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Offshore Wind Submarine Power Cables – An Introduction

Duncan Sokolowski – Sr Project Manager, Submarine Cable Services at Tetra Tech

ROSA

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cbi Consensus Building Institute

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The scale of the industry – a comparison.

Europe installed their first offshore wind farm in 1991, off Denmark. This was a 5 MW project consisting of 11 turbines. As of 2019, there were 22,000 MW of installed offshore wind power, generated by 5,000 turbines.

The American Wind Energy Association estimates that by 2030, the USA will have between 20,000 and 30,000 MW of installed offshore wind power.

20,000 MW of offshore wind power will require approximately 1,650 turbines (of 12 MW each), approximately 50 export cables (~3,000 miles) and 2,000 inter array cables (~2,000 miles).

Growth is driven by renewable energy/greenhouse gas reduction targets set by the various states. One example - NY has set a goal of 9,000 MW of installed offshore wind generation by 2035.

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An overview of the cabling.

Array Cable and Export Cable cross sections

Parameter	HVAC Arrays	HVAC Export	HVDC
Outer Diameter Range	4.25 in – 6.3 in (110 mm – 160 mm)	10 in – 13 in (250 mm – 320 mm)	Approx. 6 in (150 mm) NOTE: Return cable is of smaller diameter
Weight in Air	13 lbs/ft – 34 lbs/ft (20 kg/m – 51 kg/m)	Up to approx. 85 lbs/ft (125 kg/m)	Approx. 40 lbs/ft (60 kg/m) for entire bundle
Minimum Bend Radius	~ 6 ft (2.0 m)	~ 15 ft (5.0 m)	Varies
Conductor Cross-Section	3 x 120 mm^2 – 800 mm^2	3 x 800 mm^2 – 1400 mm^2	Up to approx. 1800 mm^2
Voltage Rating (approx.)	< 66 kV	132 – 345 kV	Up to approx. +/- 600 kV

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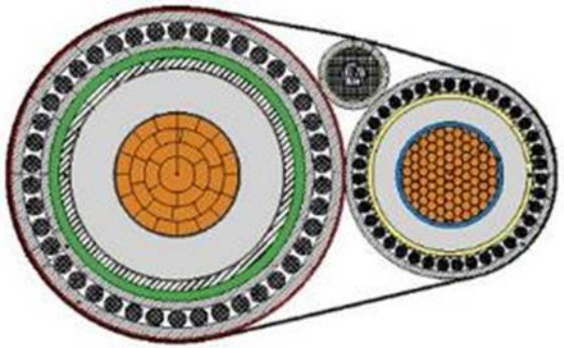

Parameter	HVAC	HVDC
Cable Cost	High	Medium
Electrical Losses	Medium	Low
Practical Maximum Length	~100 km	Theoretically unlimited, current longest submarine cable is about 600 km
System reliability	High	High
OSP/Convertor platform cost	Medium	High
Max power per cable	~400 MW	Currently Western Link; transmits 2,200 MW
Onshore footprint	Medium	Large

HVDC Cable 'slices'
Neptune project on the left, Basslink (Tasmania) on the right

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So how are submarine cables protected from external aggression?

Cable Burial is always the primary method of protection for cables.

What drives the specified cable burial depth?

- Requirements from Federal and state agencies (e.g., USACE in federally maintained shipping channels, states such as New Jersey have a burial depth requirement in their waters etc.)
- Industry guidance from (for example) standards agency such as DNV GL, experience from organizations such as the North American Submarine Cable owners Association (NASCA) etc.
- Site and region-specific risk factors and soil conditions.

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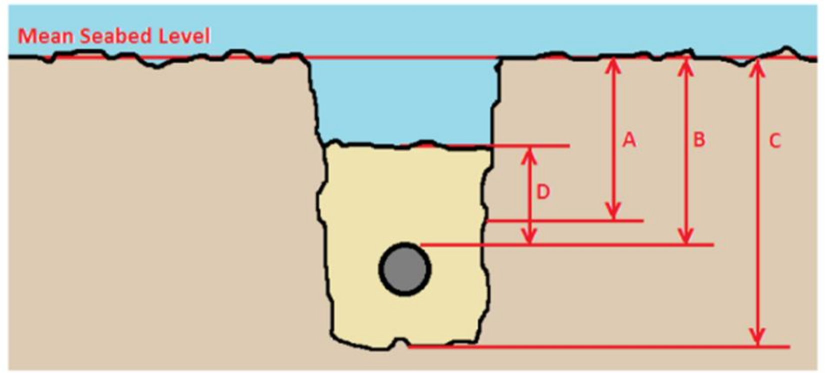
Cable Burial Risk Assessment (CBRA)

A CBRA is a risk-based methodology used to determine the minimum recommended Depth Of Lowering (DOL) for a submarine cable. The CBRA was developed by the U.K's Carbon Trust which commissioned a group of subject matter experts to create a method of determining risk to a submarine cable system and therefore specify a DOL that will reduce risk 'As Low As is Reasonably Practicable' (ALARP).

The CBRA will determine a minimum recommended DOL (A) at each point along the cable route.
To achieve this, the installation contractor will select a burial method to achieve a target DOL (B). This allows for a slight margin of error in case of unexpected hard soils, for example.
A target trench depth (C) will help to ensure that the minimum DOL is attained by accounting for any potential backfill.



A Recommended Minimum Depth of Lowering
B Target Depth of Lowering
C Target Trench Depth
D Depth of Cover

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What goes into a CBRA?
Any external factor that can damage the cable, or in turn can be damaged by the cable is taken into consideration, these are a mix of natural and human (anthropogenic) factors.

- Commercial vessel activity
- Commercial (& recreational) fishing activity
- Dumping areas
- Dredging activity
- Obstructions (wrecks etc.)
- Cultural sites
- UXO
- Existing seabed assets
- Steep slopes, shoals, ravines, hard seafloor
- Sediment mobility
- Wind, waves, tides, currents
- Environmentally sensitive areas

Proper route planning will avoid challenging geophysical conditions (steep slopes, hard sediments etc.) as well as areas of human activity where possible. Where this isn't possible, the CBRA will ensure that risk to the cable is reduced as far as is reasonably practicable

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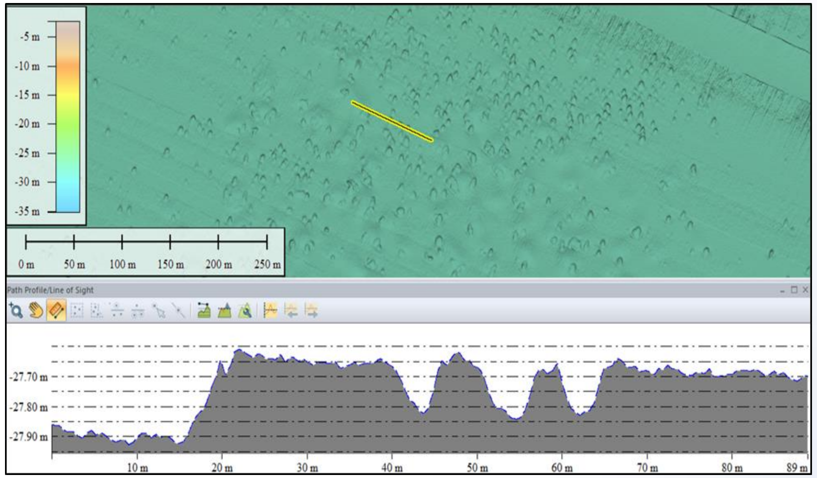
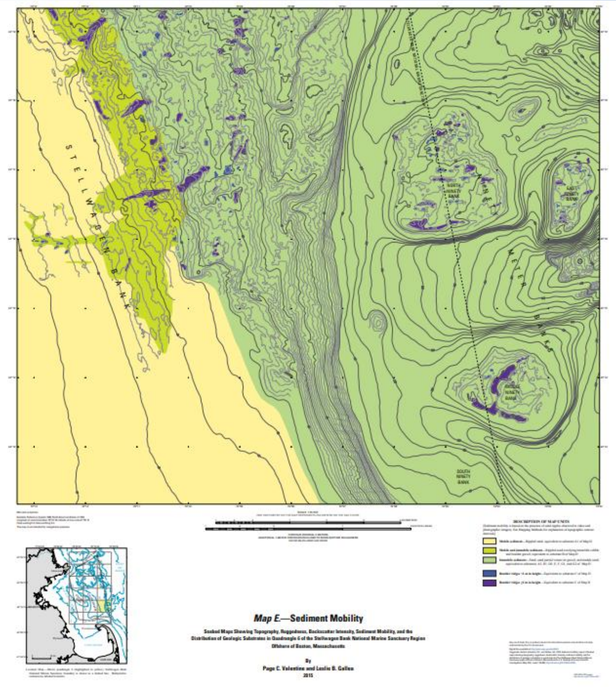
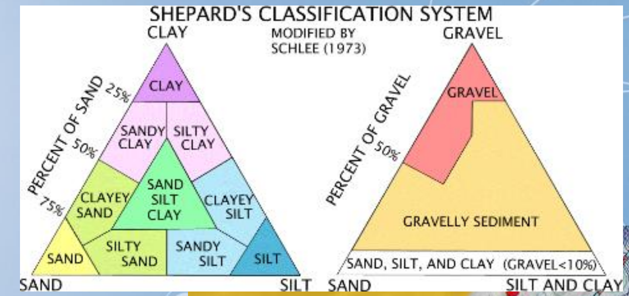
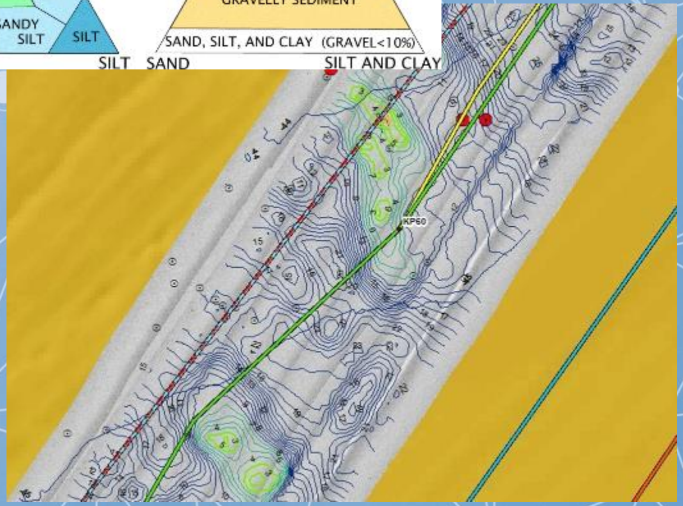
What goes into a CBRA?









Seabed Bathymetry

Sediment Mobility

Seabed Geology

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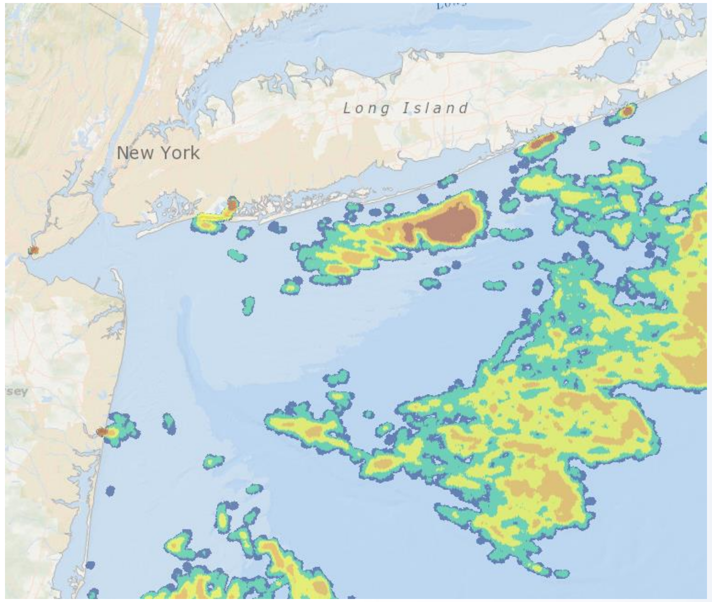
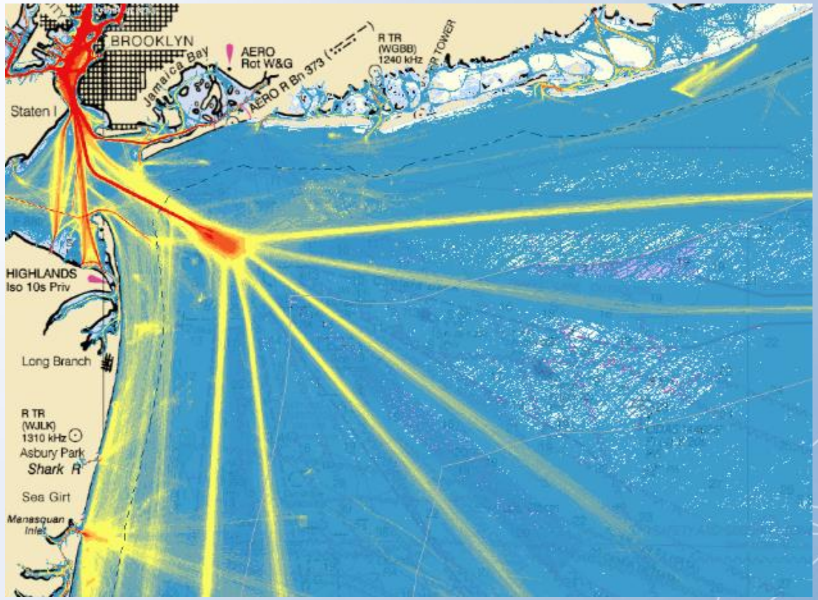
What goes into a CBRA?



Fishing Activity
(Hydraulic surf clam dredging, 2015 & 2016 VMS data)



Shipping Activity
(2019 AIS Data, Marine Cadastre)

Analysis of fishing types & commercial vessel types encountered

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CBRA Output

KP Range	KP0 to KP2	KP2 to KP4	KP4 to KP6	KP6 to KP8	KP8 to KP10	KP10 to KP12	KP12 to KP14	KP14 to KP16	KP16 to KP18	KP18 to KP20	KP20 to KP22	KP22 to KP24	KP24 to KP26	KP26 to KP28	KP28 to KP30	KP30 to KP32	KP32 to KP34	KP34 to KP36	KP36 to KP38	KP38 to KP40	KP40 to KP42	KP42 to KP44	KP44 to KP46	KP46 to KP48	KP48 to KP50	KP50 to KP52	KP52 to KP54	KP54 to KP56	KP56 to KP58	KP58 to KP60	KP60 to KP62	KP62 to KP64	KP64 to KP64.1
Water Depth (m)	-9	-11	-12	-13	-13	-15	-16	-17	-19	-18	-21	-21	-20	-22	-20	-21	-21	-21	-21	-23	-24	-24	-25	-24	-28	-28	-25	-28	-29	-25	-30	-27	-25
Large Vessels:																																	
Intentional Anchoring	1	1	1	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	3	3
Accidental Anchor Deployment (on transit)	1	1	1	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	3	3
Emergency Anchoring	1	1	1	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	3	3
Commercial Fishing	4	4	4	4	4	4	4	3	3	3	3	3	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dropped Objects	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Military Operations and Anchoring	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1
Dumping and Sand Borrow Operations	4	4	4	4	3	3	3	3	3	3	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
UXO Risks	4	4	4	4	4	4	4	4	3	3	3	3	2	2	2	2	2	2	2	Unknown													
(<1m) Minor Scour/Erosion	5	5	5	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	4	4	4	5	5	4	5	4	4	5	5	5	4
(<1m) Minor Mobile Seabed & Potential Overburial	5	5	4	3	3	3	3	3	3	3	5	5	5	5	5	5	5	5	4	4	4	4	4	4	4	4	4	4	5	5	4	4	4
(>1m) Major Scour/Erosion	5	4	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	2	2	2	3	3	3	3	3
(>1m) Major Mobile Seabed & Potential Overburial	5	4	2	2	2	2	2	2	2	2	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	2	2	2	3	3	3	3	3

Risks presented in this table should be considered the unmitigated risks--i.e., those before outreach and marine liason to make mariners aware of cables, as well as before any burial or cable protection. An analysis of residual risks will be possible with better constraints on anchor penetration, mitigation of mobile seabed through routing, etc.

1	Highly Unlikely	2	Unlikely	3	Possible	4	Likely	5	Nearly Certain

Risk Assessment

Depth Of Lowering recommendations

KP Range	KP0 to KP2	KP2 to KP4	KP4 to KP6	KP6 to KP8	KP8 to KP10	KP10 to KP12	KP12 to KP14	KP14 to KP16	KP16 to KP18	KP18 to KP20	KP20 to KP22	KP22 to KP24	KP24 to KP26	KP26 to KP28	KP28 to KP30	KP30 to KP32	KP32 to KP34	KP34 to KP36	KP36 to KP38	KP38 to KP40	KP40 to KP42	KP42 to KP44	KP44 to KP46	KP46 to KP48	KP48 to KP50	KP50 to KP52	KP52 to KP54	KP54 to KP56	KP56 to KP58	KP58 to KP60	KP60 to KP62	KP62 to KP64	KP64 to KP64.1
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Large Vessels:	HDD to extent feasible to get below storm wave base																																
Intentional Anchoring																																	
Accidental Anchor Deployment (on transit)		1	1	1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Emergency Anchoring					Pending geotechnical evaluation of the seabed to understand soil strength and anchor penetration potential.																												
Commercial Fishing		1.5	1.5	1.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dropped Objects		Pending further analysis																															
Military Operations and Anchoring		1	1	1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Dumping and Sand Borrow Operations		2	2	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UXO Risks		Not mitigated by cable burial																															
Scour and Seabed Mobility (These numbers are moderately conservative and assume worst-case routing to avoid largest mobile seabed features. Further reduction may be possible if substantial micro siting allows.)		1.5	1.5	1	1	1	1	1	1	1	2	2	4	4	4	4	4	3	3	3	3	2	2	3	1	1	1	2	3	3	3	3	3
Greatest Depth of Lowering Value from Risk		2	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Greatest Depth of Lowering PLUS Seabed Mobility Mitigation Depth		3.5	3.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3.5	3.5	5.5	5.5	5.5	5.5	5.5	4.5	4.5	5	5	4	4	5	3	3	3	4	5	5	5	5	5

The need for very deep burial areas may be able to be mitigated through routing to minimize traverse of highly mobile seabed and through dredging to get below the seabed reference level for mobile bedforms. More detailed routing is needed to adequately capture and evaluate this. Pending ECC Geotechnical information may also indicate that anchor penetration is substantially lower if the sediments appear harder than assumed. These areas of deeper burial may only be small spans within each 2-km subsegment.

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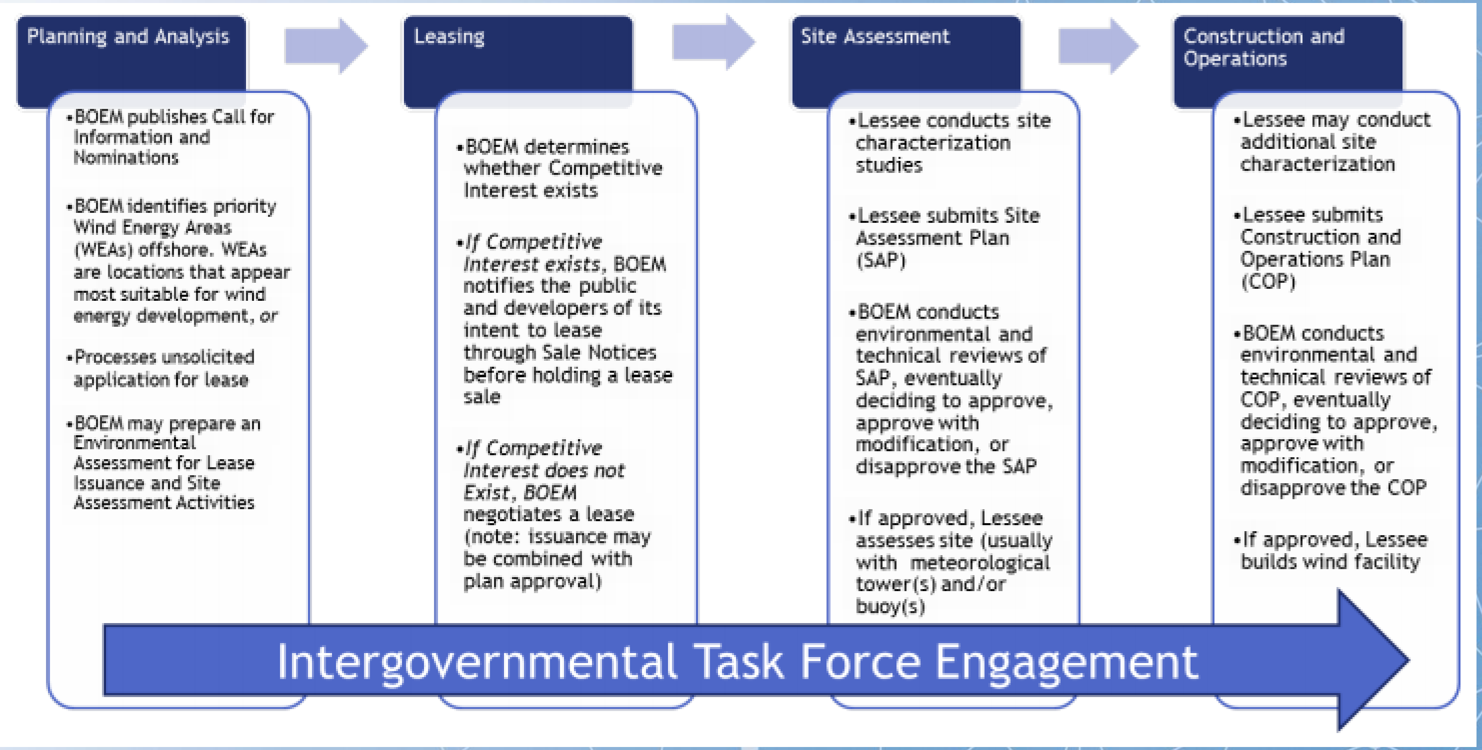
When can cable installation commence?

The permitting of an offshore wind farm is a process coordinated by BOEM under the National Environmental Policy Act (NEPA) of 1969.

Part of the permit requirements will include installation windows that will limit construction activities to times that won't impact migratory species, fish spawning, etc.



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Cable Installation And Burial – Two common methods

Simultaneous Lay and Burial

The Cable Lay Vessel (CLV) lays and buries the cable in a single operation.

Only one vessel required so saves on vessel day rates, however, the lay operations are a lot slower than if the cable is laid with no burial (surface lay). Therefore longer weather windows are required.

Post Lay Burial

The CLV lays the cable on the seabed, it is then buried via a separate operation (usually by a different vessel).

Two vessels required but a lot of flexibility with regard to making the full use out of weather windows.

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Simultaneous Lay and Burial

Towed Plow
~3m/10' burial depth
15m long, 6.5m wide
Weighs approx. 50T

Towed jetting sled
~3m/10' burial depth
For shallower water & softer soils

Large Towed jetting sled
~8m/25' burial depth
For shallower water, has optional chain cutter for harder soils

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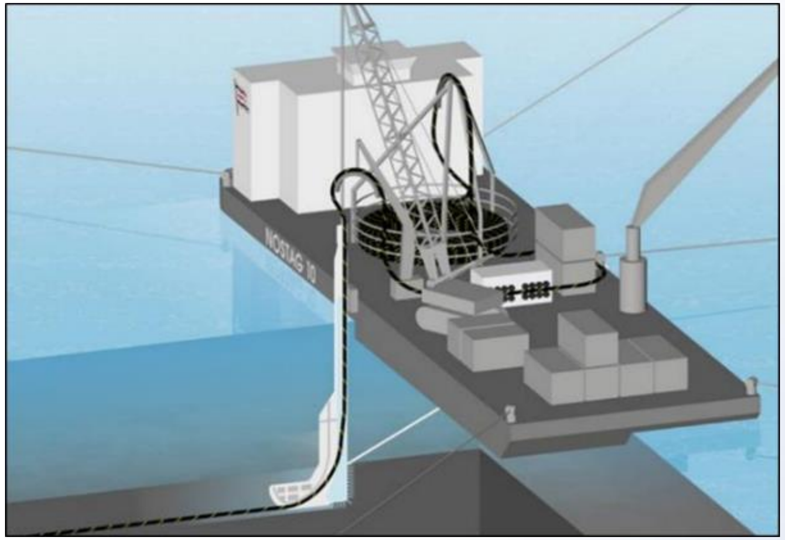
Simultaneous Lay and Burial



Vertical Injector
Up to 10m/33’ burial depth
Deployed from a barge
Shallow water, softer soils

Tracked Trencher
Deepoceans T3200
Weighs 170T, jetting and chain cutting up to 3.5m burial depth

Tracked Trencher
Van Oord’s ‘Deep Dig-It’
Weighs 125T, jetting and chain cutting up to 5.0m burial depth

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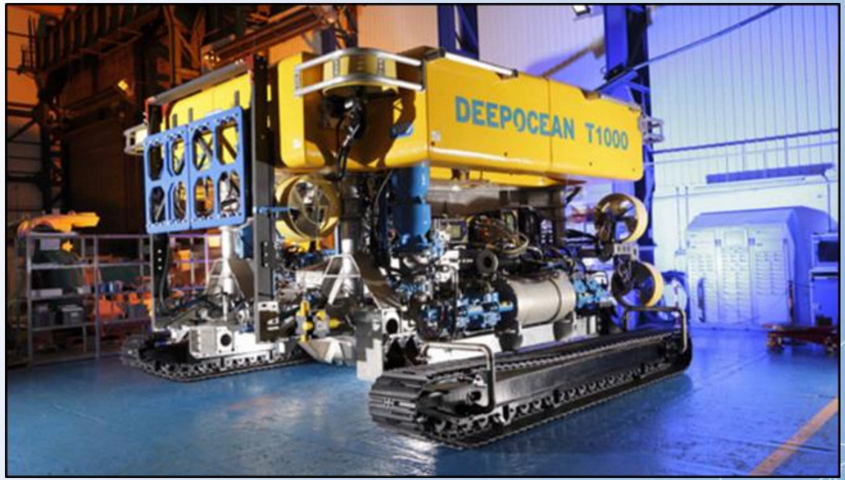
Post Lay Burial



ROV
Canyon's T1200
Up to 3m/10' burial depth
Water jetting only

ROV
Deepocean's T1000
Up to 3m/10' burial depth
Water jetting only

ROV in 'free-flying' mode
For softer sediments where tracks would sink and cause a loss in maneuverability

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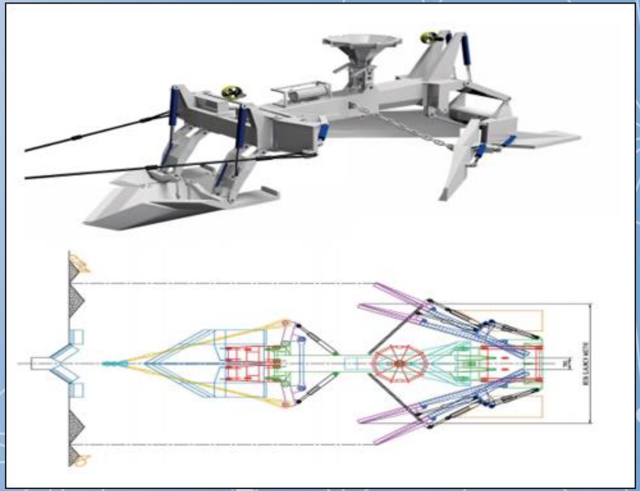
Other burial techniques



Mass Flow Excavator (MFE)

Multimode plow can clear boulders (route clearance mode), cut a trench into which the cable is laid, then can backfill the trench after cable lay. Typically can cut a 'V' or 'Y' shaped trench between 1.0 and 2.0m in depth, depending upon soil conditions

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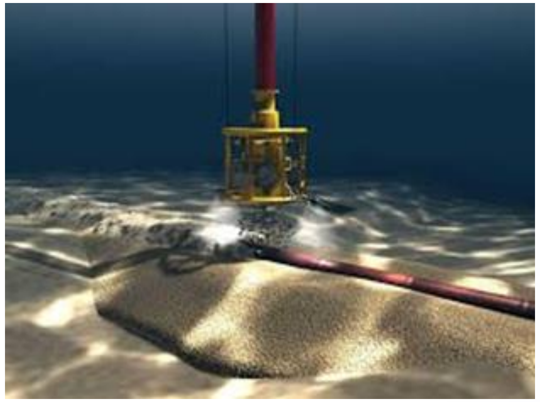
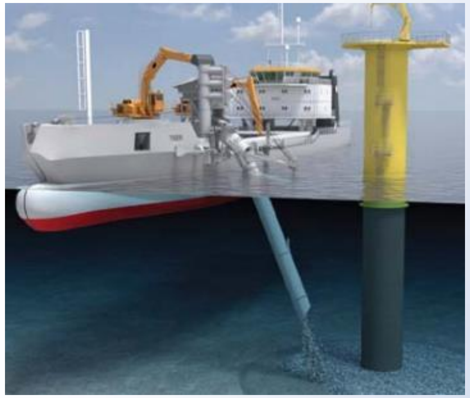
Other Cable Protection





Rock Dumping

Grout/Rock Bags

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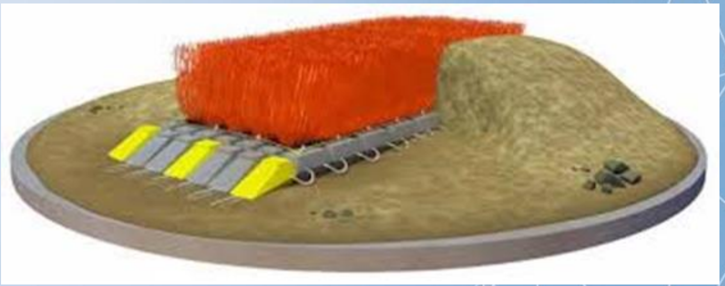
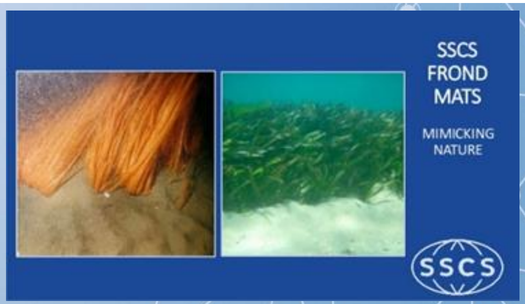
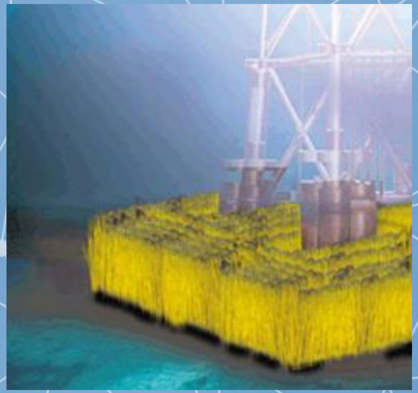
Other Cable Protection







Concrete Mattresses

Frond Matts/Nature Inclusive Designs

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Other Cable Protection

Articulated Split Pipe

Uraduct

Cable Protection Systems

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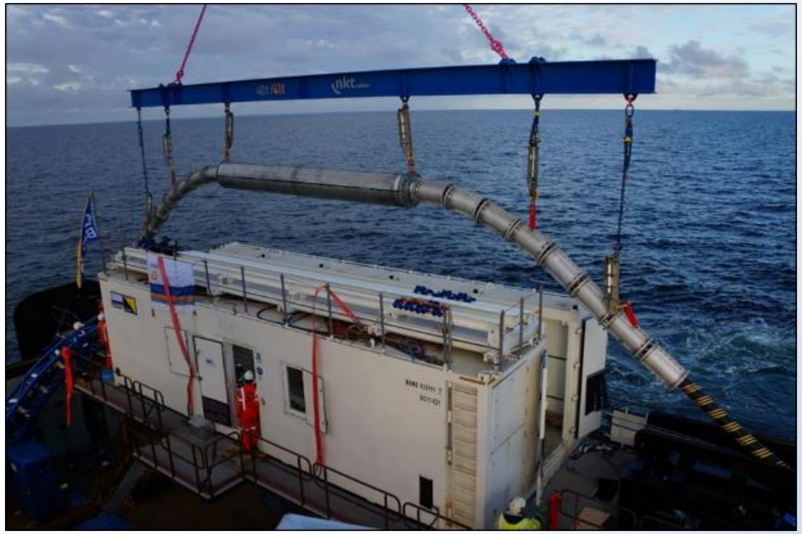
Cable Repairs



Cable joint being lifted out of jointing container

Cable joint being deployed from vessel

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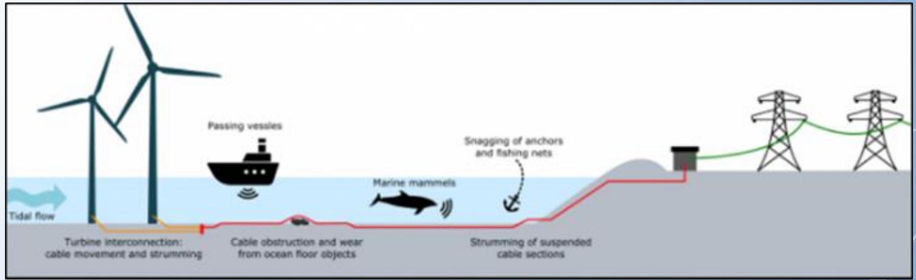
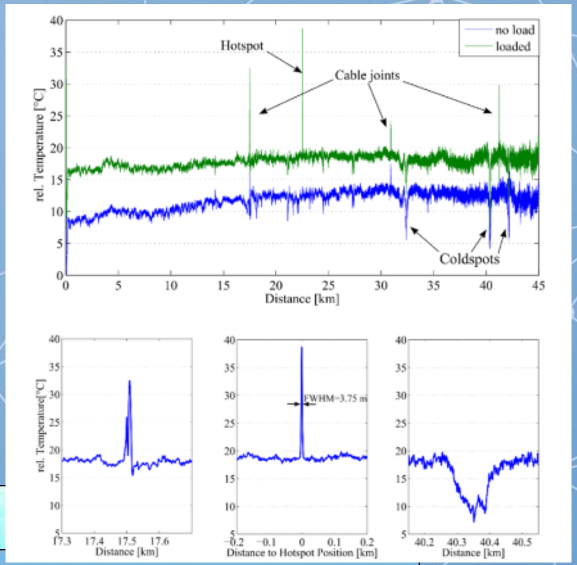
Cable Surveys

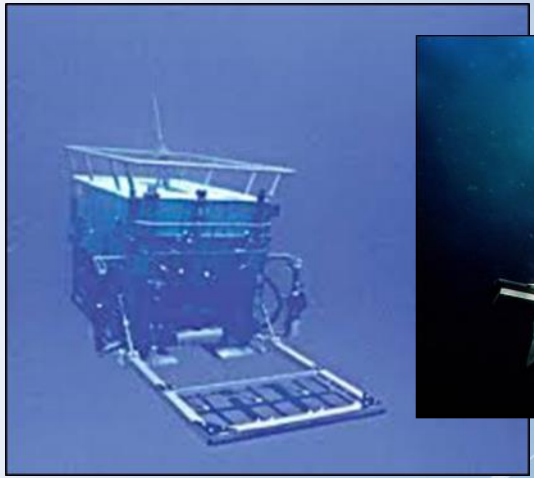
Cables are surveyed to ensure that the target depth of lowering has been achieved (after burial) and at periodic intervals to ensure that the cable isn't becoming too shallow or conversely, that the cable isn't becoming too deeply buried.

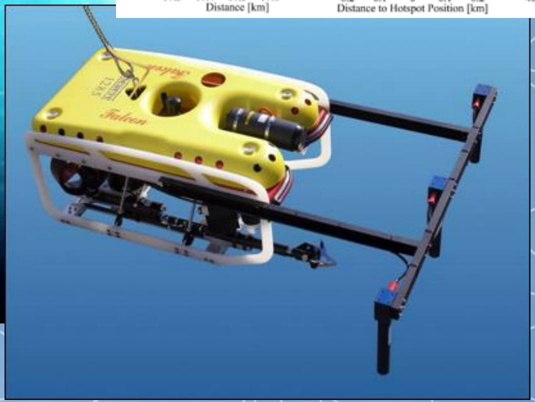
Cables that get shallower (mobile sediments move away for example) are at risk of damage.
Cables that get deeper reduce the current carrying capability due to the reduction in thermal conductivity.

How often?
It depends on site-specific conditions (e.g., how mobile the seabed is) as well as regulatory permitting requirements. It may be that initially, surveys are carried out every 1 to 2 years to establish baseline data, then the frequency can be reduced once the cable burial depth trend is more understood.









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Any Questions?

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NYSERDA have commissioned a submarine cabling informational report. The initial draft will be released imminently. Please contact Morgan Brunbauer for further details.

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