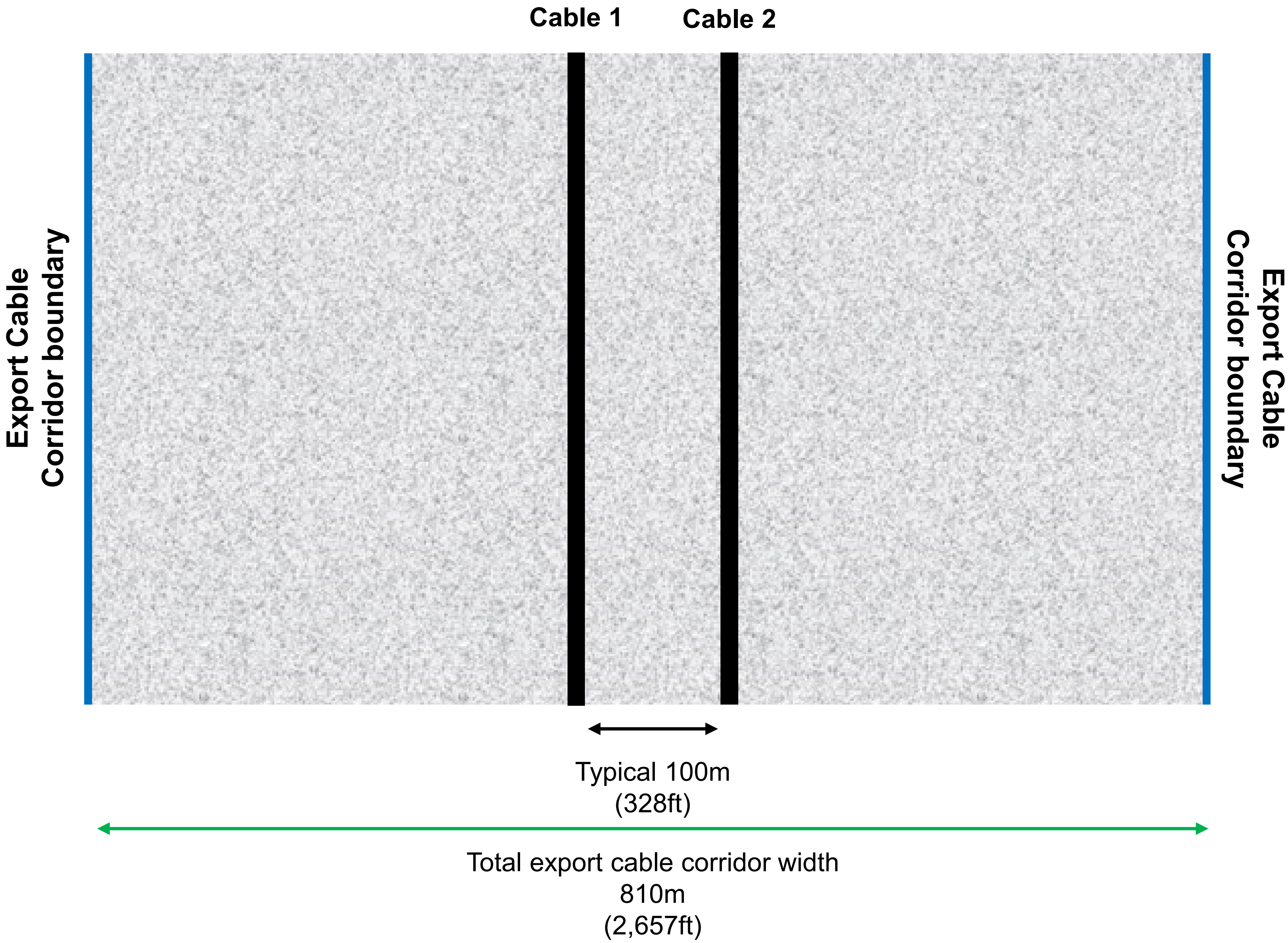
Figure 3.1-15b

Offshore Export Cable Corridor



Note: A 810 m wide corridor is planned. However, the corridor may up to 1,000 m wide in areas where more maneuverability is required during construction. In addition, the corridor width may be decreased where the cable crosses sensitive habitat areas or where shoreline constrictions do not allow access.

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Figure 3.1-16

Offshore Export Cable Spacing

Design:

1 Conductor (Al or Cu)

2 Inner semi-conducting layer

3 XLPE insulation

4 Outer semi-conducting layer

5 Swellable tape

6 Lead sheath

7 PE oversheath

8 Fibre optic cable

9 Filler profiles

10 Bedding (PP)

11 Armouring

12 Outer sheath (PP)

Figure 3.1-17

Typical Submarine Cable Cutaway

As already noted, two offshore export cables will be used for the Project. Additionally, if 400 MW conventional ESPs are used, the two ESPs will be inter-linked using the same 220 kV cable. All designs would provide sufficient redundancy, thus improving reliability, and would also ensure sufficient transmission capacity under conditions where full wind speeds are sustained for a long period of time.

Cable Protection

All offshore export and inter-array cables will be protected through the use of protection conduits put in place at the approach to the foundations and ESPs (see Figure 3.1-9). This protection consists of different components of composite material that protect the cables from fatigue loads and mechanical loads as they approach and enter the structures (for a distance of approximately 30 m [98 ft] outside the foundation). The cable protection system will be mounted around the cable on board the installation vessel and secured to the cable with a pull-in head.

In addition, in the event sufficient burial depths cannot be achieved or the cables need to cross other infrastructure (e.g., existing cables, pipes, etc.), alternative cable protection methods will be used. These alternative methods are:

- Rock placement, which involves laying rocks on top of the cable to provide protection.
- Concrete mattresses, which are prefabricated flexible concrete coverings that are laid on top of the cable. Alternately, the mattresses may be filled with grout and/or sand (referred to as grout/sand bags); this method is generally applied on smaller scale applications than concrete mattresses.
- Half-shell pipes or similar products made from composite materials (e.g., Subsea Uraduct from Trelleborg Offshore) or cast iron with suitable corrosion protection. Half-shell pipes come in two halves and are fixed around the cable to provide mechanical protection. Half-shell pipes or similar solutions are generally used for short spans, at crossings or near offshore structures, where there is a high risk from falling objects. The pipes do not provide protection from damage due to fishing trawls or anchor drags.

Vineyard Wind conservatively estimates that up to 10% of the total length of the offshore export cable system could require one of these alternative protection measures. The estimated length and area of offshore cables potentially requiring protection is presented in Table 6.5-5 of Volume III. Vineyard Wind intends to avoid or minimize the need for cable protection to the greatest extent feasible through careful site assessment and thoughtful selection of the most appropriate cable installation tool to achieve sufficient burial; therefore, the 10% value is expected to be a conservative estimate. For additional details, see the Initial Cable Burial Performance Assessment included as Appendix A of the COP Addendum.

3.1.6 *Inter-array Cables*

As already noted, the WTGs will be connected to the ESPs via 66 kV inter-array cables. These inter-array cables will be buried beneath the seafloor at a target depth of 1.5-2.5 m (5-8 ft); the minimum target burial depth is 1.5 m (5 ft) (see Section 4.2.3.6 for a description of inter-array cable installation). The expected cable type is the same three-core AC cable to be used for the offshore export cables, as described above in Section 3.1.5.3. The maximum outer diameter of these cables is anticipated to be 155-165 mm (6.1-6.5 inches). As they transmit different amounts of power, three different cross sections are envisaged for the cable: the likely copper or aluminum core cross sections are 240, 500, and 630 square millimeters ("mm^2"); however, a maximum size of 800 mm^2 may be considered to account for updates in technology.

The inter-array cables will connect radial "strings" of six to 10 WTGs to the ESPs. The design and optimization of the inter-array cable system will occur during final design of the Project, and will consider cable design and capacity, ground conditions, wind farm operating conditions, and installation conditions. This means Vineyard Wind is permitting an Envelope approach for the inter-array cables that will include any potential layout within areas of the WDA that have been surveyed.

One potential inter-array cable layout is provided on Figure 3.1-18 for illustrative purposes. As shown in here, the farthest WTG will have one outgoing connection and each subsequent WTG will have both an incoming and outgoing cable. As noted previously, the Project Envelope for the inter-array cable layout includes any portion of the WDA that has been surveyed; this survey area (which corresponds to the Area of Potential Effect) is shown on Figure 3.1-19. The maximum anticipated length of the inter-array cables for an 800 MW Project is approximately 275 km (171 mi).

As explained above in Section 3.1.5.3, all export and inter-array cables will be protected through the use of protection conduits at the approach to the foundations and ESPs. Additionally, for cases where the cables cannot be buried to a sufficient depth, the same protection methods described in Section 3.1.5.3 will be used. Vineyard Wind estimates that up to 10% of the total length of the inter-array cable could require one of these alternative protection measures.

3.2 Onshore Facilities

The Project's onshore facilities include the Landfall Site, the onshore export cables from the Landfall Site to the onshore substation, the onshore substation itself, and the connections from the substation to the existing bulk power grid.

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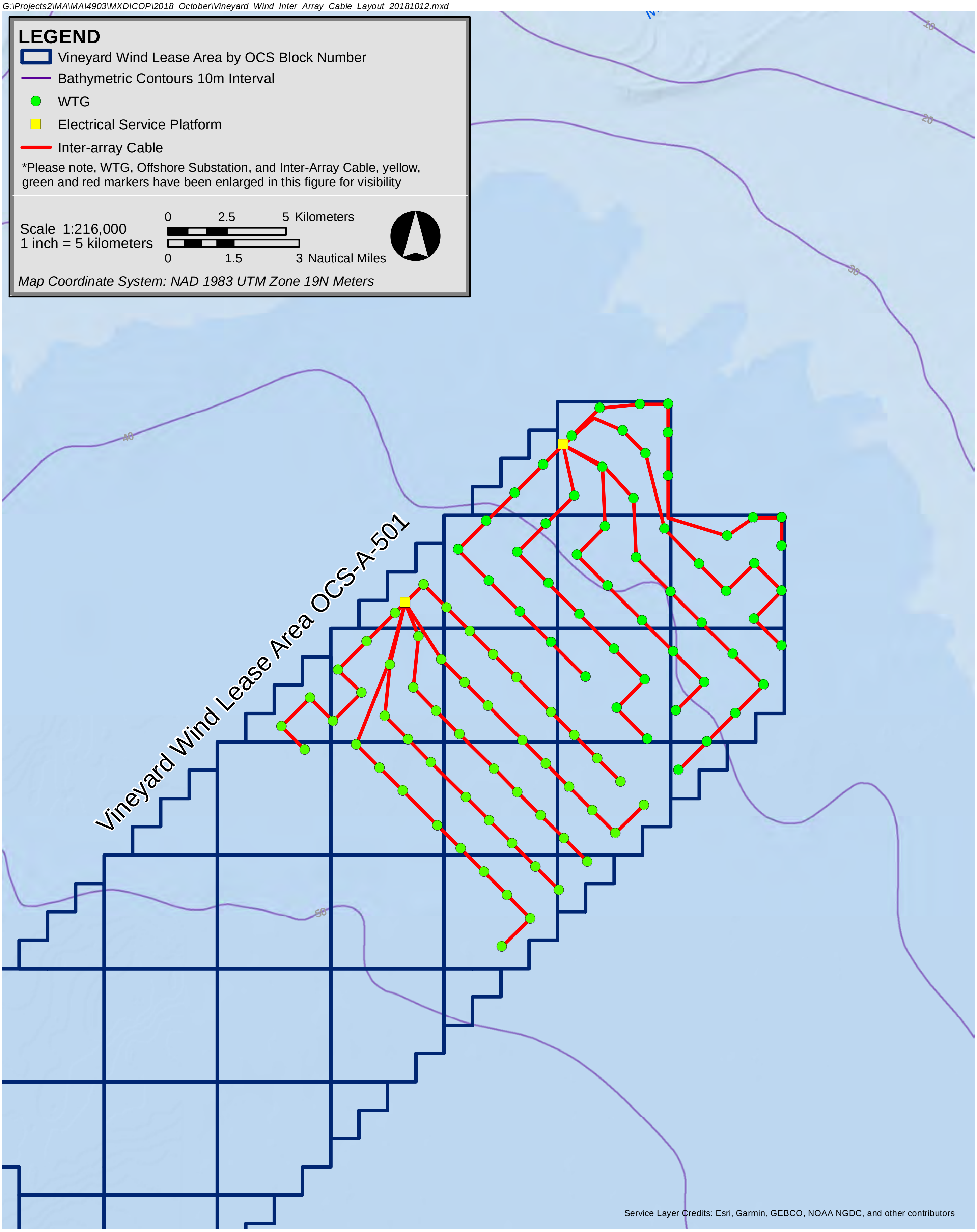

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Figure 3.1-18a

Vineyard Wind Turbine Layout: Inter-array Cable Layout Example

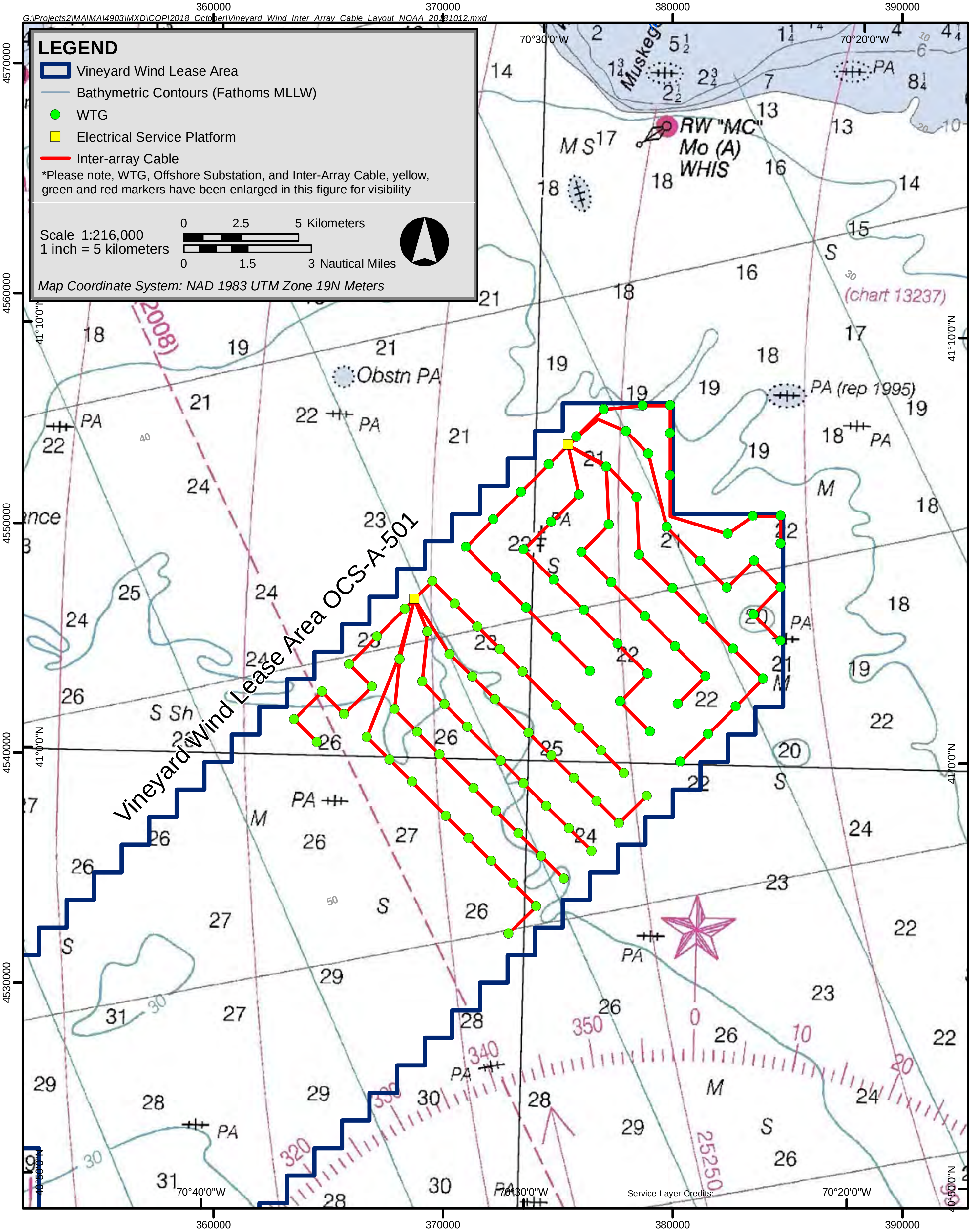

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Figure 3.1-18b

Vineyard Wind Turbine Layout: Inter-array Cable Layout Example

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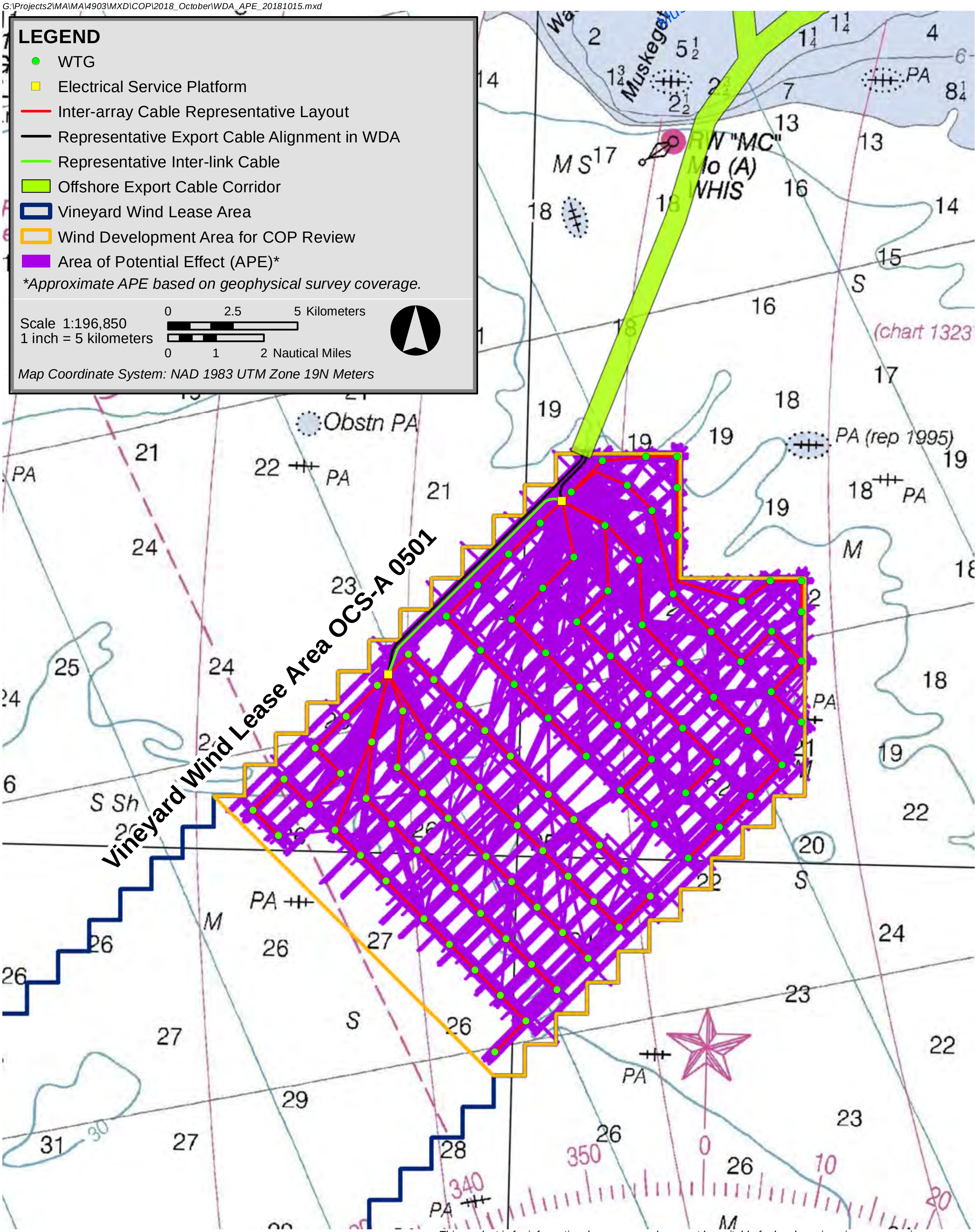

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Figure 3.1-19

WDA Area of Potential Effect

3.2.1 Landfall Site

Both offshore export cables will make landfall at the Covell's Beach Landfall Site in Barnstable (see Figure 3.1-15). The Covell's Beach Landfall Site is located on Craigville Beach Road near the paved parking lot entrance to a public beach that is owned and managed by the Town of Barnstable. This Landfall Site is considered advantageous for its relatively protected location within the Centerville Harbor bight. The Landfall Site is also considered a good candidate for cable landing given its superior egress and favorable inland routing to the Barnstable Switching Station via public roads.

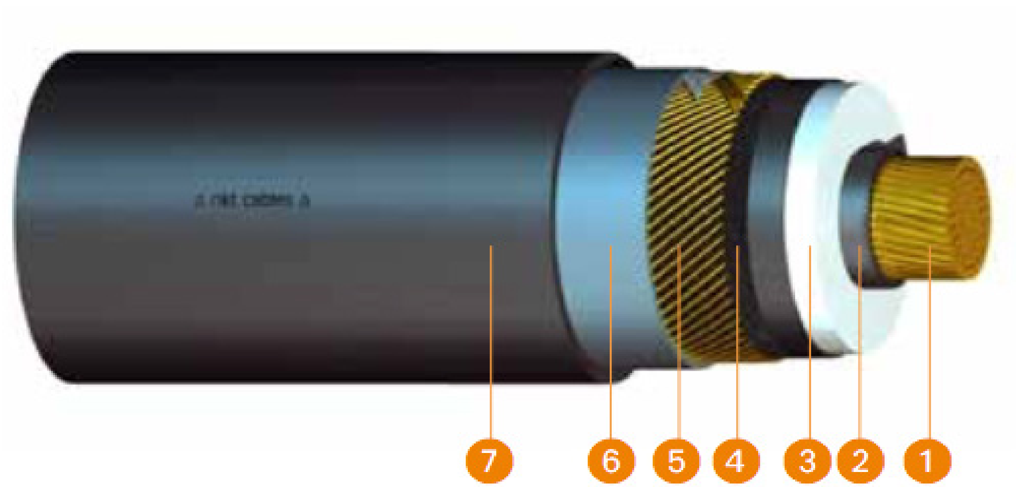
As the offshore export cables near the shoreline, horizontal directional drilling will be used to bring the cables beneath the nearshore area, the tidal zone, the beach, and adjoining coastal areas to the Covell's Beach Landfall Site. Construction of the Landfall Site is further discussed in Section 4.2.3.8.

3.2.2 Offshore to Onshore Transition

After the offshore export cables are brought to shore at the Landfall Site, the physical connection between the offshore export cables and the onshore export cables will be made in one or more underground concrete transition vaults. From the surface, the only visible components of the cable system will be the manhole covers.

Inside the vaults, each three-core submarine cable will be separated and spliced into three separate single-core cables. A manufacturer's cutaway of the landside cable is provided as Figure 3.2-1; three of these cables make up a single 220 kV AC circuit. The onshore export cables will be placed within a single duct bank, which is installed underground for the entire length of the Onshore Export Cable Route (discussed below in Section 3.2.3). The duct bank is constructed using heavy wall PVC pipes encased in concrete.

The layout of conduits within the duct bank, and hence the duct bank dimensions, will vary somewhat along the Onshore Export Cable Route. These conduits will be arrayed four conduits wide by two conduits deep (flat layout) or two conduits wide by four conduits deep (upright layout), with the total duct bank measuring approximately 1.5 m (five feet) wide and 0.8 m (2.5 feet) deep or vice versa.



Design:

1. Conductor (Al or Cu)
2. Inner semi-conducting layer
3. XLPE insulation
4. Outer semi-conducting layer
5. Wire screen (Al or Cu)
6. Lead sheath
7. PE oversheath

Figure 3.2-1

Onshore Cable Cutaway

The top of the duct bank typically has a minimum of 0.9 m (three feet) of cover comprised of properly compacted sand topped by pavement.

Once the duct bank is in place, the cables (one cable per sleeve) are pulled into place via underground splice vaults and associated manholes, which are placed every 457-607 m (1,500-2,000 ft) or more along the duct bank. The splice vaults are typically two-piece (top and bottom) pre-formed concrete "boxes" with holes at both ends to connect with the PVC piping and admit the cables.

3.2.3 Onshore Export Cable Route

The Onshore Export Cable Route will provide a connection from the underground vault at the Covell's Beach Landfall Site to the new onshore substation. The proposed Onshore Export Cable Route will allow the onshore export cables to be located entirely underground beneath public roadway layouts. The underground Onshore Export Cable Route is on the order of 8.5 km (5.3 mi) in length. The Onshore Export Cable Route is shown on Figure 2.2-1.

3.2.4 Onshore Substation and Grid Connection

As previously noted, the Project includes the construction of a new onshore substation. The Project's onshore substation site is located on the eastern portion of a previously developed site adjacent to an existing substation within the Independence Park commercial/industrial area in Barnstable. It consists of approximately 0.03 km^2 (8.55 acres) of mostly wooded land, but the site also includes previously disturbed land, portions of an existing building (the Cape Cod Times Production Center), a small building on the northern portion of the site, paved circulation roads, landscaped dividers, and parking lots for the former Cape Cod Times Production Center.

The onshore substation site is bordered to the north by the Barnstable Switching Station, to the west by part of the former Cape Cod Times building, to the south by Independence Drive, and to the east by an electric transmission corridor (see Figure 2.2-1). The buried duct bank will enter the Project onshore substation site via Independence Drive. The Project connection into the bulk power grid will be made via available positions at Eversource's Barnstable Switching Station, located just to the north of the onshore substation site.

The Project's substation will house up to four 220 kV /115 kV "stepdown" transformers, switchgear, and other necessary equipment. A battery may also be installed at the onshore substation to store power.

3.2.5 Construction Facilities

Vineyard Wind has signed a letter of intent to the use the New Bedford Marine Commerce Terminal ("New Bedford Terminal"), owned by the Massachusetts Clean Energy Center ("MassCEC"), to support Project construction. The 26-acre New Bedford Terminal is located on the City's extensive industrial waterfront and was purpose built to support offshore wind energy projects. The terminal is just upstream of the Army Corps of Engineers hurricane barrier and has ready access to interstate highways. An aerial photo of the New Bedford Terminal and the surrounding marine industrial area is provided as Figure 3.2-2.

Vineyard Wind plans to use the New Bedford Terminal to offload shipments of components, prepare them for installation, and then load components onto jack-up barges or other suitable vessels for delivery to the lease area for installation.[10] Some component fabrication and fitup may also take place at New Bedford Terminal.

However, given the scale of the Project and the possibility that one or more other offshore wind projects may be using portions of the New Bedford Terminal at the same time, Vineyard Wind may need to stage certain activities from other Massachusetts or North Atlantic commercial seaports. (At this juncture, the Project may use a port facility in nearby Rhode Island to offload, store, and stage the turbine blades or other components for delivery to the offshore Wind Development Area, as needed.) Consequently, one or more of the ports listed in Table 3.2-1 may be used during construction of the Project. These ports are shown on Figure 3.2-3.

Each port facility being considered for the Project is located within an industrial waterfront area and was selected for further evaluation, in part, based on the port's existing infrastructure and capacity to host construction and installation activities. The greatest distance from a potential port to the WDA is 188 nautical miles (this value represents the distance between the WDA and the point where a vessel leaving a potential Canadian port enters the US Exclusive Economic Zone)[11].

[10] Monopiles may not be loaded onto vessels for transport but may instead be pulled by tugs while floating in the water.

[11] Vessels traveling from Europe to New Bedford may travel farther through US waters (approximately 300 nautical miles).

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Data Source: Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, Information Technology Division

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Figure 3.2-2

New Bedford Marine Commerce Terminal

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Data Source: Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, Information Technology Division

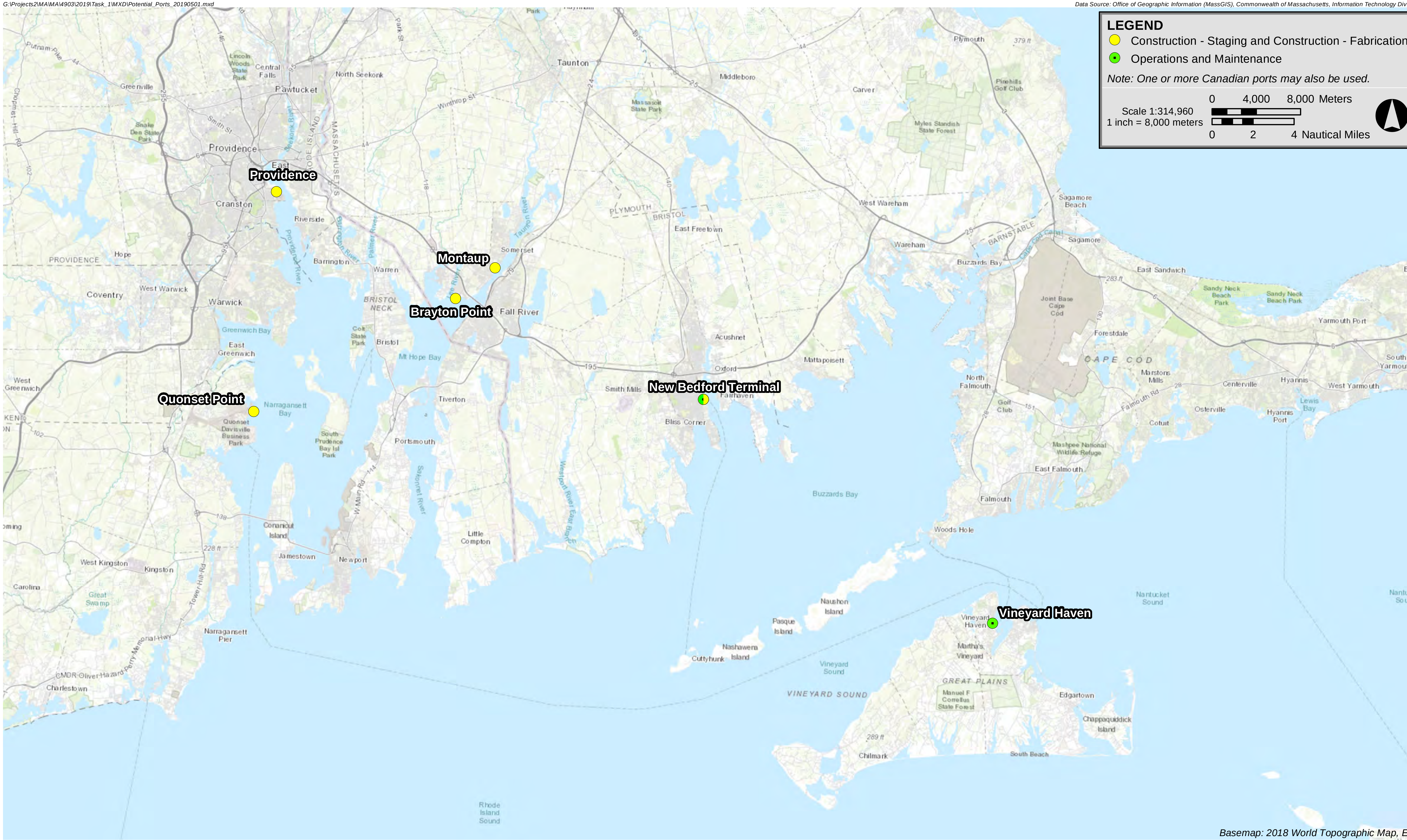

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Figure 3.2-3

Possible US Ports Used During Construction and O&M

The construction and installation phase will likely require port facilities with high load-bearing ground and deck capacity, adequate vessel berthing parameters, and suitable laydown and fabrication space. Site-specific modifications performed by the site owner/lessor may be required to meet those requirements. Grading and resurfacing of land-side areas, for example, may be required to accommodate materials and equipment used during construction and installation. The port facility may also require shoreline stabilization, maintenance dredging, and installation of miscellaneous equipment to berth construction and installation vessels. New structures to accommodate workforce and equipment needs may also be required.

Table 3.2-1 describes the ports that may be used during construction. See Table 3.2-2 in Section 3.2.6 for a discussion of ports used by the Project during O&M. Vineyard Wind will not direct or implement any port improvements that may be made. Rather, Vineyard Wind will consider whether the ports are suitable for Vineyard Wind's needs if and when any necessary upgrades are made by the owner/lessor.

Table 3.2-1 Possible Ports Used During Construction

Port
Massachusetts Ports
New Bedford Marine Commerce Terminal
Other areas in New Bedford Port
Brayton Point
Montaup
Rhode Island Ports
Providence
Quonset Point
Canadian Ports*
Sheet Harbor
St. John
Halifax

Note: Ports used during Operations and Maintenance are described in Table 3.2-2.

*Analysis of potential Canadian ports that may be used is ongoing.

Additionally, the MassCEC recently finalized a study that identified and characterized other Massachusetts port facilities which could be used to support offshore wind energy construction projects. Vineyard Wind is committed to continuing to work cooperatively with the MassCEC and will work to integrate the results of this study into construction planning efforts.

3.2.6 Operations & Maintenance Facilities

Once the first increment of the Vineyard Wind project is installed, tested, and commissioned, the Project will enter an up to 30-year operating phase. In support of project operations and the necessary maintenance activities, Vineyard Wind will develop Operations and Maintenance Facilities (O&M Facilities) that will include management and administrative team offices, a control room, office and training space for technicians and engineers, shop space, and warehouse space for parts and tools. These functions will be co-located, if feasible.

The O&M Facilities will also include pier space for Crew Transport Vessels ("CTV") and other larger support vessels. CTVs are purpose built to support offshore wind energy projects; they are typically about 23 m (75 ft) in length and set up to safely and quickly transport personnel, parts, and equipment (see Figure 3.2-4 for a photo of a representative CTV). CTVs are typically used in conjunction with helicopters. Helicopters can be used when rough weather limits or precludes the use of CTVs as well as for fast response visual inspections and repair activities, as needed. The helicopter(s) used to support operations and maintenance activities would ideally be based at a general aviation airport in reasonable proximity to the O&M Facilities.

Larger support vessels are typically a Service Operations Vessel ("SOV"). These larger vessels have onboard crew and maintenance team quarters, shop facilities, a large open deck, appropriate lifting and winch capacity, and, in some instances, a helipad. These vessels are typically 80-90 m (~260-300 ft) in length. SOVs are usually diesel electric powered with dynamic positioning.

Vineyard Wind plans to locate the Project's O&M Facilities in Vineyard Haven on Martha's Vineyard. However, Vineyard Wind intends to use port facilities at both Vineyard Haven and the New Bedford Terminal to support O&M activities (see Table 3.2-2). Smaller vessels (e.g. CTVs or SOVs) used for O&M activities will likely be based out of Vineyard Haven. Larger vessels used for major repairs during O&M (e.g. jack-up vessels, heavy cargo vessels, etc.) would likely use the New Bedford Terminal.

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Figure 3.2-4

Crew Transfer Vessel (CTV) Examples

Table 3.2-2 Possible Ports Used During O&M

Port	Types of Improvements That May Be Required (To Be Completed by Port Owner/Operator Prior to Use by Vineyard Wind)
Massachusetts Ports	
New Bedford Marine Commerce Terminal	N/A. The New Bedford Terminal was specifically developed to accommodate offshore wind development.
Vineyard Haven	Improvements to existing marine infrastructure (e.g., dock space for CTVs, access, etc.) and to structures (office and warehouse space). It is expected that any needed improvements would be coordinated with the lessor.

3.3 Fabrication

Project components will be fabricated by skilled manufacturers in the US, Europe, or elsewhere. Fabrication for the Project is summarized in Table 3.3-1 below.

Table 3.3-1 Summary of Fabrication for the Project

Project Component	Description
Monopiles	A large diameter steel pile built up by cylindrical steel cans joined by circumferential welds.
Transition Pieces	A structure made of various steel structures welded together, with a platform that is mounted onto the end of the monopile to provide a stable platform for the wind turbine.
Jackets and Transition Pieces	A large lattice type structure jointed by x-bracing of cylindrical steel joined by welding.
Tower	Steel component placed on top of the transition piece. It consists of sections which are bolted together with flange joints.
Nacelle	The top section of the tower. The nacelle is made of fiberglass covering the structural part made of steel.
Hub	Steel component that supports the three blade bearings and transfers the forces from the blades to the generator.
Blades	Blades are composed of carbon and fiberglass.
220 kV Cables	Copper or aluminum triple-core cables.
66 kV Cables	Copper or aluminum core cables.
ESP Foundations	See monopiles and jackets above.
ESP Topside Structure	Upper part of the ESP including the transformers and other electrical equipment.