4.0 Electric Grid Interconnection

A suitable grid interconnection site for a proposed offshore wind pilot project must be capable of handling 15 to 30 MW of wind generation at an interconnection voltage of 34.5 kV. The interconnection location must be relatively close to the coast line to minimize the overall distance between the interconnection point and the wind project, to minimize the length of the generator leader line and provide the most economic connection to the Maine Electric grid.

4.1 INTERCONNECTION LOCATIONS

A list of potential electrical interconnection locations was created by identifying all medium voltage (34.5 kV) and high voltage (115 kV) electric facilities within ten (10) miles of the Maine coastline. This process resulted in a compilation of 61 potential sites in Central Maine Power Company's (CMP) service territory and 18 potential sites in Bangor Hydro Electric Company's (BHE) service territory as follows in Table 4-1:

Table 4-1: Potential interconnection locations by County

CENTRAL MAINE POWER AREA	
York County	18
Cumberland County	20
Sagadahoc County	4
Lincoln County	7
Knox County	7
Waldo County	5

BANGOR HYDRO ELECTRIC AREA	
Hancock County	10
Washington County	8

Figure 4-1 shows a map of the potential interconnection locations in the Central Maine Power and the Bangor Hydro Electric service areas.

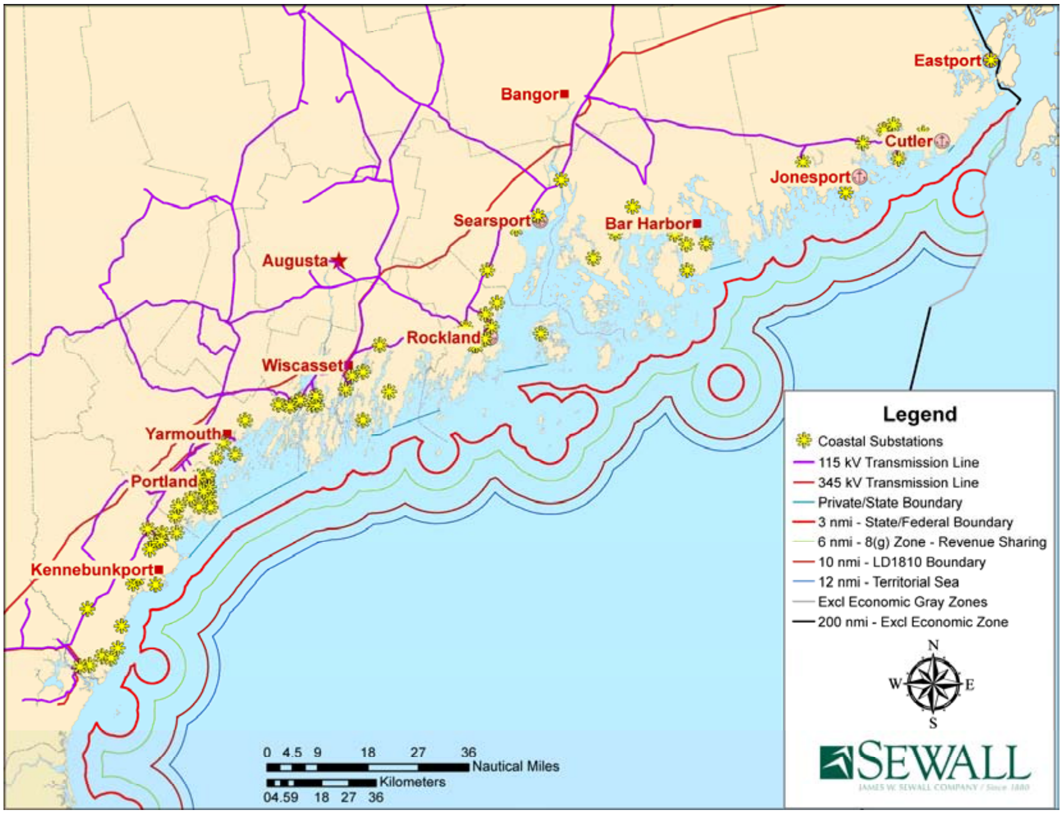

Figure 4-1: Potential interconnection locations in Central Maine Power and Bangor Hydro service areas

These interconnection sites were further evaluated based on their relative grid stiffness (ratio of available fault duty to project size), their general readiness to accept up to 30 MW of wind generation and their location relative to the proposed wind project areas of interest. Any interconnection site that offered a grid stiffness ratio of less than 5:1 was rejected as a viable site. Any interconnection site that could not accommodate the transmission of 30 MW over its existing transmission system was also rejected as a viable site. Finally, any interconnection site that was in excess of 60 km from a proposed wind project was rejected as a viable site. A second evaluation was conducted November 2010 to identify any additional interconnection sites that could accommodate a smaller 15 MW wind project.

For the purpose of completing this interconnection study, four (4) areas of interest for offshore project development have been identified off the coast the Maine (see Figure 4-2). These sites run from the southern part of Maine off York Beach to the eastern part of coastal Maine near Machias Bay. These sites are identified as Areas 1 through 4 with Area No. 1 being the southernmost and Area No. 4 being the easternmost. Each area is characterized by a different range of interconnection locations and options.

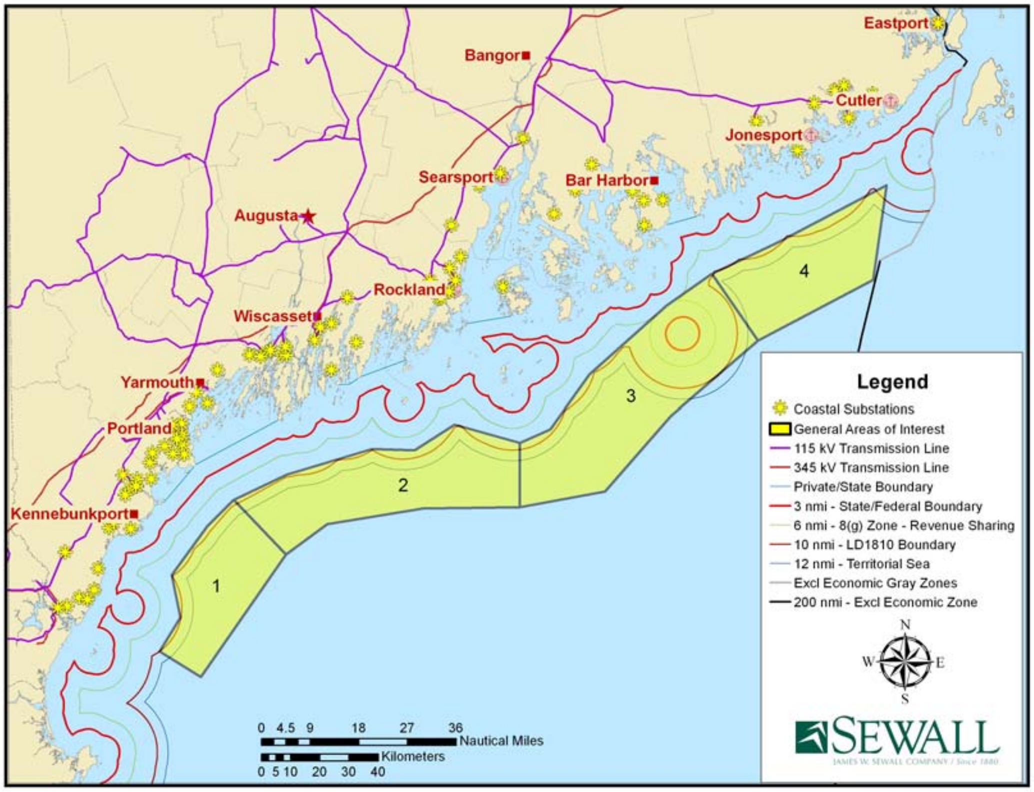

Figure 4-2: General areas of interest for offshore wind project development

Area No. 1 offers a generous range of interconnection opportunities that exist in York and Cumberland Counties. There are an assortment of good 34.5 kV and 115 kV interconnection locations in this vicinity with the best candidates listed in Table 4-2.

Table 4-2: Interconnection locations for Area No. 1 (Projects 30 MW or less)

OWNER	SUBSTATION NAME	VOLTAGE
CMP	York – 1	34.5 kV
CMP	York – 2	34.5 kV & 115 kV
CMP	York – 7	34.5 kV
CMP	York – 8	34.5kV
CMP	Cumberland – 1	34.5 kV & 115 kV
CMP	Cumberland – 5	115 kV
CMP	Cumberland – 8	34.5 kV & 115 kV
CMP	Cumberland – 10	34.5 kV & 115 kV
CMP	Cumberland – 11	34.5 kV
CMP	Cumberland – 15	115 kV

Table 4-3 lists additional interconnection locations for Area No. 1 for projects of 15 MW or less as determined by the November 2010 interconnection evaluation.

Table 4-3: Additional interconnection locations for Area No. 1 (15 MW or less)

OWNER	SUBSTATION NAME	VOLTAGE
CMP	York – 4	34.5 kV
CMP	York – 6	34.5 kV
CMP	York – 9	34.5 kV
CMP	York – 10	34.5kV
CMP	York-16	34.5 kV
CMP	Cumberland – 2	34.5 kV

Area No. 2 also offers a good range of interconnection opportunities that exist in Cumberland, Sagadahoc, Lincoln and Knox Counties. There are an assortment of 34.5 kV and 115 kV interconnection locations in this vicinity with the best candidates listed in Table 4-4.

Table 4-4: Interconnection locations for Area No. 2 (Projects 30 MW or less)

OWNER	SUBSTATION NAME	VOLTAGE
CMP	Cumberland – 1	34.5 kV & 115 kV
CMP	Cumberland – 5	115 kV
CMP	Cumberland – 8	34.5 kV & 115 kV
CMP	Cumberland – 10	34.5 kV & 115 kV
CMP	Cumberland – 11	34.5 kV
CMP	Cumberland – 15	115 kV
CMP	Lincoln – 3	115 kV
CMP	Lincoln – 4	34.5 kV & 115 kV
CMP	Lincoln – 7	34.5 kV
CMP	Sagadahoc -1	34.5 kV & 115 kV
CMP	Sagadahoc – 2	34.5 kV
Private	Knox – 1	34.5 kV & 115 kV

Table 4-5 lists additional interconnection locations for Area No. 2 for projects of 15 MW or less as determined by the November 2010 interconnection evaluation.

Table 4-5: Additional interconnection locations for Area No. 2 (15 MW or less)

OWNER	SUBSTATION NAME	VOLTAGE
CMP	Lincoln – 1	34.5 kV

Area No. 3 offers an extremely limited range of interconnection opportunities that exist in Knox and Hancock Counties. This area of interest is positioned off the barrier islands of Vinalhaven, Isle au Haut, Swans Island, Stonington, and Deer Isle. The electric systems in this area are very weak and largely consist of 15 kV distribution systems capable of handling less than ten (10) MW of load. There is a very limited selection of interconnection locations in this vicinity with the best candidates listed in Table 4-6.

Table 4-6: Potential interconnection locations for Area No. 3

OWNER	SUBSTATION NAME	VOLTAGE
Private	Knox – 1	34.5 kV & 115 kV
CMP	Knox – 4	34.5 kV & 115 kV
BHE	Hancock – 6	34.5 kV – less than 15 MW

No additional interconnection locations were determined for Area No. 3 from the November 2010 evaluation of a smaller 15 MW project.

Area No. 4 offers a limited range of interconnection opportunities that exist in Washington County. Due to the rural nature of this area, there is a limited selection of 34.5 kV and 115 kV interconnection locations in this vicinity with the best candidates listed in Table 4-7.

Table 4-7: Potential interconnection locations for Area No. 4

OWNER	SUBSTATION NAME	VOLTAGE
BHE	Washington – 1	34.5 kV– less than 25 MW
BHE	Washington – 2	34.5 kV – less than 15 MW
BHE	Washington – 3	34.5 kV – less than 15 MW
BHE	Washington – 4	34.5 kV – less than 15 MW
BHE	Washington – 7	34.5 kV
BHE	Washington – 8	34.5 kV & 115kV

These identified sites will require further specific load flow study analysis to verify that there would likely be no significant adverse impacts to the transmission system resulting

from the interconnection of 15 to 30 MW of wind turbine generation.
The following pre-feasibility study provides a cursory examination of these sites.

4.2 CONNECTION PRE-FEASBILITY STUDY/AVAILABLE CAPACITY

The primary objectives of this pre-feasibility study are to evaluate potential interconnection locations for 30 MW of offshore wind generation and to perform a cursory assessment as to whether the interconnection will have a significant adverse impact on the steady-state reliability of the Central Maine Power (CMP) Company 115 kV transmission and 34.5 kV sub-transmission systems. Note that stability conditions were not analyzed in as part of this study.

4.2.1 Study Area

Transmission System

The primary focus of this study is the 34.5 kV and 115 kV facilities located along the coastal region of CMP's service territory. The Project is assumed to be either interconnected directly into the 34.5 kV sub-transmission system or to the 115 kV transmission system via an additional 115/34.5 kV step-up transformer. The Project interconnection will also involve a significant, radial, submarine cable that will span the distance between the offshore collector system and the onshore interconnection point.

The substation facilities listed in Table 4-8 and identified in Figure 4-3 were evaluated in this study as possible locations for a 30 MW or less interconnection. In a similar manner, the substation facilities listed in Table 4-9 and identified in Figure 4-4 were evaluated for this study as possible locations for a 15 MW or less interconnection.

Table 4-8: Substation facilities evaluated in the pre-feasibility study for a 30 MW or less interconnection

SUBSTATION	VOLTAGE
CMP – Cumberland – 1	34.5 kV
CMP – Cumberland – 5	115kV
CMP – Cumberland – 8	115kV
CMP – Cumberland – 10	34.5 kV
CMP – Cumberland – 11	34.5 kV
CMP – Cumberland – 15	115kV
Private – Knox – 1	115kV
CMP – Knox – 4	34.5 kV
CMP – Lincoln – 3	115kV
CMP – Lincoln – 4	34.5 kV
CMP – Lincoln – 7	34.5 kV
CMP – Sagadahoc – 2	34.5 kV
CMP – York – 1	34.5 kV
CMP – York – 2	34.5 kV
CMP – York – 7	34.5 kV
CMP – York – 8	34.5 kV

Table 4-9: Substation facilities evaluated in the pre-feasibility study for a 15 MW or less interconnection

SUBSTATION	VOLTAGE
CMP – Cumberland – 2	34.5 kV
CMP – Lincoln – 1	34.5 kV
CMP – York – 4	34.5 kV
CMP – York – 6	34.5 kV
CMP – York – 9	34.5 kV
CMP – York – 10	34.5 kV
CMP – York – 16	34.5 kV

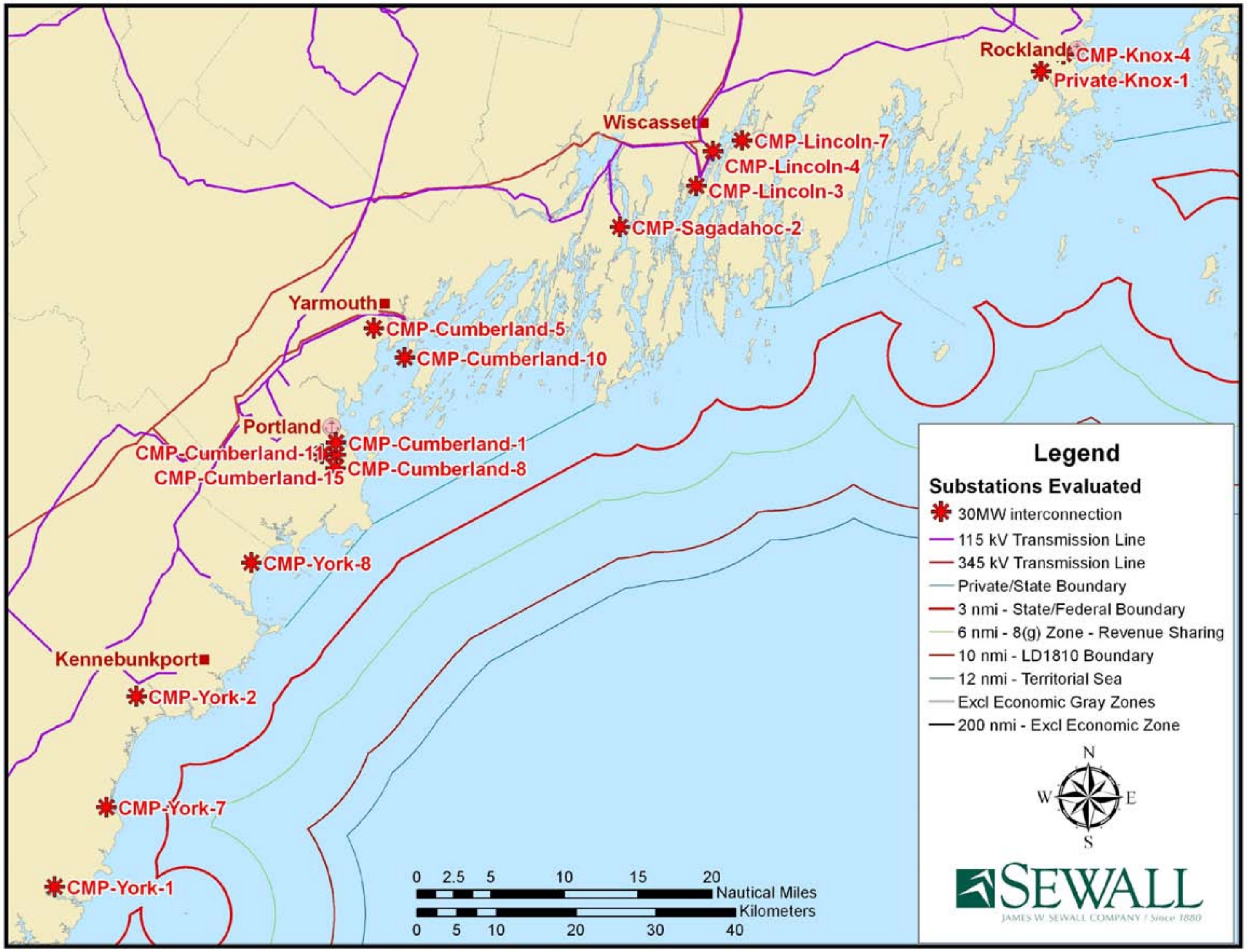

Figure 4-3: Connection pre-feasibility study substations (30 MW or less)

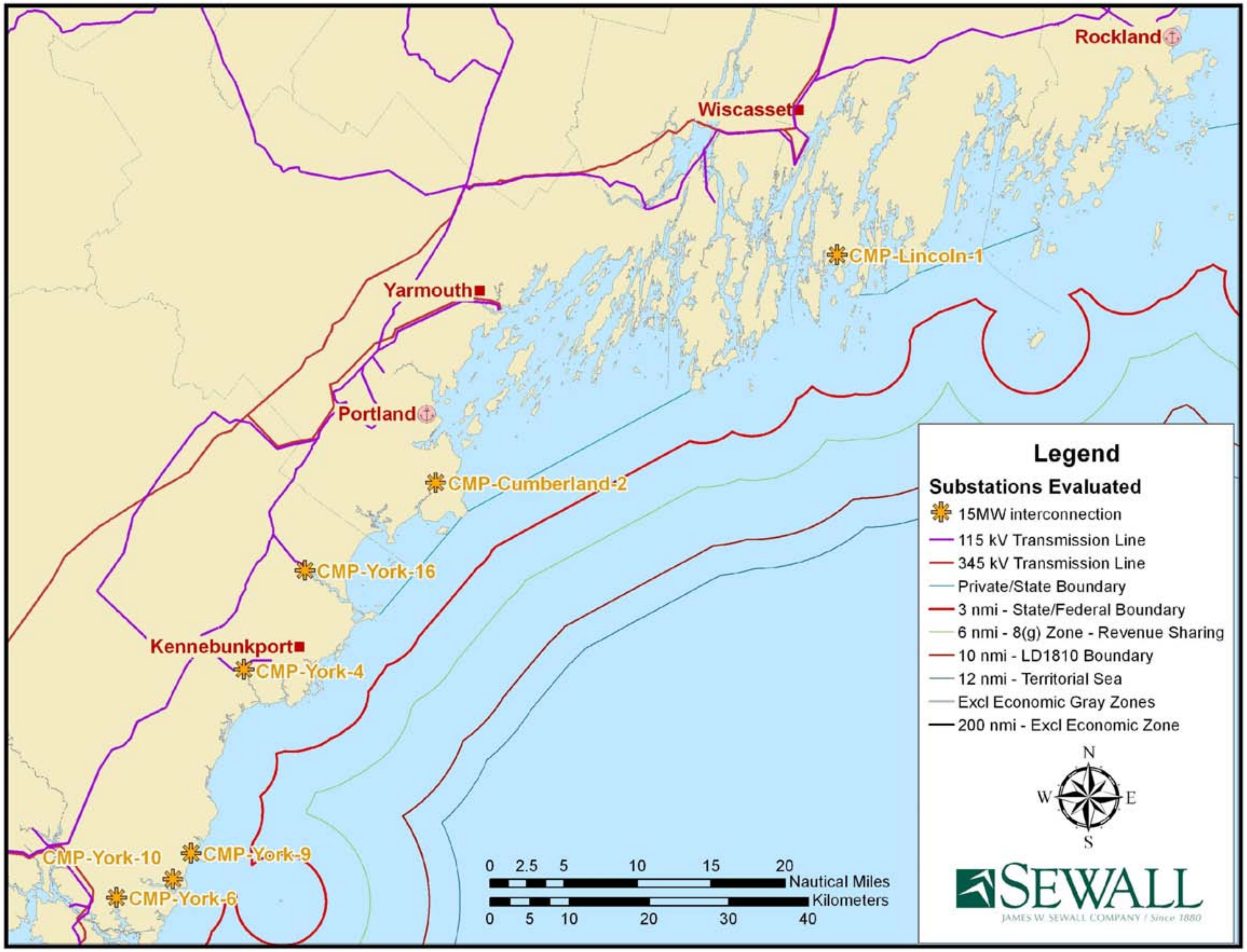

Figure 4-4: Connection pre-feasibility study substations (15 MW or less)

Base Case Development

The base case power flow for this study originated from CMP and included a model of CMP's 34.5 kV sub-transmission system. Steady-state analyses were conducted using a Summer peak 2010 load level.

Steady-state Analysis Methodology

The steady-state analysis was performed using the GE Power Systems PSLF load flow software package, Version 17. Steady-state thermal and voltage analyses initially examined system performance without the proposed Project in order to establish a baseline for comparison. System performance was then re-evaluated with the Project interconnected at the various interconnection sites listed above and compared with the previous baseline performance to demonstrate the impact of the Project on area transmission reliability. At each site, evaluations were conducted for the base system followed by first contingency (an outage of a transmission line or transformer).

Steady-state Voltage Limits

Table 4-10 identifies the voltage criteria used by CMP in the primary Study area for steady-state voltage assessment.

Table 4-10: Steady-state voltage criteria

VOLTAGE CLASS	ACCEPTABLE VOLTAGE RANGE	
	PRE-CONTINGENCY (NORMAL CONDITIONS)	POST-CONTINGENCY (EMERGENCY CONDITIONS)
115 kV	0.95 to 1.05pu	0.95 to 1.05pu
Below 115 kV	0.95 to 1.05pu	0.95 to 1.05pu

Steady-state Thermal Limits

Table 4-11 contains the thermal loading performance criteria applied to transmission lines and transformers in this Study.

Table 4-11: Steady-state thermal criteria

SYSTEM CONDITION	TIME INTERVAL	MAXIMUM ALLOWABLE FACILITY LOADING
PRE-CONTINGENCY (ALL LINES IN)	Continuous	Normal Rating*
POST-CONTINGENCY	Less than 15 minutes after contingency occurs	Short Term Emergency (STE) Rating**
	More than 15 minutes after contingency occurs	Long Term Emergency (LTE) Rating***

*Normal Rating – Maximum loading permitted without incurring equipment loss of life above design criteria.

**Short Term Emergency Rating – Maximum 15 minute loading before thermal damage is experienced.

***Long Term Emergency Rating – Maximum loading allowed for a period of 12 hours (Summer) or 4 hours (Winter)

4.2.2 Steady-state Analysis Results

Error! Reference source not found. summarizes the relative impact of adding 30 MW of wind generation to the substations sites identified in this report. The table offers a cursory assessment by comparing the interconnection conditions before (Base Case) and after the addition of a 30 MW Project. The per unit values (pu) indicate the relative voltage or thermal performance at the interconnection site under likely contingency outage conditions.

The general conclusion reached from the cursory assessment is that the interconnection of up to 30 MW at any of the sites identified above is not expected to have an adverse impact on thermal or voltage related issues on the CMP medium or high voltage transmission system.

Table 4-13 summarizes the relative impact of adding up to a 15 MW of wind generation to the supplemental substations sites identified in this report. See Table 4-9 for the additional sites capable of accommodating an interconnection of up to 15 MW of generation. The table offers a cursory assessment by comparing the interconnection conditions before (Base Case) and after the addition of a 15 MW Project. The per unit values (pu) indicate the relative voltage or thermal performance at the interconnection site under likely contingency outage conditions.

Table 4-12: Summary results of the steady-state analysis on the injection of 30 MW wind-generated energy at various interconnection points

LOCATION	VIOLATION		CONTINGENCY	PRE-PROJECT (price unit)	POST 30 MW PROJECT (price unit)	REMARKS
CMP-Cumberland-1	Voltage	No Violations				No impact
	Thermal	No Violations				
CMP-Cumberland-5	Voltage	34.5 kV Bus	Base Case	1.065	1.065	No impact
		34.5 kV Bus	Base Case	1.078	1.078	
		34.5 kV Bus	Contingency 1	0.929	0.931	
	Thermal	Power Transformer	Base Case	1.006	1.006	
		34.5 kV Section	Contingency 1	1.049	1.047	
CMP-Cumberland-8	Voltage	No Violations				No impact
	Thermal	No Violations				
CMP-Cumberland-10	Voltage	No Violations				No impact
	Thermal	34.5 kV Section	Contingency 1	0.997	1.004	
CMP-Cumberland-11	Voltage	No Violations				No impact
	Thermal	No Violations				
CMP-Cumberland-15	Voltage	No Violations				No impact
	Thermal	No Violations				
Private-Knox-1	Voltage	34.5 kV Bus	Contingency 1	0.837	0.843	Marginal improvement in voltage for loss of transmission Section
		34.5 kV Bus	Contingency 2	0.903	0.909	
		34.5 kV Bus	Contingency 3	0.921	0.927	
		34.5 kV Bus	Contingency 4	0.948	0.954	
		34.5 kV Bus	Contingency 5	0.948	0.954	
		34.5 kV Bus	Contingency 6	0.930	0.937	
		34.5 kV Bus	Contingency 7	0.940	0.943	
	Thermal					

Table 4-12 continued

LOCATION	VIOLATION		CONTINGENCY	PRE-PROJECT (price unit)	POST 30 MW PROJECT (price unit)	REMARKS
CMP-Knox-4	Voltage	34.5 kV Bus	Contingency 1	0.945	0.975	No impact
	Thermal	Power Transformer	Base Case	1.075	1.077	
		Power Transformer	Base Case	1.080	1.081	
CMP-Lincoln-3	Voltage	No Violations				No impact
	Thermal	Power Transformer	Base Case	1.079	1.079	
		Power Transformer	Base Case	1.120	1.120	
CMP-Lincoln-4	Voltage	34.5 kV Bus	Contingency 1	0.938	0.934	No impact
		34.5 kV Bus	Contingency 2	0.951	0.945	
		34.5 kV Bus	Contingency 3	0.949	0.956	
	Thermal	No Violations				
CMP-Lincoln-7	Voltage	34.5 kV Bus	Contingency 1	0.928	0.954	Generation improves CMP-Lincoln-1 voltage during contingencies
		34.5 kV Bus	Contingency 2	0.920	0.942	
	Thermal	No Violations				
CMP-Sagadahoc-2	Voltage	No Violations				No impact
	Thermal	Power Transformer	Base Case	1.120	1.119	
		Power Transformer	Base Case	1.483	1.050	

Table 4-12 continued

LOCATION	VIOLATION		CONTINGENCY	PRE-PROJECT (price unit)	POST 30 MW PROJECT (price unit)	REMARKS
CMP-York-1	Voltage	34.5 kV Bus	Contingency 1	0.910	0.976	Generation improves voltage for loss of transmission Section
		34.5 kV Bus	Contingency 2	0.922	0.973	
		34.5 kV Bus	Contingency 3	0.915	0.966	
	Thermal	Power Transformer	Base Case	1.022	1.022	
		34.5 kV Section	Base Case	1.011	1.011	
		Power Transformer	Base Case	2.132	2.206	
CMP-York-2	Voltage	34.5 kV Bus	Base Case	1.081	1.078	No impact
		34.5 kV Bus	Base Case	0.945	0.946	
		34.5 kV Bus	Contingency A	1.051	1.036	
	Thermal	34.5 kV Section	Base Case	1.029	1.032	
		Power Transformer	Base Case	1.150	1.150	

Table 4-12 continued

LOCATION	VIOLATION		CONTINGENCY	PRE-PROJECT (price unit)	POST 30 MW PROJECT (price unit)	REMARKS
CMP-York-7	Voltage	34.5 kV Bus	Contingency 1	0.843	0.985	Generation improves voltage and thermal performance following Loss of Transmission Section
		34.5 kV Bus	Contingency 2	0.886	0.977	
		34.5 kV Bus	Contingency 3	0.884	0.971	
		34.5 kV Bus	Contingency 4	0.935	0.993	
		34.5 kV Bus	Contingency 5	0.890	0.978	
		12.47 kV Bus	Contingency 6	0.901	1.037	
		12.47 kV Bus	Contingency 7	0.905	1.035	
		12.47 kV Bus	Contingency 8	0.926	0.926	
		34.5 kV Bus	Contingency 9	0.912	0.912	
	Thermal	34.5 kV Section	Base Case	1.020	1.017	
		Power Transformer	Base Case	1.861	1.843	
		Power Transformer	Base Case	1.150	1.149	
		34.5 kV Section	Contingency 1	1.023	1.021	
		34.5 kV Section	Contingency 2	1.134	0.131	
		34.5 kV Section	Contingency 3	1.479	0.598	
		34.5 kV Section	Contingency 4	1.215	0.347	
		34.5 kV Section	Contingency 5	1.343	0.240	
		Power Transformer	Contingency 6	1.066	0.628	
		Power Transformer	Contingency 7	0.324	1.277	
CMP-York-8	Voltage	34.5 kV Section	Contingency 1	0.943	0.993	Improves performance following loss of transmission Section
	Thermal	34.5 kV Section	Base Case	1.268	0.965	
		Power Transformer	Base Case	1.086	1.084	
		34.5 kV Section	Contingency 1	1.016	0.537	
		34.5 kV Section	Contingency 2	1.870	1.163	

Table 4-13: Summary results of the steady-state analysis on the injection of 15 MW wind-generated energy at various interconnection points

LOCATION	VIOLATION		CONTINGENCY	PRE-PROJECT (price unit)	POST 15 MW PROJECT (price unit)	REMARKS
CMP-Cumberland-2	Voltage	No Violations				No Impact
	Thermal	No Violations				
CMP-Lincoln-1	Voltage	Lincoln-1 34.5 bus	Base Case	0.941	0.994	Generation improves voltage
	Thermal	No Violations				
CMP-York-4	Voltage	No Violations				Generation improves thermal performance
	Thermal	34.5 kV Line Tap	Base Case	1.021	0.541	
CMP-York-6	Voltage	No Violations				No Impact
	Thermal	No Violations				
CMP-York-9	Voltage	York 1 34.5 kV	Contingency 1	0.910	0.971	Generation improves voltage and thermal performance
		York 9 34.5 kV	Contingency 2	0.922	0.983	
		York 10 34.5 kV	Contingency 3	0.915	0.975	
	Thermal	34.5 kV Section 1	Base Case	1.011	1.006	
		34.5 kV Section 2	Contingency A	1.146	0.991	
		34.5 kV Section 2	Contingency B	1.250	0.987	

Table 4-13 continued

LOCATION	VIOLATION		CONTINGENCY	PRE-PROJECT (price unit)	POST 15 MW PROJECT (price unit)	REMARKS
CMP-York-10	Voltage	York 7 34.5 kV	Contingency 1	0.843	0.926	Generation improves voltage and thermal performance
		York 1 34.5 kV	Contingency 2	0.908	0.967	
		York 9 34.5 kV	Contingency 2	0.920	0.978	
		York 10 34.5 kV	Contingency 2	0.913	0.984	
	Thermal	34.5 kV Section 1	Base Case	1.013	1.008	
		34.5 kV Section 2	Contingency A	1.131	1.028	
		34.5 kV Section 3	Contingency B	1.143	0.991	
CMP-York-16	Voltage	York 15 34.5 kV	Contingency 1	0.928	0.976	Generation improves voltage and thermal performance
		York 8 34.5 kV	Contingency 2	0.932	0.953	
		34.5 kV Bus	Contingency 3	0.928	0.976	
	Thermal	34.5 kV Section 1	Base Case	1.268	0.963	
		34.5 kV Section 2	Contingency A	1.400	0.984	
		34.5 kV Section 3	Contingency B	1.161	0.752	

4.3 GRID IMPROVEMENTS AND INTERCONNECTION COSTS

4.3.1 Grid Improvements

Based upon the assessment above, no significant grid or transmission improvements to the CMP transmission system are likely to be required for a 15 to 30 MW wind turbine addition. However, there may be a need to improve protection systems, add transformation, or expand a substation to accommodate the physical interconnection. These improvements will need to be assessed on a case-by-case basis.

4.3.2 Interconnection Costs

Interconnection costs will vary with each interconnection site and depend upon a number factors such as (1) distance of site from the coast line, (2) acceptable line route between the on shore cable landing and the interconnection site, (3) available unused circuit positions, (4) site expandability, (5) site compatibility and (6) interconnection constructability. At a minimum, most interconnections of this size will utilize a 34,500-volt power system, which will require an interconnection to an existing facility via a 34.5 kV line terminal equipped with a properly sized circuit breaker, disconnect switches, metering equipment, auxiliary alternating current and direct current (AC & DC) power systems, and protection & control systems. Typical interconnection costs (± 25%) associated with interconnecting a 30 MW generator to an existing 34.5 kV facility would likely consist of the following elements identified in Table 4-14.

Table 4-14: Interconnection costs for a 30 MW wind energy project

INTERCONNECTION ASSOCIATED ACTIVITIES	ESTIMATED ACTIVITY COST (USD)
Real Estate	$50,000
Site Preparation	$35,000
Expansion of Ground Grid	$30,000
34.5 kV Bus Expansion	$25,000
34.5 kV Line Terminal Addition (including Circuit Breaker)	$250,000
Metering System	$60,000
SCADA Systems	$25,000
Protection and Control Systems	$80,000
Protection and Control Shelter	$30,000
Auxiliary AC and DC Power Systems	$50,000
Communication Systems	$45,000
Engineering	$50,000
Commissioning	$60,000
SUBTOTAL	**$790,000**

Additional cost for the generator leader between the submarine cable landing and the substation is estimated to be \$ 65.00 per foot to \$ 75.00 per foot for aerial line and \$300 per foot to \$400 per foot for underground lines.

Sites offering a higher voltage than 34.5 kV will additionally require the installation of a power transformer (20/37 MVA) and associated protective equipment to provide a suitable 34.5 kV interconnection. The additional cost of interconnecting to the 115 kV system would require more yard expansion, a high voltage breaker terminal with associated protective relays, and a power transformer. The incremental cost, in addition to those identified above, to create an interconnection to the 115 kV system is projected to be \$ 1.2 million.

4.4 SUBSEA CABLE FEASIBILITY (35KM, 45 KM AND 60KM AC CABLE)

An assessment of available submarine cable systems was conducted and it was determined that a 34.5 kV submarine cable, 60 km in length, capable of transmitting up to 30 MW of electricity is possible, but not without performance issues. Due the cable's significant length, voltage drop and cable losses are a concern, with maximum estimated voltage drop and cable energy losses in the eight percent (8%) to nine percent (9%) range. These values would run even higher if not for the application of compensation reactors at each end of the cable to mitigate some of the loading affects caused by the charging currents in the cable.

Based upon information provided by Nexan Energy, an international submarine cable manufacturer, a three-phase cable with 800 mm^2 copper conductors is recommended for a 30 MW project requiring a 60 km cable length to transmit its output. Nexan also recommended that the cable be installed with compensation reactors at each end of the cable. The size of the compensation reactors vary with cable length. For a 60 km, 34.5 kV, 800 mm^2 cable, a 5.2 Mvar reactor at each end is suggested. For a shorter, 35 km cable the reactors can be reduced to 3.0 Mvar.

4.4.1 Subsea Alternating Current (A/C) Cable Selection

The subsea collector cable system should be kept as short in length as reasonably possible. For a 30 MW project with a 60 km collector cable, the minimum cable conductor size should be 800 mm^2 copper with a design maximum operating temperature of 90°C. A cable of this size will provide sufficient capability to transmit the full output of the facility but will only provide marginal voltage regulation on the line along with significant line loss. To improve the voltage regulation of the cable to a more acceptable level, a maximum cable length of 45 km would be more suitable for a 34.5 kV cable system with this level of loading.

4.4.2 Voltage Drop and Power Loss Calculations

800 mm^2 Submarine Cable Characteristics

Based upon information provided by Nexan Energy, a cable of this type would consist of the following suggested construction:

- 35.0 mm, round, stranded, compressed, copper conductor of 61 strands filled with a semiconducting compound.
- Conductor screen comprised of a semiconducting cross-linked compound.
- 8.0 mm thick cross-linked polyethylene (XLPE) insulation.
- Insulation screen comprised of an extruded layer of semiconducting cross-linked compound.
- Metallic screen comprised of 0.1 mm layer of copper tape.
- Polypropylene yarn fillers and fiber optic cable located in the interstices between the cable cores.
- Inner sheath of 2.2 mm extruded semiconducting polyethylene.
- Armor comprised of 51 to 54 7.5 x 2.5 mm, galvanized steel, flat, armor wires layered in 2 layers applied in opposite directions.
- Outer serving comprised of two layers of polypropylene yarn and bitumen.
- Cable diameter – 149 mm
- Cable weight (in air) – 48 kg/m
- Minimum bending radius – 2.7 meter
- Maximum pulling tension 290 kN

Based upon cable characteristic data provided by Nexan Energy, Figure 4-5 and Figure 4-6 were developed to identify the respective per unit voltage drop and the kW loss over the 34.5 kV 800 mm^2 cable at different operating conditions (0%, 50%, 80% and 100%) and cable lengths (35 km, 45 km and 60 km).

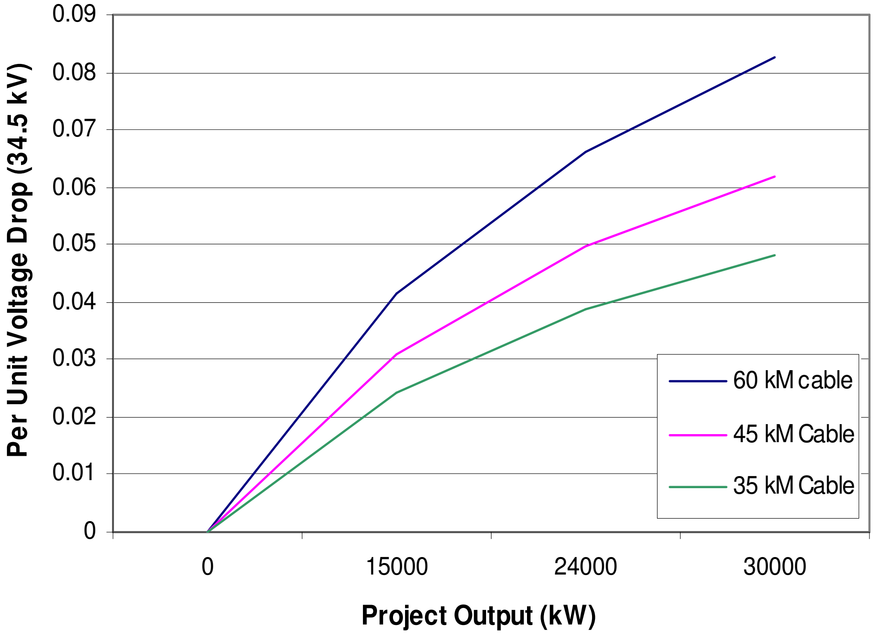

Figure 4-5: Voltage drop characteristics for 800 mm^2 cable

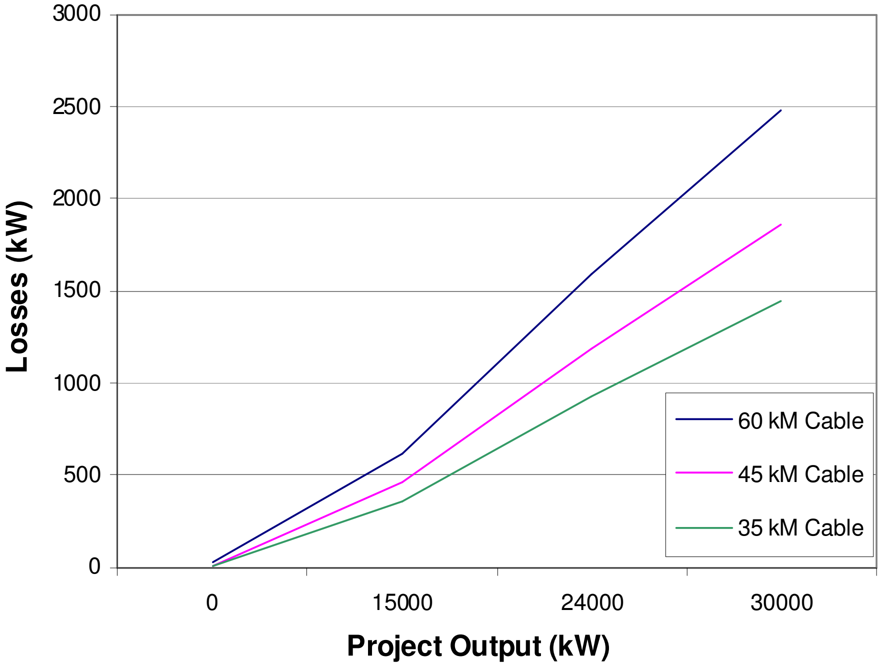

Figure 4-6: Kilowatt (kW) loss characteristics for 800 mm^2 cable

240 mm^2 Submarine Cable Characteristics

In addition to the 800 mm^2 cable specifications, Nexan Energy also provided specifications for a smaller 240 mm^2 cable which would facilitate the interconnection of a downsized (15 MW) project.

Based upon information provided by Nexan Energy, a cable of this type would consist of the following suggested construction:

- 18.4 mm, round, stranded, compressed, copper conductor of 37 strands filled with a semiconducting compound.
- Conductor screen comprised of a semiconducting cross-linked compound.
- 8.0 mm thick cross-linked polyethylene (XLPE) insulation.
- Insulation screen comprised of an extruded layer of semiconducting cross-linked compound.
- Metallic screen comprised of 0.1 mm layer of copper tape.
- Polypropylene yarn fillers and fiber optic cable located in the interstices between the cable cores.
- Inner sheath of 2.0 mm extruded semiconducting polyethylene.
- Armor comprised of 35 to 37 7.5 x 2.5 mm, galvanized steel, flat, armor wires layered in two (2) layers applied in opposite directions.
- Outer serving comprised of two layers of polypropylene yarn and bitumen.
- Cable diameter – 108 mm
- Cable weight (in air) – 23 kg/m
- Minimum bending radius – 1.9 meter
- Maximum pulling tension 150 kN

Similar to Figure 4-5 and Figure 4-6, Figure 4-7 and Figure 4-8 were developed to identify the respective per unit voltage drop and the kW loss over the 34.5 kV 240 mm^2 cable at different operating conditions (0%, 50%, 80% and 100%) and cable lengths (35 km, 45 km and 60 km).

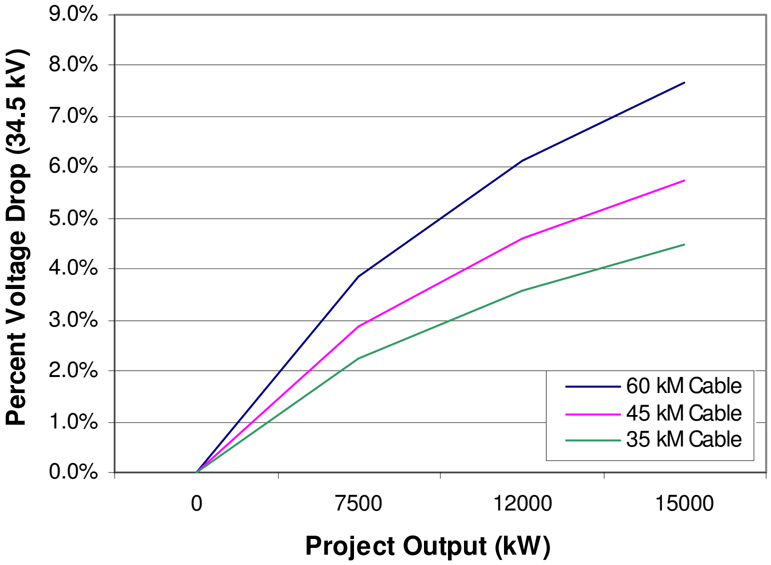

Figure 4-7: Voltage drop characteristics for 240 mm^2 cable

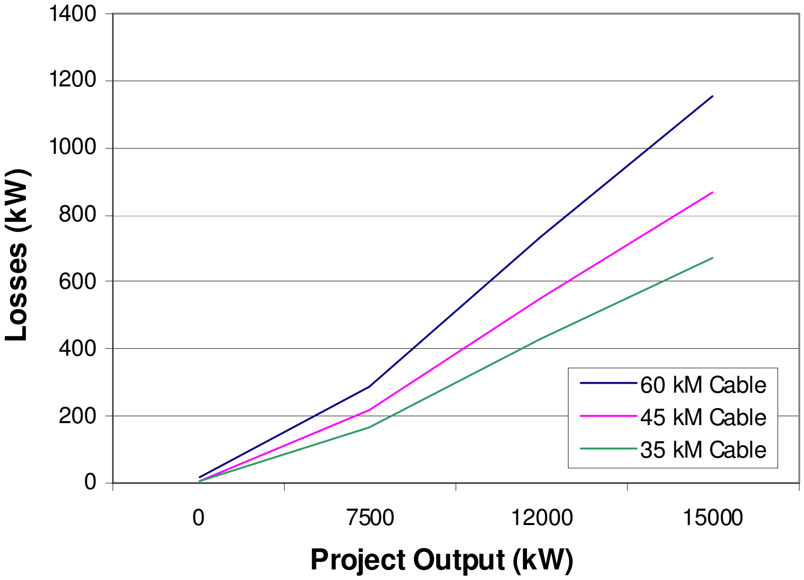

Figure 4-8: Kilowatt (kW) loss characteristics for 240 mm^2 cable

4.5 LARGE OFFSHORE WIND INTERCONNECTIONS

The preceding interconnection assessments have been focused on the interconnection of small (30 MW or less) offshore projects. Most of the coastal Maine electrical transmission infrastructure has limitations to the amount of generation that can be added to those facilities without significant upgrades. A fair number of sites can readily accommodate the smaller, 15 to 30 MW, projects without major adjustments to the system infrastructure.

Larger projects in the 200 MW to 300 MW range present a broader range of issues and concerns that are beyond the scope of this assessment. Projects of this size are better suited to interconnection to the 345 kV transmission system or significant 115 kV multi-line facilities due to the greater level of capability. The most immediate sites for an off shore interconnection of this size are located in Lincoln County.

4.6 OFFSHORE CABLING ASSESSMENT

This section has been prepared to provide a summary of the coastal-engineering, environmental and permitting issues associated with transmission cable laying/trenching and operations for a proposed demonstration project of a floating offshore wind turbine in the GoM. The intent of this assessment is not to plan a cable route, but rather to provide a summary of considerations for the selection of an appropriate cable route.

An introduction to the key coastal physical forces is presented, along with anthropogenic concerns associated with marine space-use conflicts. The commonly used approaches to installing submarine cables at offshore wind farms are described, along with the interaction and importance of physical forces during the installation process. In addition, guidance suggestions for the preliminary planning of cable routes are provided.

Furthermore, environmental concerns are identified, along with a summary of endangered species and endangered habitats that may be encountered in the area to be considered. The permitting process required for the installation of a subsea transmission line is also discussed, along with identification of the appropriate jurisdictions and regulatory agencies to be involved.

4.6.1 Key Coastal Forces

The primary marine physical processes associated with infrastructure placed in the offshore environment are waves, water levels (tides and surges), currents, and ice. A secondary response to the marine physical forces is the movement of sediments and supporting soils. While this is not intended to be a met-ocean study, some insight into each process is relevant to later discussions, so each will be described briefly. Detailed data on met-ocean conditions in the GoM is provided in Section 3.0.

Waves

In the GoM there are two types of waves: wind waves and swell waves. Wind waves are generated locally within the Gulf itself due to the wind stress over the water. These waves tend to have a relatively short wave period, and are subject to fluctuations associated with the passage of individual weather systems. Swell waves are longer period waves that may be generated hundreds or thousands of kilometers away and have typically travelled great distances before reaching the point of interest.

With regard to extreme wave events, the GoM is subject to hurricanes and extra-tropical storms, as well as North Atlantic storms commonly referred to as Nor'easters. These extreme wave events are likely to be the wave conditions governing design. It is therefore necessary to consider these extreme events when determining extreme loads due to waves.

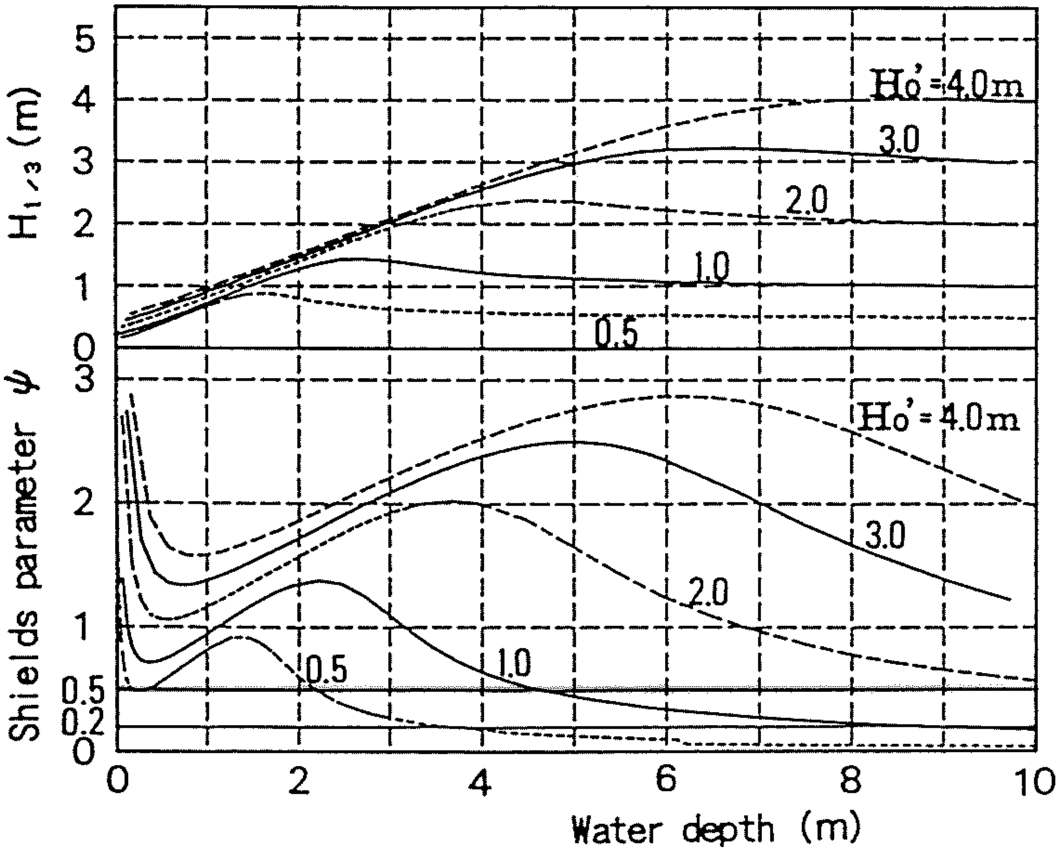

Figure 4-9: Cross-shore distribution of Shields Parameter (ψ) under different wave conditions (Watanabe et al., 1991)

With regard to submarine cabling interests, there are two primary concerns. One is the presence of waves during construction/installation, and the other is the velocities at the bed associated with wave-induced currents that act throughout a cable's operational period of service. Figure 4-9 illustrates that in most wave conditions, nearshore bed material exceeds a Shields parameter of 0.5. This indicates that the material is close to entering the sheet flow regime[3]. Cable in this area would experience scour (described later in this section).

Water levels

Water levels in the GoM are dominated by the motion of the tides. Table 4-15 provides tidal statistics for Portland and Bar Harbor. Information on tidal benchmarks, datums, harmonic constituents, and sea level trends is available at the NOAA National Ocean Service (NOS) website http://tidesandcurrents.noaa.gov . Information is available for the current tidal epoch (1983 – 2001) and the previous (superseded) tidal epoch. Benchmark elevation information relative to North American Vertical Datum of 1988 (NAVD 88) and National Geodetic Vertical Datum of 1929 (NGVD 29) is available via web links to the NOAA National Geodetic Survey (NGS).

Tidal fluctuations are predictable and it is possible to predict future tidal variation with relative ease. Over the short term, water levels also vary in response to climatic conditions (referred to as storm surge). A local rise in the sea surface due to a low pressure system is possible, although relative to the tides on the GoM, the amplitude of water level fluctuations from barometric change are relatively insignificant; on a macro-scale, however, the fluctuations caused by barometric change can drive synoptic-scale currents that impact sediment transport. In nearshore areas, the effects of storm surge can be amplified by wind and wave setup. Over the long term, the changes are related to global sea level rise and local tectonic change.

Long term sea level rise is an ongoing process throughout the world. Historic rates are generally estimated to be on the range of 3.2 mm/year (or 0.16 m over 50 years). The rate of sea level rise is increasing however, and while climate change scenarios are not precise, they range from approximately 0.16m to 0.5 m over the next 50 years (IPCC, 2007 and Rahmstorf, 2007). While there is great uncertainty in climate change estimates, prudence suggests some consideration should be given to it.

Water levels are of importance to the cabling on potential projects in several ways: first, the tidal change and barometric pressure associated with Nor'easters generates significant currents (discussed in the next subsection), as well as issues associated with installation tension/equipment limitations, and operational slack from the floating unit.

Water levels can be affected by winds, the inverse barometer effect driven by large atmospheric weather patterns (1 mb atmospheric pressure ~ 1 cm change in water level), differential heating and cooling, and ocean currents.

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[3] Sheet flow describes a condition where when the sediment is mobilized across the seabed. The sheet flow condition is identified as the most important sediment transport mode due to the large sediment transport rate. (Hsu, 2003)

Table 4-15: Tidal Statistics for Portland and Bar Harbor, Maine (based on NOAA National Ocean Service benchmark tables)

TIDAL STATISTICS	Portland (8418150)		Bar Harbor (8413320)	
	(m)	(ft)	(m)	(ft)
Highest Observed Water Level	4.305	14.12	4.941	16.21
Mean Higher High Water (MHHW)	3.019	9.90	3.466	11.37
Mean High Water (MHW)	2.886	9.47	3.336	10.94
North American Vertical Datum 1988 (NAVD88)	1.601	5.25	1.821	5.97
Mean Sea Level (MSL)	1.505	4.94	1.728	5.67
Mean Tide Level (MTL)	1.495	4.90	1.726	5.66
Mean Low Water (MLW)	0.105	0.34	0.116	0.38
Mean Lower Low Water (MLLW)	0	0	0	0
Lowest Observed Water Level	-1.053	-3.45	-0.775	-2.54

Water levels are higher in the GoM – Bay of Fundy system than other areas of the East Coast due to constructive wave-wave interaction as a result of a near match in the natural resonance period of the basin (~13 hours) and the M_2 (12.42 hours) and the N_2 (12.66 hours) tidal constituent periods.

Currents

There are several primary sources of currents throughout the nearshore areas in the GoM. These include wave-induced currents, tidal currents, density-driven currents, and large scale synoptic currents associated with Nor'easters and other surge events. Near the surface, wind-induced currents can also play an important role. In deeper waters offshore, there are additional ocean currents associated with oceanic and regional scale currents however these are of less significance to cabling installation and operation. The importance of currents is significant as it is often not possible to use divers or some types of submarine equipment such as remotely operated vehicles (ROVs) when the currents are too strong, and currents act as driving forces for sediment transport.

Tidal currents are more predictable than wave-induced currents, but the magnitude of the currents can still be a significant limitation for commercial diving operations in support of nearshore cabling and/or ROV work. In addition, the presence of cables or other infrastructure on the sea bed may result in scour, or vibrations induced by vortex shedding that could damage the infrastructure.

Finally, several studies have identified the presence of synoptic currents due to the large-scale Nor'easter events that drive overall currents near the shore to the south along the Atlantic coast of Canada and the United States. These large-scale currents carry material suspended by waves and drive migration of major sand and gravel shoals present in water depths of up to 40 m (about 130 ft).

Ice

Ice is not a significant concern to submarine cables in the GoM and as such will not be discussed.

Sediment Transport

Sediment transport is the process of sediment moving along the sea bed in response to an external force (usually a current). Sediment transport rates in the GoM are generally greatest in nearshore areas with breaking waves and near the mouth of rivers. Sediment transport is the primary driver of dynamic bed change relevant to cabling processes. From the perspective of cabling, there are two major concerns during the operational phase: Scour and the overall movement (or migration) of large seabed features. During installation, the mobility of the sediment is also a critical element that may govern the installation approach.

Scour is the erosion of sediments caused by the presence of a hardened feature on or near the bed. The modified hydrodynamics as the water flows around the structure causes the scour pattern to develop. The concern is that quite often the material that is scouring is supporting soil, which could lead to the failure of the infrastructure. The time-scale of scour can be on the order of minutes and hours in sand, gravel and loosely consolidated fines, however it is slower in clay, generally on the order of weeks, months, and years. Scour is also possible in bedrock, although the process is slower still (measured over years or decades) and is usually dependent upon the presence of an abrading agent such as thin veneers of sand or gravel (Sumer and Fredsøe, 2002). In areas with variable bed conditions, some areas may scour more readily, creating free-spanning sections of cable that could experience fatigue from vortex-induced vibrations as well as additional tensile load.

The longer term morphology of seabed features, particularly sand and gravel deposits is also of concern. There is documented evidence of sand and gravel features on the outer and inner continental shelves migrating at 2 – 12 m (6.5 – 40 ft) per year due to large scale synoptic currents driven by Nor'easters (Swift and Field 1981, and USACE 2008). These features are not as prominent in the rocky areas of Maine's inner continental shelf, however there is some evidence that they exist.

Fine silts and cohesive materials with significant amounts of clay particles on the bed is also a distinct issue with regards to sediment transport – the material that is mobilized enters suspension very easily and is often too fine to settle quickly in the local area of disturbance, instead it is dispersed and settles elsewhere, often very far from the area of disturbance. In general, when conducting underwater construction, silts or clays disturbed may be considered to be dispersed and not available for backfilling of trenches or other submarine excavations. They are also the material most likely to cause clouding of the water and the negative environmental and construction conditions associated with the reduced visibility. The muddy seabed regions of Maine's inner continental shelf may exhibit these characteristics.

Rare Underwater Events

Submarine cables may be subject to submarine landslides or fault dislocation (earthquakes). These events are considered rare, special cases. During the detailed design and geophysical investigation phases, however, designers should look for fault lines and unstable soil masses.

4.6.2 Marine-based Anthropogenic Concerns

The primary marine-based anthropogenic concerns to offshore power cables are associated with damage to the cables from fishing equipment (in particular, trawlers) and dragged anchors. This is a condition that has long been an issue in the communication and power transmission cable industries. Restrictions on fishing and anchoring activities are often posted on hydrographic charts, and these pose the greatest space-use conflicts for submarine portions of transmission cables. Where existing shipping lanes or fishing grounds are established, alternate cable routes may be the only alternative acceptable to regulatory agencies and insurance companies alike. Where cables must cross these areas, significant mitigation measures should be planned, and shipping/fishing schedules worked around during construction. A separate anthropogenic issue is related to archaeological targets, such as shipwrecks and UXO (unexploded ordnance). In general the cable route must go around these items; surveys carried out prior to the final cable route planning should detect them.

4.6.3 Mitigation of Primary Hazards and Concerns – Trenching and Armoring

Proactive mitigation against coastal forces and anthropogenic concerns typically involves trenching the cable below the bed surface and re-instatement of the bed above the cable. This provides some degree of protection for the cable and separates the cable from the benthic habitat to reduce the introduction of anthropogenic material in the benthic region. In some cases, trenches are backfilled with material that is more stable than the original material, such as coarse stone and gravel. This is more common in locations where the native material has some stability issues or is too fine to settle back into the trench on its own (Michel et al., 2007). In extreme cases, rock protection or articulating concrete block mattresses may be laid over cables. There is the further opportunity to install cables with additional internal-armor steel cabling. This armoring will not typically protect the cable from all anthropogenic damages (i.e. fishing and anchor drag).

Trenching of submarine transmission cables for offshore wind farms has become standard practice, however in some cases the smaller cables that run between individual units has not been trenched, opting instead for laying an armored cable directly on the bed (Wright et al., 2002). Depth of trenching is usually in the range of one to three m (about three to ten feet), however the cost increases for increasing depth, particularly in firm soils. The following sections will describe the cable-laying process, including the various approaches for trenching. In water depths greater than approximately 1000 m, the ICPC suggests disturbances from anthropogenic sources are very rare and therefore burial is not necessary (Carter et al., 2009). These water depths are not expected to be encountered for the proposed project.

4.6.4 Cable-laying Techniques for Offshore Power Transmission

Transmission cables for offshore wind farms are normally placed below the seabed in a trench, particularly for the main transmission lines. Smaller lines that run between individual turbines within a wind farm are often laid directly on the sea bed. This section describes the process of laying the cables and trenching them. The equipment will be briefly presented, and where appropriate, limitations on its use provided.

Cable-laying Vessels

Cable-laying vessels are purpose-built or specially-modified ships with design features specifically for the laying and maintenance of submarine cables. The primary feature of these vessels is the capability to un-coil and lays the cable directly onto the bottom. This is conventionally done off the stern of the ship, however some vessels are equipped with the capability to deploy cable from the bow of the vessel as well. The vessels normally have clean-rooms available for splicing cables. All of the equipment associated with the deployment of the cable (including ROVs and ploughs) is controlled directly from the ship, and is linked to the laying vessel's positional system.

Although depth restrictions are vessel-specific, in general the vessels are ocean-going vessels and they cannot typically operate in shallow nearshore waters, relying on tenders and other shallow-draft barges to assist with the deployment in water depths less than (typically) 8-10 m. The presence of the cable essentially constrains the vessel to a relatively small area and a single course or heading. Since it is very expensive to cut and splice a cable unnecessarily, cable-laying vessels are often considered immovable obstacles to other sea traffic due to this constrained maneuverability. Their reduced mobility and the cost of severing the cable unnecessarily means that it is advantageous to lay cable in continuous stretches, undisturbed by met-ocean conditions and shipping traffic. It is therefore critical that appropriate planning is conducted to achieve the maximum up-time possible during the cable-laying process.

Mechanical Plough

A mechanical plough is a device towed behind the cable-laying vessel that runs along the bottom and simultaneously digs a trench and lays the cable into the trench. The sledges can be adjusted to achieve optimal burial depth. Under ideal conditions, it is possible for a plough sledge to lay a cable up to five m deep (15-16 ft). With most ploughs, the sediments are displaced in such a way that they are likely to settle back into the trench, essentially covering the cables back over. This is not true, however, in very fine silts and clays, where the material is likely to enter into suspension and be transported away from the trench. Mechanical plowing is relatively efficient in sands and cohesive material with moderate levels of compaction. With stiffer soils, alternative measures may be required. Extremely soft soils (loose organic matter, for example) create some challenges for this installation technique as the ploughs sink into the bed rather than skimming across the top on their skids.

Some modern mechanical ploughs are assisted with high-pressure water jet nozzles. The water jets help to fluidize the sediments, reducing the stress on mechanical components of the plough, and increasing the rate at which the trenching operation can occur without measurably increasing the towing load on the vessel. The addition of the jets also helps the trenching process achieve greater depths in stiffer soils. Under good conditions, mechanical ploughs can trench and lay cables at rates in excess of 18 m (60 ft) per minute.

Jet Plough

Jet-plowing is a technique where a high-pressure jet of water is directed at the bed, fluidizing the bed sediments and creating a trench that a (typically) previously-laid cable settles into. The jets may be mounted to a guide-head from a ship-based pumping system, or located on the underside of an ROV. Guide-heads and ROVs are normally designed to use the existing cable as a guide. This technology is also used to re-bury cables if they become exposed, and to assist with the recovery of previously buried cables. Similar to mechanical plowing, jet-plowing usually results in the material settling back into the trench, unless the material is very fine. ROVs that bear on the soils may become bogged-down in extremely soft soils.

The rate of trenching is dependent upon the conditions. During the installation of the Q7 wind farm in Holland, sandy soils were trenched at approximately 3.3 m (10.8 ft) per minute in the shallow nearshore, and 10.2 m (33.5 ft) per minute in the deeper portions using an ROV-based jet plough (Subtrench Pty Ltd., 2010).

ROV Drilling/Chainsawing

When very firm soils or rock is encountered, an ROV equipped with a rock-saw is required. The saw is essentially an underwater chain saw that saws through rock along the cable route. While the progress is slow and expensive (less than two meters per minute (2 m/min)), the tools are capable of trenching into solid rock where necessary. In many cases, the ROVs that are equipped for jet-plowing can be fitted with the rock-cutting tools. Rock-cut trenches are often backfilled with a stable material.

Dredging

Dredging is a conventional technology that is sometimes used in the installation of buried cables and pipelines, particularly when there are contaminated sediments that cannot be allowed to re-settle onto the bottom. Dredged material can be pumped up to a ship and disposed of elsewhere, or cleaned and pumped back down to the trench. Dredged channels are generally wider, take longer to cut, and are more expensive than the previously-mentioned approaches to trenching.

Energetic Zones – Shoreline Approach and Cable Landing

From a coastal perspective, the most energetic and dynamic zone is near the shore, where waves break. This dissipation of wave energy creates a dynamic environment under constant change – sediment features, particularly on sandy shores, migrate in both the long-shore and cross-shore directions. Natural and anthropogenic features that interrupt the movement of sediment can cause significant and relatively rapid changes to the nearshore bed surface.

Nearshore areas also tend to be productive ecological areas. For this reason, cable burial is always recommended, and many recent and proposed projects have taken advantage of horizontal directional drilling (HDD) (Worzyk, 2009).

HDD can be conducted from land, creating a conduit that the cable is passed through. Lengths in excess of 1000 m (3280 ft) can be achieved when working from shore. The use of HDD virtually eliminates any interruption to the local habitat in the nearshore regions and allows the cable to be buried much deeper than conventional trenching technologies would allow. HDD can be conducted in most soil conditions, including rock – although it is more expensive and slower than through soil.

If the cable is not buried to sufficient depth, armor above the cable is recommended to protect the cable from coastal forces. In the nearshore, this typically consists of stone or concrete armor units of considerable size.

4.6.5 Recommended Coastal-Related Investigations to Support Cabling Design and Planning

There are two primary studies that are recommended to support the cable-laying process in conjunction with these projects. This work should include a geophysical investigation and a coastal engineering study. Each will be described in general below.

Geophysical Investigations

Geophysical investigations are required along the entire cable route. The timing of this work may be synchronized with other offshore field work to minimize repeated mobilizations. While this summary is not intended to provide a complete scope of work for a geophysical investigation, the following elements should be considered for a geophysical study:

- **Desktop study**: The desktop study should prepare a synthesis of known anthropogenic and natural features of relevant importance, including (but not limited to) shipwrecks, fault lines, anticipated sediment types, historical feature migration, historical bathymetry, and the geological history of the area.
- **Multi-beam hydrographic survey**: Det Norske Veritas (DNV, 2007) suggests that multiband coverage is recommended along the planned cable route area at a minimum using the following performance specification: IHO S44 "Special Order" (5th Edition, February 2008). This standard is used as the baseline for most of the other standard reference documents used in hydrographic surveying throughout the world. This will allow for the detection of items on the seafloor and will give an accurate depiction of bathymetric changes along the cable route. Single-beam echo sounders typically do not provide the required resolution for accurate planning of a cable route.

- **Sidescan sonar**: Sidescan sonar investigations can detect objects on the seafloor that are difficult or impossible to trench through. Sidescan sonar is specified as a minimum requirement by BSH (BSH, 2003) along planned cable routes.

- **Sub-surface profiling**: The use of sub-bottom profilers (boomers or chirp units) is useful for detecting layers of different materials within the bed, as well as the possibility of detecting erratics or other features that may make cable trenching difficult. BSH (BSH, 2003) recommends a minimum resolution of 0.5 m along planned cable routes.

- **Sediment quality**: Sediment grab samples along the planned cable route should be tested for contaminants and heavy metals that may create environmental challenges.

- **Archaeological searches**: Magnetometers and drop-cameras are recommended to detect any archaeological or cultural artifacts that require protection under local regulations.

- **Later geotechnical sites**: During the geophysical investigations, it is recommended that possible sites for later geotechnical work be identified and additional geophysical data be collected at these sites, including shallow cores. These shallow cores will provide some understanding of the trenchability of the material. In particular, it may be possible that some sites classified historically as muddy are more consolidated than the remote sensing suggests. Local testing is recommended to estimate the strength of the soils for supporting trenching equipment. In addition to conventional soil properties such as grain size, gradations and shear strengths, recommended tests for trenchability are: strain rate effects, permeability (sands/silt), shell content, plasticity, compressibility and relative density (Offshore Soil Investigation Forum, 1999)

Coastal Engineering Study

In the context of cable route planning, a coastal engineering study should encompass met-ocean investigations and shore/bed morphology.

- **Waves**: A full wave climate should be developed. In most cases, getting a long enough record of the wave climate will require undertaking a wave hindcast, or leveraging an existing wave hindcast. Extreme value analysis and risk-based approaches should be employed to select representative events for further analysis and wave transformation. The measurement of waves near proposed project areas is recommended to calibrate the models to the local conditions. It is also recommended that the wave climate near the cable-landing site be determined for use in sediment transport modeling and to support the design of protection measures over the cable trench, if necessary.

It is recommended that wave modeling undertaken for the coastal engineering study be synchronized with wave modeling undertaken for other design elements in the study. DNV (DNV 2007) and GL (GL, 2005) both recommend accurate wave hindcasts be developed and calibrated with site-specific measured waves for the design and planning of offshore wind farms.

- **Water levels**: A desktop study of recorded water levels in the vicinity of the planned cable route is recommended. Where these values are not available, measured values for at least 28 days to establish local tidal constituents is recommended. In the vicinity of the areas of interest, there are existing NOAA water level recording stations at Portland and Bar Harbor. Preferably an event would also be captured to get an understanding of the surge and setup associated with the passage of storm events in the local area. In the GoM, this is especially relevant with the passage of Nor'easters. The understanding of the water level climate can be used in the calibration of hydrodynamic models and to understand the tidal currents.
- **Currents**: Tidal currents, wave-induced currents, and synoptic currents are important in the GoM. It is recommended that existing hydrodynamic models for the GoM be leveraged and the resolution improved in the vicinity of the proposed project area, or new models be developed to gain a full understanding of the currents throughout the study area. Current measurements for calibration of the model(s) are highly recommended. A resolution sufficient to identify areas of strong or focused currents along the cable route should be employed.

  Strong currents can dictate change to bed conditions and also provide conditions during construction where the use of divers and remotely operated vehicles is limited. There may be geographic areas where specific tidal windows are required to allow for safe installation of submarine cables, and the hydrodynamic model can identify these for the planning of the installation process.
- **Sediment transport**: A study of the baseline sediment transport conditions across the entire planned cable route is recommended. This includes identifications of dynamic features (ridges and shoals), as well as an assessment of longshore sediment transport and shoreline change in the vicinity of the cable landing area. Any areas that are particularly susceptible to scour can also be identified and appropriate measures recommended.

4.6.6 Summary of Guidance and Constraints

The following represents key guidance issues and coastal engineering considerations to take into account when planning a cable route:

- **Bed material – type**: In general, there are two types of soil conditions to be avoided if possible: bedrock and thick layers of very soft sediments like silts and soft organics. The areas of exposed bedrock may require drilling/sawing to trench the cables, and in the very soft areas, trenching equipment may not be able to be supported by the bed. Mud is the second most common seafloor type on the Maine Inner Continental Shelf, comprising 39% of the seafloor substrate (Department of Conservation, 1996). It may be necessary to work with specialized light equipment to trench through muddy areas if trenching is desired in these areas. It may also be possible that current data (based upon remote sensing techniques) does not provide a good representation of the bed material strength in these areas. Material strength testing is recommended during a geophysical study.

The most preferred material is sand and gravel of medium to medium-low compaction. Unfortunately, these are not common features on the seafloor of Maine's Inner Continental Shelf. Heavily compacted sand and cohesive material is difficult to trench through and is therefore less desirable in areas where trenching will be used. Unfortunately, close to 41% of the geology on Maine's Inner Continental Shelf is comprised of exposed rock (Department of Conservation, 1996). Therefore sites with access to sandy cable routing corridors should be preferred from a cabling perspective.

- **Bed material – quality**: In areas where the sediment contains contaminants or other minerals that should not be re-suspended into the water column, more costly installation measures may be required. If possible, areas with known contaminants should be avoided or minimized. Areas where contaminants are frequently found offshore include offshore disposal sites of dredgeate, the vicinity of current or historical port operations, the mouth of rivers, nearby historical waste outfalls, and offshore mineral extraction sites.
- **Bed conditions – items to be avoided**: Any identified anthropogenic items like shipwrecks and unexploded ordnances should be avoided at all costs, usually by routing the cable around these features. Additional features or areas that should be avoided include areas with a high number of erratic boulders from glaciations and other pipelines/cables. While it is sometimes done, crossing other pipelines and cables is generally expensive and carries with it a greater risk of damage to existing infrastructure; the ICPC dictates the individual or organization laying the second cable is liable for any damages to the first one – repair of damaged cables and pipelines can be extremely expensive.
- **Bathymetry and bed features**: Large sand and gravel ridges and shoals on the inner continental shelf are dynamic and subject to migration and change in form. Most of the offshore ridges and shoals that exhibit migratory behavior in the GoM can be identified by their Southwest – Northeast elongated shape. They may be quite large and in some cases could be unavoidable, but generally placing cables a reasonable distance from these is less risky than placing cable across them. An appropriate distance is the migration rate times the number of years in the planning horizon for the project site (e.g., A cable intended to be in service for 25 years should be a minimum of 12 m/year x 25 years x 2 (factor of safety), or 600 m total from a feature that has historically migrated at 12 m per year). In some cases

underwater canyons and rapid changes in bathymetry will necessitate longer lengths of cable than following the level contours.

- **Local complex met-ocean conditions**: The identification of bathymetric features likely to cause localized extreme currents or bed change should be identified, and if at all possible, these areas avoided or as a minimum trenched through. In locations where wave breaking conditions exist, particularly in the nearshore, it is highly recommended that trenching or directional drilling be considered. If there are sheltered locations available with minimal or no exposure to breaking waves available for the cable landing, these areas should be considered as they may provide for lower cable trenching costs.
- **Navigation concerns**: Close to one quarter of all damages to submarine cables in the Mediterranean Sea between 1993 and 2007 were caused by anchors (France Telecom Marine). For this reason alone, it is prudent to avoid primary navigation corridors. Additionally, the installation vessel is generally not maneuverable outside of its planned heading during cable installation and is therefore a hazard to navigation. The ICPC recommends that hydrographic charts get updated with cable locations and areas restricting anchoring be identified (Carter et al., 2009). If navigation channels must be crossed, they should be crossed in the most direct way possible, and additional protective measures should be planned.
- **Fishery concerns**: Close to half of all damages to submarine cables in the Mediterranean Sea between 1993 and 2007 were caused by fishing activity and hardware (France Telecom Marine). Similar to navigation concerns, fishing grounds should generally be avoided if at all possible. The ICPC recommends that hydrographic charts get updated with cable locations and areas restricting fishing be identified (Carter et al., 2009). If fishing grounds must be entered by cable routes, it is recommended that the cables be trenched and appropriate substrate suitable for fish habitat be placed on top of the trench.
- **Undertake recommended studies**: Once sites are selected, it is highly recommended that the geophysical and coastal engineering studies be undertaken to minimize risks and reduce uncertainty related to the laying and/or trenching of cables. It is likely that the investigations will also identify areas of concern that can be avoided to reduce the cost of the cable installation process.

4.6.7 Environmental Concerns and Impacts

Given that the best and most flexible grid interconnection points are within the Bath, Wiscasset, Boothbay and Rockland areas, it is likely the subsea transmission line may run along or under the seabed from a project site onto shore in the area of Linekin Bay and part of the tidal Damariscotta River and Johns Bay to connect with the electrical grid. There are 2,485 known species of plants and animals in the GoM including phytoplankton (310), macrophytes (271), invertebrates (1,414), chordates (37), fishes (252), birds (177), and mammals (24). The GoM supports mainly boreal, cold temperate, and non-migratory species.

The Linekin Bay, Johns Bay and tidal Damariscotta River forms a complex of bays, inlets, bights and estuaries that provide habitat that supports extensive fisheries for benthic fauna, including crustaceans (lobster, rock crab and shrimp), and mollusks (scallop, oyster, and blue mussel aquaculture, and soft shell clam harvest). Lobster and crab have affinity to bottom cover such as rock outcrops and kelp beds and are thus trapped, whereas shrimp are somewhat more pelagic and harvested in trawls. Scallop are harvested with bottom trawls, whereas oyster and blue mussel are raised in floating pen structures near shore in protected coves; clams are harvested manually from intertidal mud flats. The upper Damariscotta estuary represents the northernmost point of distribution of native populations of the Virginia oyster (*Crassostrea virginica*). The upper extremity of the estuary is one of a few remnant Virginian refugia ecosystems remaining in the GoM (P. Larsen, Bigelow Laboratory, Boothbay Harbor, personal communication).

Several migratory fish species may transiently occupy the area considered for the subsea cable. The estuary directly or indirectly supports a significant anadromous alewife run that migrates up the tidal river to spawn in Damariscotta Lake in Newcastle during May and June. Juvenile alewife exits the estuary during September and October. Atlantic salmon inhabit the adjoining Sheepscot River watershed, and some component of this population may pass through the Linekin Bay/Damariscotta River area during the marine migration. In the spring (late April through June)
pre-spawning adults would enter the freshwater river and juvenile smolts would exit to begin the marine phase of their maturation. Some post-spawned adults may leave the river and potentially pass through a project area in the fall (late October through November). Most of the tidal and estuarine area in the Midcoast area between the Kennebec and Damariscotta rivers (including a potential project vicinity) is known to be inhabited by shortnose and Atlantic sturgeon.

The Endangered Species Act (ESA) prohibits any action that results in the take of a federally listed species. A Biological Assessment is required to determine if the installation of the cable would result in a take of a federally listed species (see Section 5.1.2) and if this is determined to be the case, an incidental take permit will be needed. To obtain an incidental take permit, a habitat conservation plan needs to be developed with input from the National Marine Fisheries Service (NMFS). The Marine Mammal Protection Act (MMPA) prohibits the take of marine mammals. Similar to the ESA, the MMPA contains an incidental take provision. Some marine mammals (i.e., Northern right whale and marine turtles) are also on the ESA list.

Federally listed species in this area that will need to be assessed include five endangered whales: northern right whale (*Eubalaena glacialis*), humpback whale (*Megaptera novaeangliae*), finback whale (*Balaenoptera physalus*), sperm whale (*Physeter catodon*), and sei whale (*Balaenoptera* *borealis*), two endangered turtles: leatherback turtle (*Dermochelys coriacea*), Atlantic ridley turtle, also known as Kemp's ridley (*Lepidochelys kempi*), and one state and federally listed threatened turtle: loggerhead turtle (*Caretta caretta*). The shortnose sturgeon (*Acipenser brevirostrum*) is a federally listed endangered fish, as is the Atlantic salmon (*Salmo salar*). NMFS recently completed as ESA status review for Atlantic sturgeon (*Acipenser oxyrinchus*) and determined that listing the species as threatened is warranted for the GoM distinct population segment.

In addition there are 32 species that will need an Essential Fish Habitat (EFH) assessment as required by the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (MSA) (amended in 1976 and 1998). This EFH assessment is based on the regulations implemented in the United States Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) EFH Final Rule, 50 Code of Federal Regulations (CFR) Part 600 (NOAA 2002). The objective of this EFH assessment is to describe how the actions of a proposed project may affect EFH and EFH-managed species within the area influenced by the proposed project. According to NMFS, EFH within the Project area includes those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. Table 4-16 is a list of EFH-managed species and life stages that have been determined to occur within the proposed cable area.

4.6.8 Permitting Considerations for Interconnection Cable

Permitting requirements for the installation of a subsea interconnection cable for projects in State waters are governed by Public Law 2009, Chapter 615. The law gives Maine Department of Environmental Protection (DEP) permitting authority over offshore wind power projects statewide. The Natural Resources Protection Act (NRPA) was amended through the law, creating a new general permit process for offshore wind energy demonstration projects. It also directed the Bureau of Parks and Lands (BPL) to enact a rule by April 9, 2011, that establishes a fee schedule for submerged lands leases for renewable ocean energy projects.

The intent of the new law, consistent with findings of the Governor's Ocean Energy Task Force (OETF) is to streamline the permitting process and limit duplication of reviews and approvals by lead agencies. Essentially this means that the same application "package" can be utilized in applying for the various agency approvals.

Table 4-16: Essential Fish Habitat designated species for Midcoast Maine

SPECIES	EGGS	LARVAE	JUVENILES	ADULTS
American Plaice, *Hippoglossoides platessoides*	X	X	X	X
Atlantic Cod, *Gadus morhua*	X	X	X	X
Atlantic Halibut, *Hippoglossus hippoglossus*			X	X
Atlantic Herring, *Clupea harengus*	X	X	X	X
Goosefish, *Lophius americanus*		X	X	X
Haddock, *Melanogrammus aeglefinus*	X	X	X	X
Ocean Pout, *Macrozoarces americanus*			X	X
Offshore Hake, *Merluccius albidus*		X	X	X
Pollock, *Pollachius virens*	X	X	X	X
Redfish, *Sebastes spp.*		X	X	X
Red Hake, *Urophycis chuss*	X		X	X
Sea Scallop, *Placopecten magellanicus*				X
Silver Hake, *Merluccius bilinearis*	X	X	X	X
White Hake, *Urophycis tenuis*	X	X	X	X
Windowpane, *Scophthalmus aquosus*			X	X
Winter Flounder, *Pseudopleuronectes americanus*			X	X
Witch Flounder, *Glyptocephalus cynoglossus*	X	X	X	X
Yellowtail Flounder, *Limanda ferruginea*	X	X	X	X
Red Deepsea Crab, *Chaceon quinquedens*			X	X
Barndoor Skate, *Dipturus laevis*			X	X
Little Skate, *Leucoraja erinacea*			X	X
Smooth Skate, *Malacoraja senta*			X	X
Thorny Skate, *Amblyraja radiata*			X	X
Winter Skate, *Leucoraja ocellata*			X	X

Leases or easements are required for utility cables and therefore a proposed project connecting to the ISO-NE grid will require a submerged lands lease from BPL. A permit will be required from the United States Army Corps of Engineers (USACE) under Section 10 of the Rivers and Harbors Act and Section 404 for the Clean Water Act. The application must include a written request with the following:

- Application for lease or easement of Submerged Lands;
- Application for a wetlands alteration permit, or equivalent application from the Department of Environmental Protection; an application for a building, development, great ponds, or equivalent application from the Land Use Regulation Commission; and
- Any other permitting materials prepared for other agencies with jurisdiction

Generally, the BPL will issue a Preliminary Finding within 60 days of the application, unless additional information is requested. Issuance of the finding begins a 30-day review of impacts from state and federal agencies including but not limited to the Department of Marine Resources (DMR), the Department of Environmental Protection (DEP), the State Planning Office (SPO), the Department of Transportation (MEDOT), and USACE. Qualifying activities cannot adversely impact access to or movement across the waters of the State; public trust rights – fishing, waterfowl hunting, navigation, and recreation; and/or services and facilities for commercial marine activities.

As noted above, the Maine NRPA was amended by law giving DEP authority over offshore wind demonstration projects. While the application has not been specifically modified, it is anticipated that generally the same information required under the prior NRPA application process will be necessary. This includes the following:

- Pre-application meeting;
- Supply of applicant information;
- Project description, location, size of area impacted and site plans;
- Assessment of the amount of impact on resources; and
- Any proposed mitigation measures

The application must also be provided to the Maine State Historic Preservation Officer (MSHPO). The applicant may also submit the application to the USACE. If it chooses not to, DEP will provide a copy to the USACE and coordinate review. The processing timeline for a NRPA permit can take up to 120 days.

Maine statute stipulates that no agency of the State or any political subdivision of the State can issue a lease or conveyance of public land for the purposes of constructing a transmission line unless a certificate of public convenience and necessity (CPCN) is issued by the Maine Public Utilities Commission (PUC).

A permit will also be required from USACE under Section 10 of the Rivers and Harbors Act and Section 404 for the Clean Water Act, for the portion of the subsea cable route in federal waters (over three nautical miles (3 nmi) from the coastline). Due to their cooperative process, USACE will review the same application filed with DEP and typically strives to issue written authorization (required for their Category 2 activities or individual permits) within the same timeframe as the state review process. Under the USACE General Permit review process (in addition to DEP), approvals may be required from Maine Department of Conservation: Land Use Regulation Commission (LURC), Maine Department of Marine Resources: Aquaculture Leases and Maine Department of Conservation, Bureau of Parks and Lands, Submerged Lands.

Due to the location of the proposed cable relative to fish and marine mammal habitat and migration routes, the NMFS will need to be consulted under Section 7 of the Endangered Species Act. It is anticipated that the agency would determine that a proposed project is not likely to affect adversely affect species known to inhabit or pass through the area.

The 2009 Maine state law specifically prevents a coastal municipality from banning the interconnection siting, but there still may be local zoning and/or permitting requirements to be addressed.

For sections of the cable proposed to be located in federal waters, a Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) lease for the Project area would grant one or more easements to allow for installation of the cable route. The easements would be applied for as part of a Construction and Operation Plan (COP) and would be subject to review under the National Environmental Policy Act (NEPA) as part of the COP and would be subject to Coastal Zone Management Act (CZMA) consistency determinations, ESA reviews and other aspects of BOEMRE permitting as further described under the general lease site permitting section of this report (Section 5.1).

4.6.9 Summary Conclusions of Guidance

Cable Installation Conclusions

The general conclusion surrounding the literature review is that trenching of cables is preferred to minimize the risk of damages, and that the technology to trench through all materials exists. Unfortunately, the dominant conditions present on Maine's Inner Continental Shelf do not appear to support easy or cost-effective trenching. While it may be possible to plan a cable route in trenchable materials using information presently available, given the short time period and demonstration nature of the proposed installation, a thorough quantification of risks associated with not trenching the cables could be considered.

It may also be possible to undertake additional studies on the muddy areas of the ICS to see if indeed these areas could support the trenching of cables. Existing literature suggests that most trenching equipment gets bogged down in very soft material and the cables are very difficult to recover for maintenance. If the mud is more consolidated than the Department of Conservation 1996 report on the seabed composition suggests, the material may indeed support trenching and would be the preferred approach over trenching through the bedrock.

Environmental Impact Conclusions

Potential cable routes may come onto shore in the area of Linekin Bay and part of the tidal Damariscotta River and Johns Bay. This embayment provides habitat that supports extensive fisheries, benthic fauna, lobster, rock crab, shrimp, scallop, oyster, blue mussel aquaculture and soft shell clam harvest. Federally listed species in this area that will need to be assessed include five (5) endangered whales, two (2) endangered turtles and two (2) listed and one proposed for listing fish species. In addition, 32 EFH-managed species will require an assessment. These areas will need to be assessed relative to the final cable routing zone to assess the ultimate effect of the transmission cable.

Permitting and Legislative Conclusions

Several state and federal agency approvals will be required for the construction of a subsea transmission line, primarily through permit application processes. Recently enacted state law, intended to streamline the permitting process, places primary state permitting authority with Maine Department of Environmental Protection (MDEP). However, formal permit approvals from and consultation with other agencies is necessary, as well as a submerged land lease. It is recommended that a meeting with all participating agencies take place before entering the permitting process, to confirm the information necessary and to develop a schedule of filings and reviews with agency staff.