About
Submarine Power Cables

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Role of Submarine Power Cables

- **Historically, submarine power cables linked shore-based power grids across bays, estuaries, rivers, straits, etc**
- **Now submarine cables carry power between countries and to offshore installations, e.g. oil/gas platforms and ocean science observatories**
- **Submarine cables also transfer power from offshore renewable energy schemes to shore, e.g. wind, wave and tidal systems**

Offshore wind farm, Kentish Flats, UK
Source: ELSAM Denmark

Importance of Power Cables

- Power transfer from energy sources, including offshore renewable energy schemes, to consumers
- Interconnecting different regional electrical transmission networks to allow global trading of energy
- Supply to remote areas
- Power (and communications) for offshore installations
- With growing reliance on offshore-based renewable energy schemes, many countries now class submarine power cables as critical infrastructure
- Submarine power cables are designed to be resilient, however faults can temporarily affect supply

A Brief History

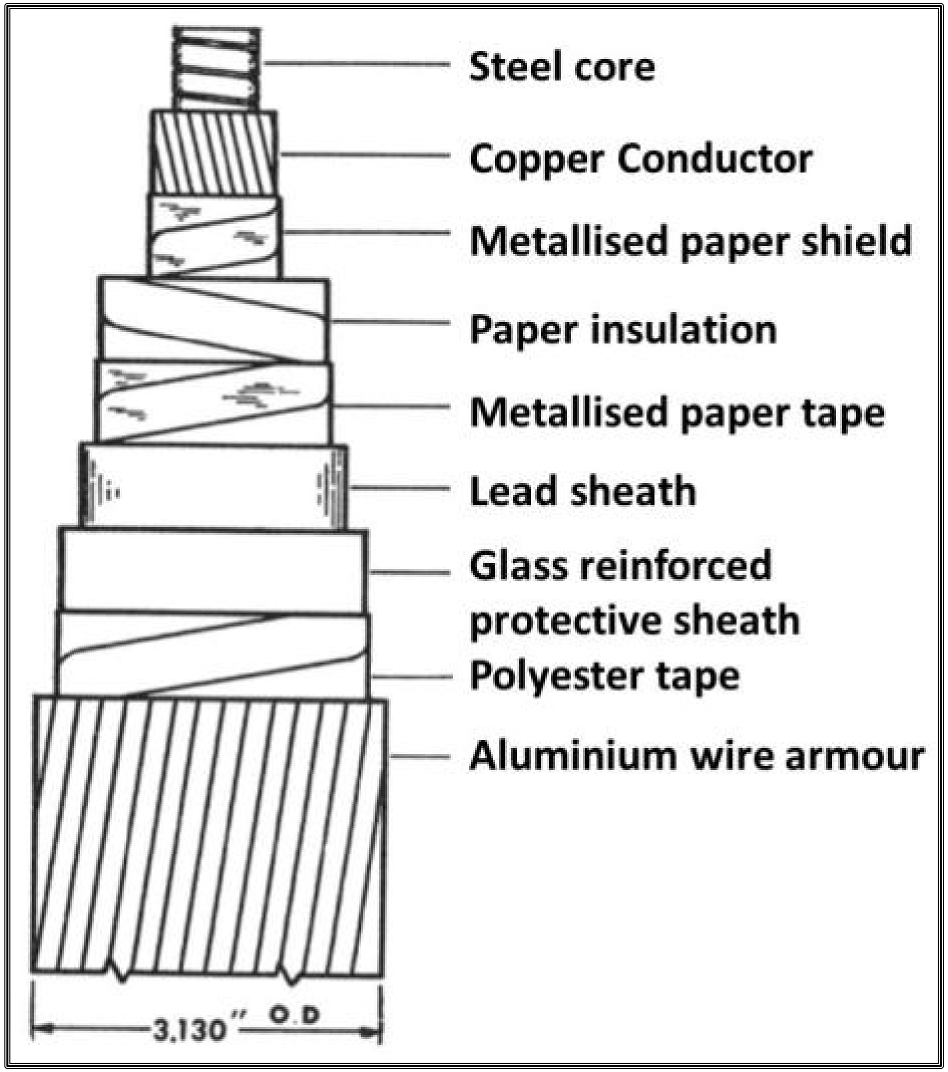
- **1811:** 1st submarine power cable installed in Germany, insulated with natural rubber
- **1924:** Lead extrusion introduced as a water barrier
- **1937:** 1st synthetic insulation cable - butyl rubber
- **1952:** Introduction of oil-filled insulation
- **1954:** 1st Submarine HVDC Cable installed between Gotland and Västervick (Sweden) - 98 km long
- **1962:** 1st ethylene-propylene rubber (EPR) insulation
- **1973:** 1st cross linked polyethylene (XLPE) insulation
- **1990's:** Oil-filled insulation mostly abandoned and replaced by plastics

Note: See Glossary for explanation of above terms

Modern HVDC cable *Source: ABB*

Modern HVAC cable with fibre optic telecom cable (arrow) *Source: ABB*

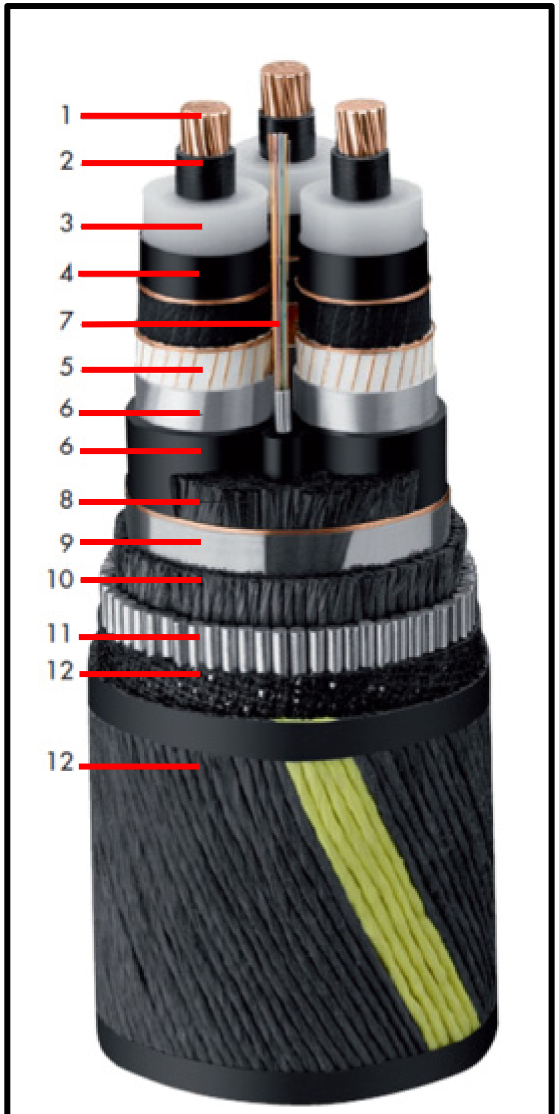
Early Submarine Power Cable



115kV single conductor submarine power cable - 1962
Source: IEEE

Horses pulling submarine power cable ashore to form terminal, around 1930; Washington, USA
Source: Kingston Community News

Modern Submarine Power Cable



Source: Nexans

1. Conductor – usually copper
2. Conductor screening – usually extruded
3. Insulation – XLPE or EPR
4. Insulation screening – semi-conductive
5. Screen
6. Laminated sheath – aluminum tape and polyethylene
7. Optical fibres – optionally used for telecommunications
8. Fillers – as needed
9. Binder tapes
10. Armour Bedding – polypropylene strings
11. Armour – galvanized round steel wires
12. Serving – bituminous compound, hessian tape with polypropylene coloured stripe

Construction varies with manufacturer and seabed conditions, with more armour added where, for example, waves and currents are strong

Power Cable Types

Two basic types of cable:

- **HVAC (High Voltage, Alternating Current) is limited by transmission distance, normally less than 80km**
- **HVDC (High Voltage, Direct Current) used for longer distances and for system interconnection. AC is converted to DC for transmission through the cable and back to AC at the other end**

Two basic types of insulation:

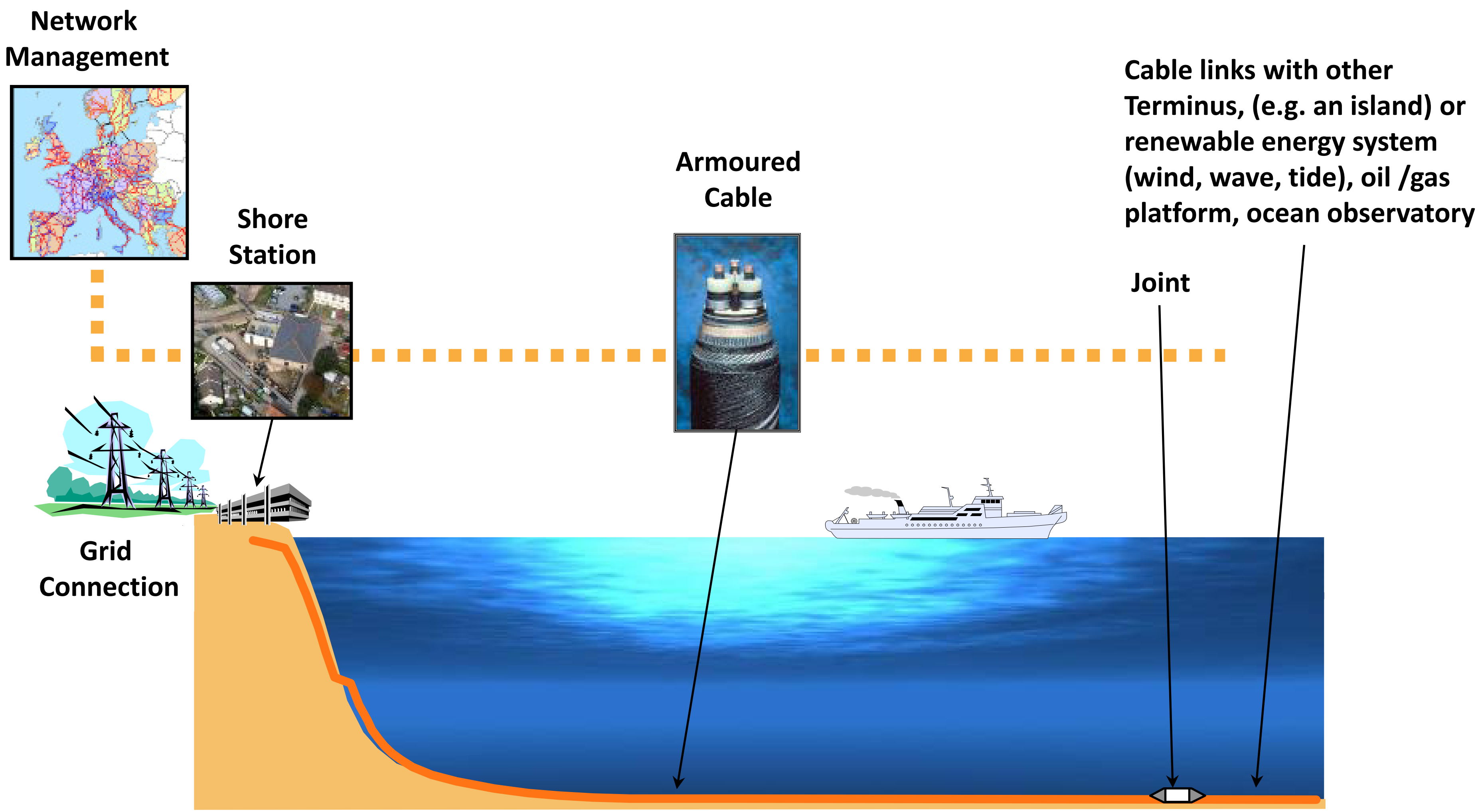
- **Paper insulated and fluid filled (often includes lead sheath for water blocking)**
- **Extruded plastic insulation (XLPE or EPR)**

How Power Cables Work

- **HVAC Cables: Alternating Current transmitted down each of three conductors**
- **HVDC Cables: Direct Current transmitted down a primary conductor and requires a return path provided via another conductor or via seawater using an anode/cathode**

Note: Communications within a power cable system are often achieved by the inclusion of a fibre-optic package to carry the laser light signals. For more information about fibre-optic submarine cables please refer to "About Submarine Telecommunications Cables" on the ICPC website.

Typical Submarine Power Cable System



NOT TO SCALE

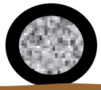
Source: UK Cable Protection Committee, Alcatel-Lucent Submarine Networks and Guernsey Electricity

Cable Size

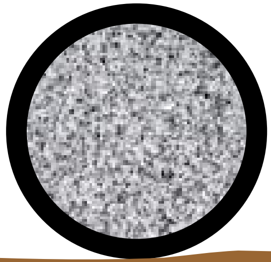
Middle range of oil/gas pipeline diameters (600 mm)

- Power cable diameters are up to 300 mm depending on current-carrying capacity and amount of armour protection
- Submarine oil/gas pipes can reach 1500 mm diameter, whereas submarine telecommunications cables are 17-50 mm diameter depending on armour

Inshore submarine fibre-optic cable (50 mm)



Submarine power cable (150 mm)



Cable Weight

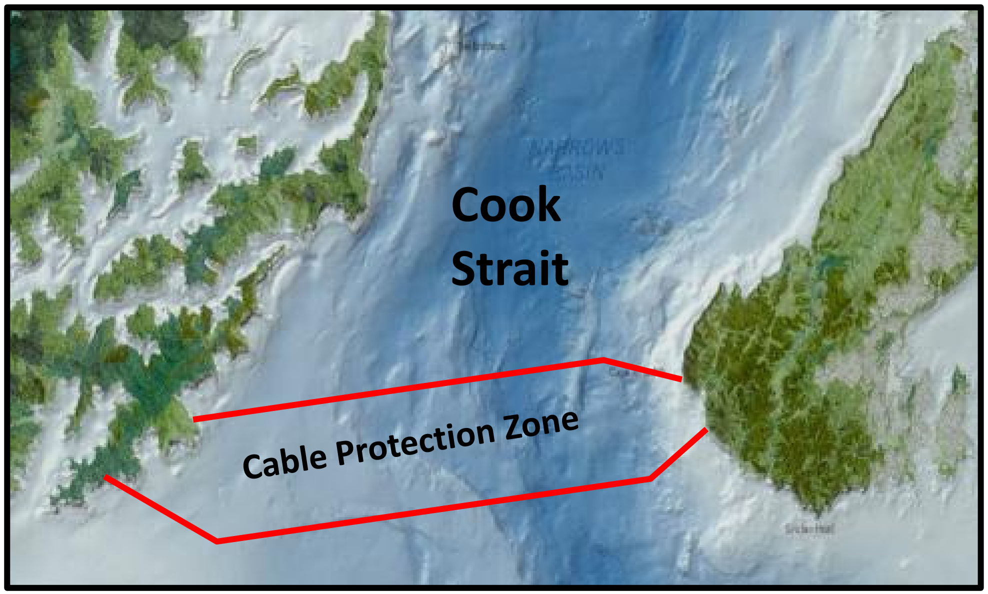
Deep-sea fibre-optic cable, sectioned to show internal construction; fine strands at top are optical fibres used to transmit data

Source: L.Carter

Source: Basslink

- **Telecommunications cables weigh from 0.7 kg /metre for unarmoured deep-water types (example shown above left) to 4.8 kg/m for cables with two layers of steel armour protection**
- **Power cables weigh up to 140 kg/m depending upon type**
- **The picture (above right) shows the composite or “bundled” system of one fibre-optic cable and two power cables, together weighing 67 kg/m, being laid onto the seabed**

Coastal Cable Routes



Cable Protection Zone that contains power and communications cables between the North and South islands of New Zealand
Source: NIWA and Transpower, NZ

- **To reduce risk, cables and protection zones are identified on nautical charts**
- **A cable protection zone is a legal entity where activities harmful to cables are banned**
- **Cable burial in water depths up to 2000 m is also a key protective measure**
- **Effective policing of zones is essential**

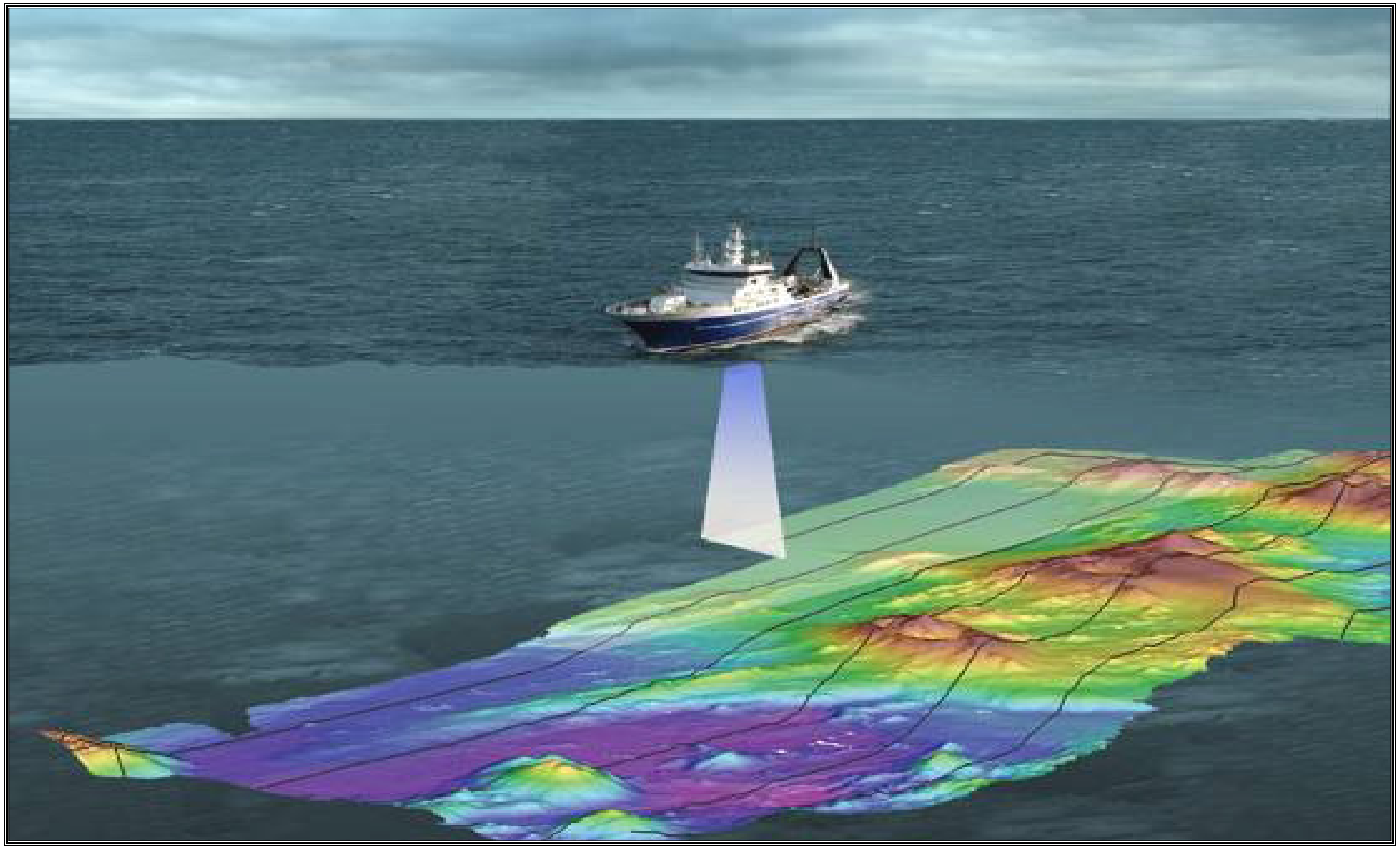
Installing a Submarine Cable

Installing a submarine cable typically involves:

- **Selection of provisional route**
- **Obtaining permission from the relevant authorities**
- **Full survey of route and its final selection**
- **Design cable system to meet conditions of selected route**
- **Laying the cable, including burial in appropriate areas**
- **In some cases, a post-lay inspection may be necessary**
- **Notification of cable position to other marine users**

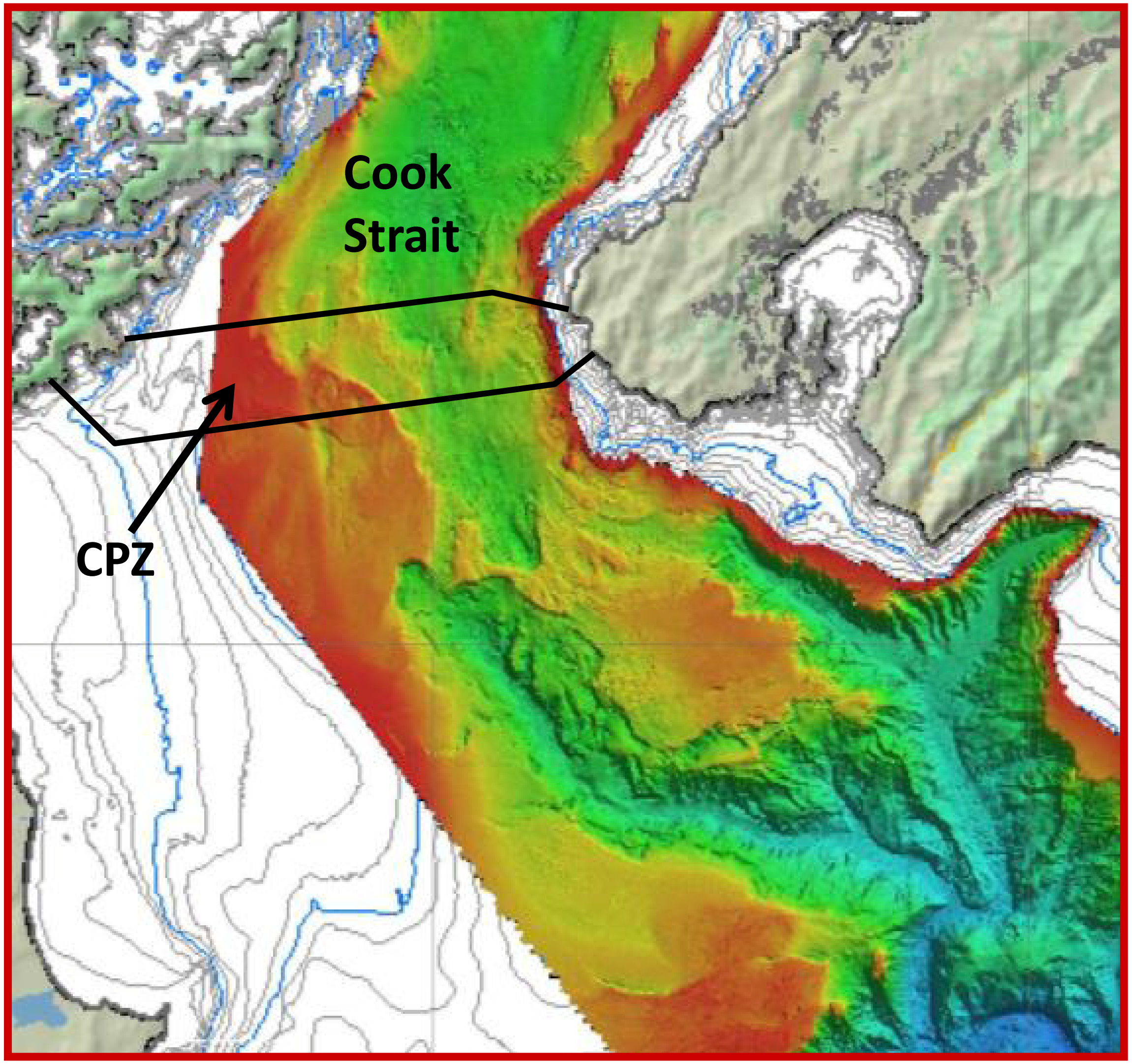
Cable Route Survey

Cable routes are carefully surveyed and selected to minimize environmental impacts and maximize cable protection



Seabed mapping systems accurately chart depth, topography, slope angles and seabed type
Source: NIWA

Cable Route Chart



Source: Transpower NZ, Seaworks NZ and NIWA

- Detailed "Multibeam" chart showing depth and topography of seabed
- Used to plan the main route for submarine power and telecommunications cables across Cook Strait within the Cable Protection Zone (CPZ)

red = < 100m deep
blue = >1000m deep

Cable Laying Vessels

CS Sovereign installing HV interconnector
Source: Global Marine Systems Ltd

CS Skagerrak installing 420 kV Cable
Source: Nexans

CLV Team Oman
Source: ABB

Cable Laying - 1

Power cable laid over the stern sheaves of a cable ship
Source: Global Marine Systems Ltd

- Purpose built ships and barges accurately place cables on or beneath the seabed, guided by the route survey
- Power cables are much larger than fibre-optic telecom cables, therefore a differently equipped cable ship is required for their installation
- Divers may be used to assist installation in shallow water
- Deep water laying may involve Remotely Operated Vehicles (ROVs)

Cable Laying - 2

Power cable storage tank
on laying ship
Source: Center Marine

Loading/unloading arm in cable
storage tank
Source: Global Marine Systems Ltd

"Bundling" power cables for laying
Source: Global Marine Systems Ltd

Cable Laying - 3

Source: Basslink

- As a cable comes ashore it may be suspended by floats and guided into position by small boats and divers
- Floats are detached or deflated and the cable is placed in its final position as determined by the route survey, which in very shallow water may be undertaken by divers
- Picture on left shows the Basslink cable, which connects the Australian mainland to Tasmania, coming ashore suspended by floats to allow guidance into its final position

Cable Repairs

- Repair of damaged power cables require specialist ships and cable jointing experts to replace the damaged section with new cable
- Completion of a repair can take anything from a few days to a few weeks, depending on the extent of the damage, location of the fault and time it takes to mobilise a suitably equipped ship
- A damaged submarine power cable can impact the supply of essential services over a wide area

A fishing grapnel snagged on a power cable
(which fortunately escaped major damage this time)
Source: Transpower NZ and Seaworks

Cable Burial - 1

- Cables may be buried in a narrow (<1 m wide) trench cut by water jet or plough
- The plough lifts a wedge of sediment so that the cable can be inserted below
- Average burial speed is around 0.2 km/hr, dependent on cable type and seabed conditions

Power cable installation using *Hydroplow*

Power cable installation using *Hydroplow*
Sources: Center Marine

Cable Burial - 2

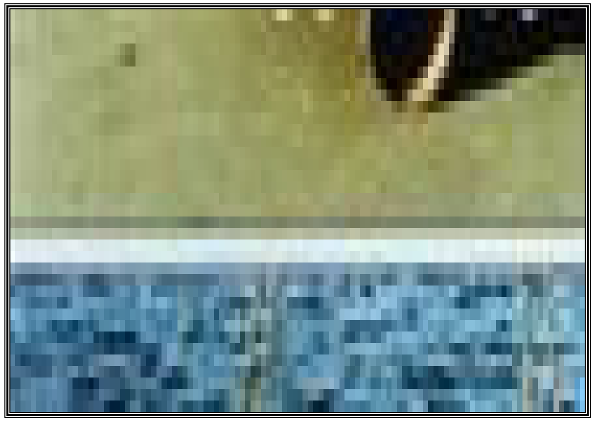
- Cables are typically buried 1 m and exceptionally up to 10 m beneath the seabed to protect against trawl fishing, anchoring and other activities
- Multiple cables in the same area are typically buried some distance apart from each other to allow for safe maintenance
- Burial may locally disrupt the seabed along a narrow path and form turbid water. The extent of this is dependent upon burial technique, seabed type and wave/current action
- In the absence of cable-based studies, analysis of seabed disturbance from fishing and other activities suggests that impacts are short-lived (months) where waves/currents are active, but possibly longer-lived in deeper, less turbulent water

Other Protection Options

- **Burial is not always possible, especially in rocky areas**
- **Alternate methods to protect cable include:**
  - **Rock placement**
  - **Articulated pipe**
  - **Concrete mattress**
- **Periodic surveys are required to check that cable remains secure**

Rock Placement Vessel
Source: Marine Traffic

Articulated Pipe
Source: EMEC



Concrete Mattress
Source: Found Ocean

Cables and the Law - 1

Recognizing the value to humanity of national and international cables (communications and power), submarine cables are protected by international treaties:

- **1884: The International Convention for the Protection of Submarine Cables**
- **1958: The Geneva Conventions of the Continental Shelf and High Seas**
- **1982: United Nations Convention on Law of the Sea (UNCLOS)**

Cables and the Law - 2

Modern international law extends the special status of international cables to all uses:

- **Telecommunications**
- **Power**
- **Scientific**
- **Military**

Cables and the Law - 3

The international treaties establish universal norms:

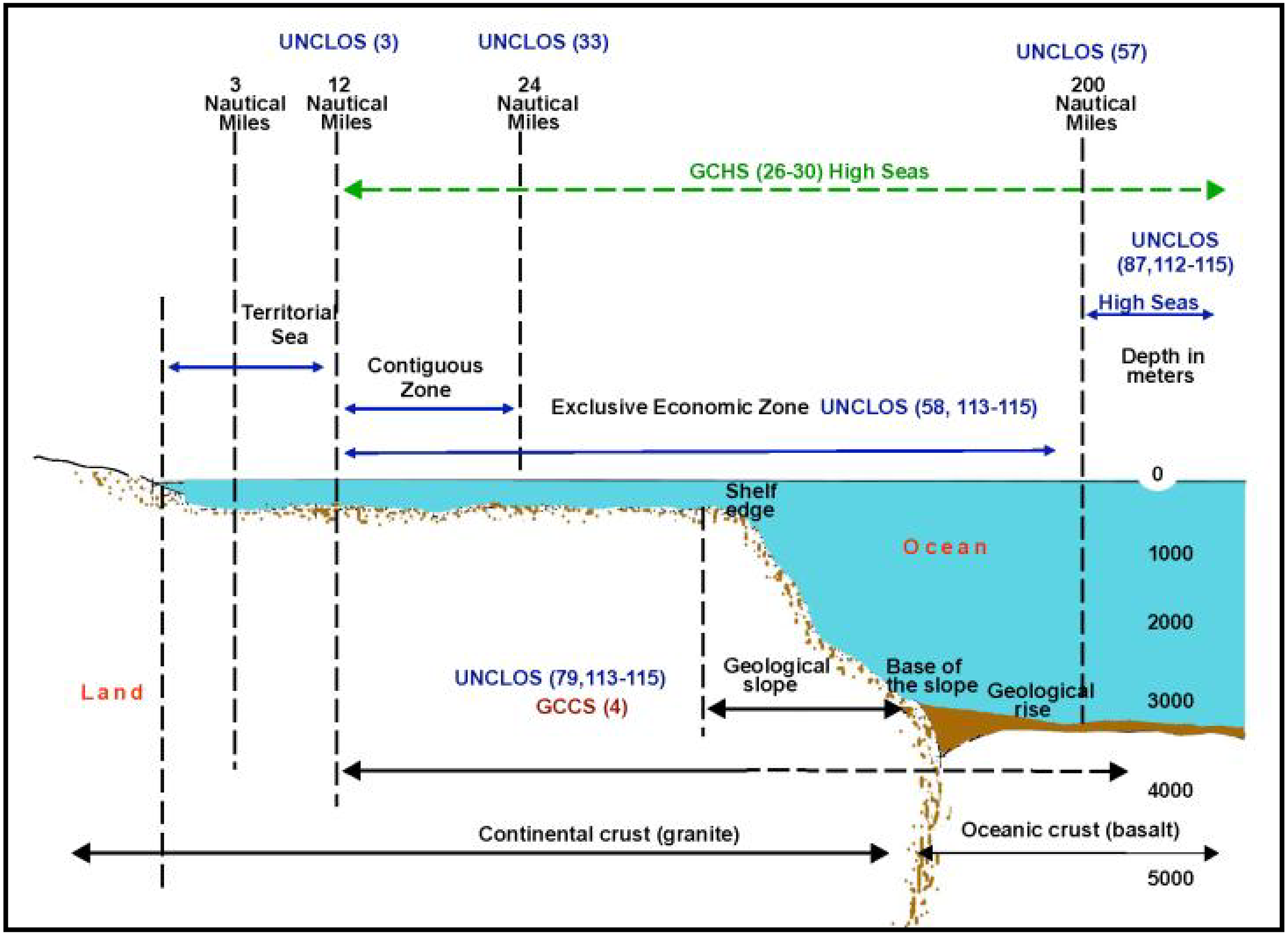
- Freedom to lay, maintain and repair cables outside of a nation's 12 nautical mile territorial sea
- National obligations to impose criminal and civil penalties for intentional or negligent injury to cables
- Special status for ships laying and repairing cables
- Indemnification for vessels that sacrifice anchors or fishing gear to avoid injury to cables
- Obligations of cables crossing earlier laid cables and pipelines to indemnify repair costs for crossing damage
- Universal access to national courts to enforce treaty obligations

Cables and the Law - 4

The International Tribunal for the Law of the Sea, Hamburg, Germany

Source: Stephan Wallocha

Cables and the Law - 5



Legal boundaries of the ocean from Territorial Seas to Exclusive Economic Zone and onto the High Seas
Note: The numbers in (brackets) refer to treaty articles
Source: Doug Burnett

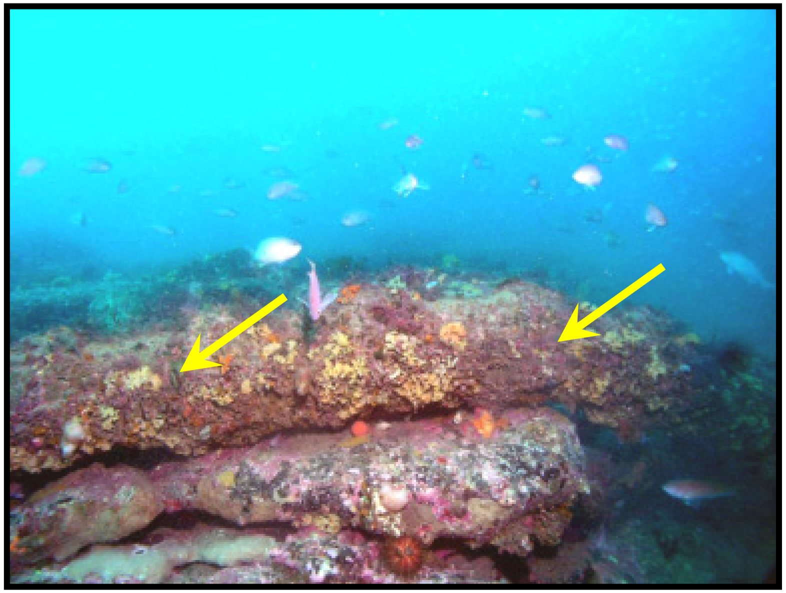
Power Cables and Renewable Energy

- Under UNCLOS, cables directly involved in offshore wind and other renewable energy production are subject to exclusive coastal state jurisdiction
- Although permission from a coastal state is not required to lay and maintain a submarine power transmission cable outside of its territorial seas, such permission is required if the power cable is to be used for production of energy from waves, currents and winds

Offshore wind farm
Source: Global Marine Systems Ltd

Power Cables and Environment

- Power cables to remote areas and islands have been in place since early the 1800's
- Electromagnetic fields vary, depending upon cable design
- Professionally installed cables have a benign association with the marine environment
- Cable burial may affect marine life in a narrow corridor, but disturbance is temporary and recolonisation follows
- Surface laid cables provide substrates for marine organisms
- Studies of sediment-dwelling animals, both near and distant from cables, show no differences in abundance or type



Taken 4 years after installation, this picture shows the Basslink submarine power cable in its articulated pipe (arrows) which is coated with a rich encrustation of marine life
Source: CEE Consultants and Basslink

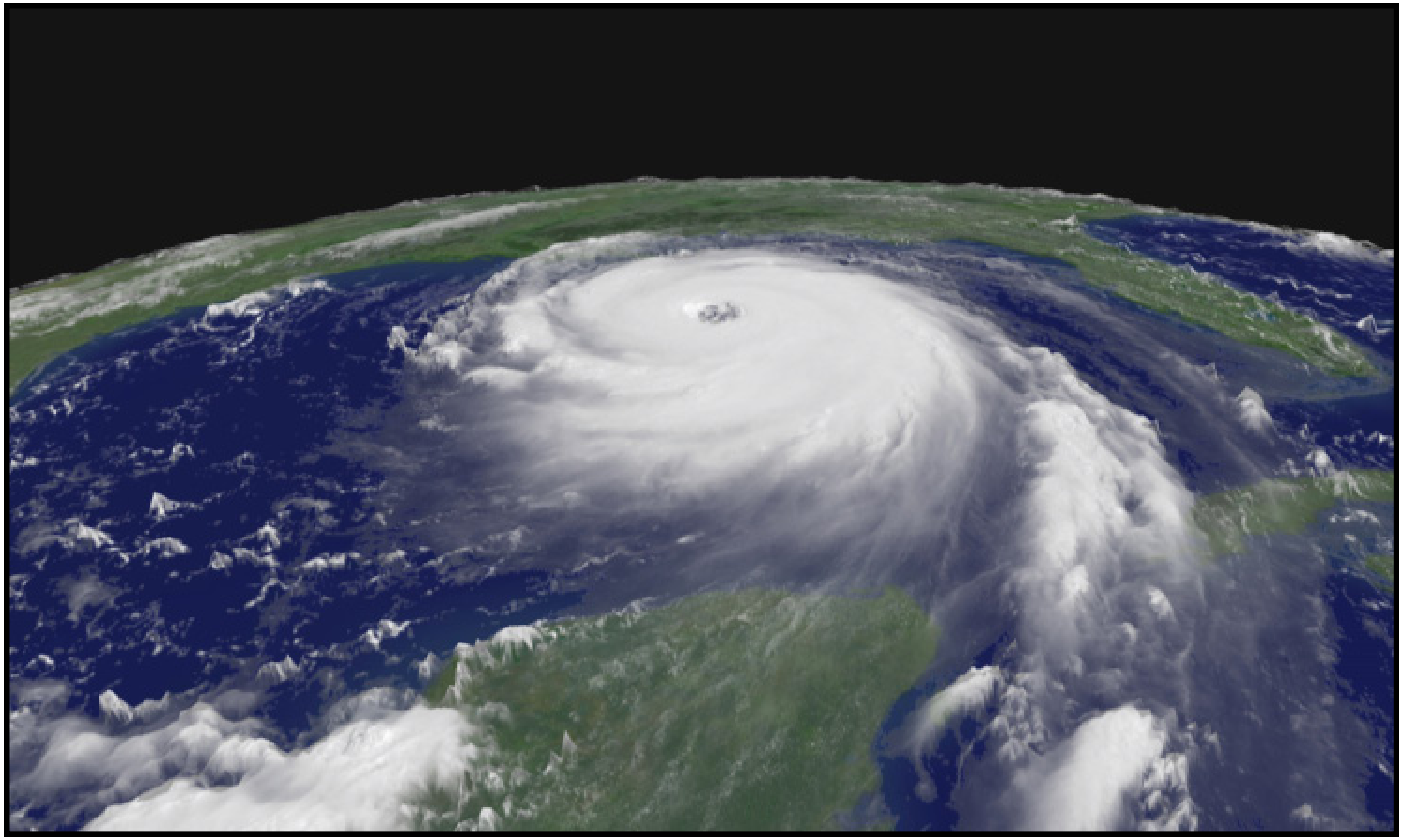
Cable Protection Zones as Sanctuaries

- Zones that are created to protect submarine cables could act as marine sanctuaries, thus improving biodiversity and fish stocks
- To be effective for this purpose, a protection zone must:
  - contain habitats that are suitable for fish and other marine life
  - exist long enough for ecosystems to develop
  - be policed to prevent illegal fishing

126mm diameter power cable in Submarine Cable Protection Zone across Cook Strait, NZ
Source: Transpower NZ

Effects of Natural Hazards - 1

Damage to submarine cable is mainly caused by human activities, less than 10% of cable faults are due to natural hazards



A major hurricane like Katrina can endanger cables by creating submarine landslides, strong ocean currents that erode the seabed, and storm surges that flood coastal facilities
Source: NOAA

Effects of Natural Hazards - 2

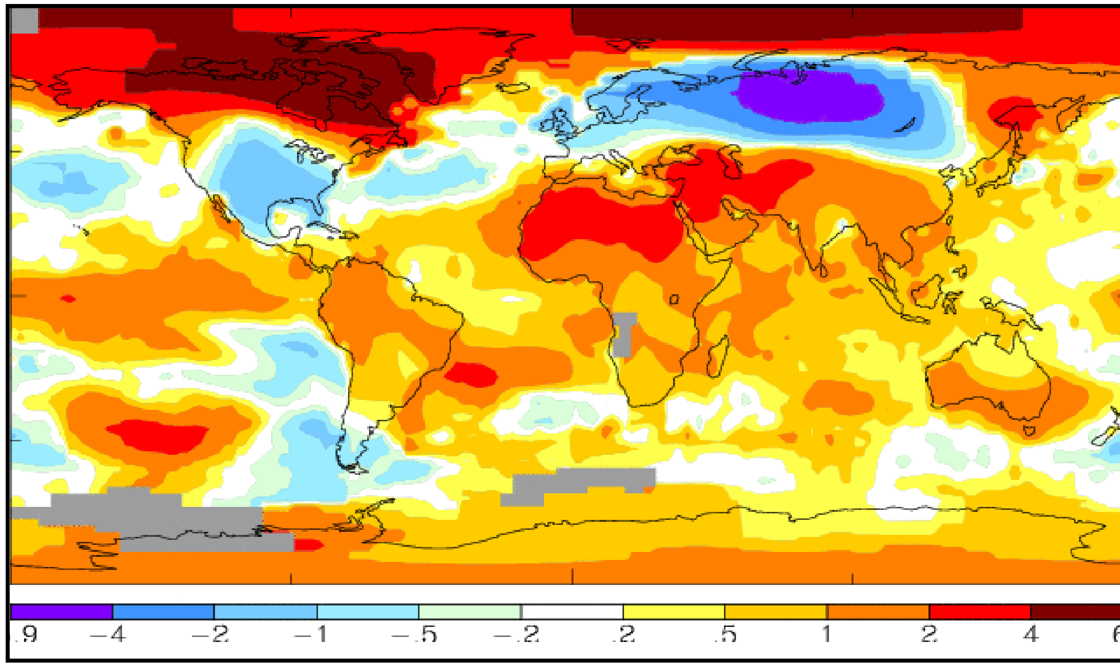
Submarine cables are exposed to a range of natural hazards in all water depths and these include:

- **Submarine earthquakes, fault lines and related landslides - break or bury cables**
- **Turbidity currents - break or bury**
- **Currents and waves - abrade, stress and fatigue**
- **Tsunami, storm surge and sea level rise - damage coastal installations**
- **Extreme weather (e.g. hurricanes) - break or bury**
- **Rarely, icebergs or volcanic activity - break or bury**

Effects of Climate Change

Cables may be exposed to risks arising from global warming, via:

- Rising sea level due to thermal expansion of ocean and melting ice
- Increased windiness and wave/current activity
- More intense storms, rainfall and floods
- Changes in offshore activities, e.g. growth of renewable energy schemes



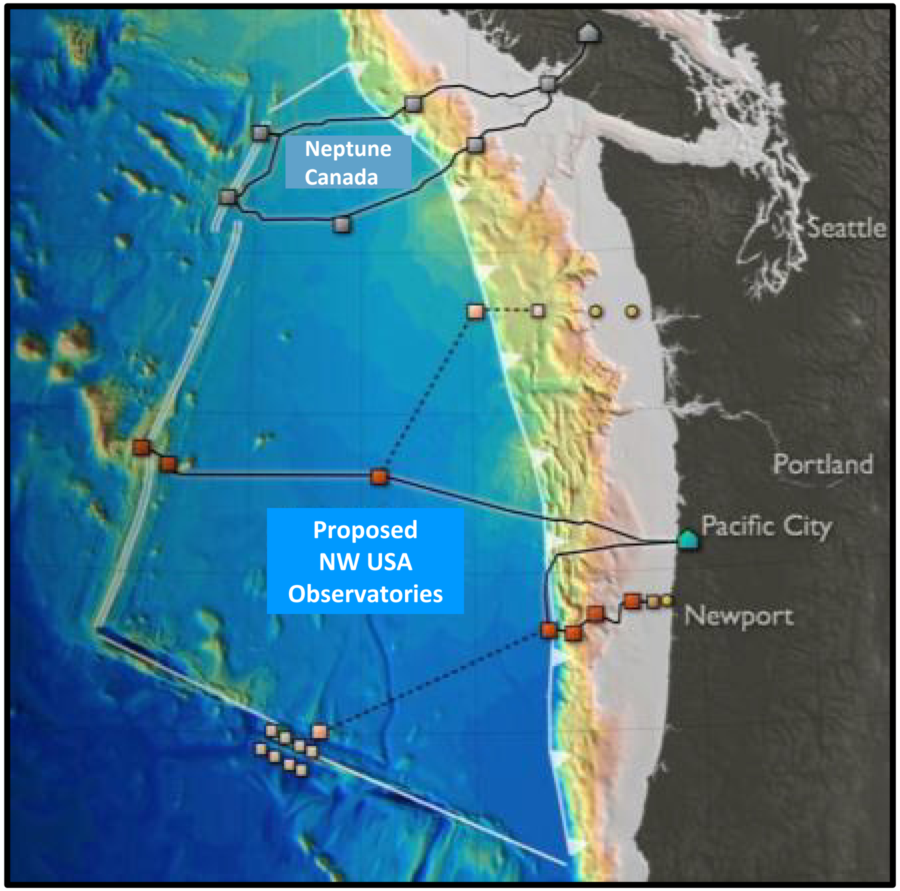
The global distribution of temperature anomalies for winter 2010. The colder than normal winter in the USA, Europe and Russia is clear, but so is the warmer than average Arctic and much of the Southern Hemisphere. This helped make 2010 the joint warmest year on record. The scale is degrees cooler/warmer than the 1951-1980 average temperature.

Source: Goddard Institute of Space Studies, NASA

Other Seabed Users

- Telecommunications cables laid throughout the world's oceans and spanning all depths
- Bottom trawl fisheries extending up to 2000 m water depth
- Harvesting of minerals and hydrocarbons
- Marine protected areas
- Ocean science observatories

ICPC strongly supports constructive interaction with other seabed users to ensure harmonious access to coastal seas and ocean



Neptune Canada and US ocean observatories with main sensor sites (grey, red, yellow shapes)
Source: University of Washington

Power Cables and the Future - 1

To secure supply, meet greater demand and reduce greenhouse gas emissions, nations are turning to offshore renewable energy schemes involving wind, wave and tidal generation.

Conceptual European SuperGrid
with selected renewable energy test sites
Source: Friends of the SuperGrid

Some test and working schemes:

European Marine Energy Centre (wave and tidal energy test site)

Galway Bay (wave energy test site)

Thanet Wind Farm (300MW existing wind farm)

Wave Hub (wave energy test site)

Power Cables and the Future - 2

LEGAL

The ICPC is very concerned about:

- **Coastal State encroachment on traditional freedoms under UNCLOS to lay, maintain and repair international cables**
- **Resolution of Continental Shelf boundaries under UNCLOS**
- **Lack of national legislation to implement UNCLOS obligations to protect international cable infrastructure beyond territorial waters**
- **Restrictions on international cables that are imposed without any scientific basis to appease local constituencies, some of which regard submarine cables as an alternative revenue source**

Power Cables and the Future - 3

TECHNOLOGY

- Cable design and operations are constantly evolving. Future systems are expected to have greater capacity, reliability and be sited in deeper water
- Longer cable routes are proposed from nations that have surplus energy, e.g. Iceland to Europe
- Offshore wind farms and oil/gas platforms will extend further offshore
- Wave and current/tidal power generation techniques are rapidly gaining interest throughout the World

Hywind floating wind turbine can be moored in water depths up to 700m
Source: Statoil

Power Cables and the Future - 4

ENVIRONMENT

- In some regions of the world, submarine cables are likely to be exposed to more natural hazards related to changing climate
- Climate change may also affect other marine activities such as fishing, with potential impacts on cables
- Electromagnetic field studies are on-going to determine any effects of power cables on marine life
- Measures to preserve biodiversity, ecosystems and resources via various protection zones in national waters and the high seas, may impinge upon cable passage
- The ocean, especially the coastal seas, will be subject to increased human activities due to expansion of renewable energy schemes

Points of Interest

- **Longest HVAC submarine cable, 104 km, installed from Isle of Man to mainland England, 1999/2000**
- **Longest HVDC cable, 580 km, installed between Norway and the Netherlands, 2008**
- **Highest voltage (500kV) and largest conductor (3000 mm²), installed off Japan, 1998**
- **Farthest offshore wind farm, 90 km off Borkum, Germany, 2011**
- **Largest offshore wind farm, 300MW, England, installed 2010**
- **First power-from-shore Dynamic AC cable for Floating Platform, 40MW, Norway, Gjøa Platform, installed 2010**

Glossary

- **Armour:** steel wires around cable for strength and protection
- **EPR:** Ethylene-propylene rubber, a dielectric developed in the 1950s and used for insulation of submarine power cables
- **Gutta percha:** a naturally occurring resin, similar to rubber, used to insulate cables up to 1930s
- **HVAC:** High voltage alternating current for a multidirectional flow of electric charge (type of power delivered to buildings and homes for conventional use)
- **HVDC:** High voltage direct current for a unidirectional flow of electric charge (type of power typically delivered by batteries)
- **Fibre-optic cable:** Single conductor cable with a fibre optic core used for communications
- **XLPE:** Cross linked polyethylene, a plastic developed in 1930s and used for submarine power cable insulation

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LD TravOcean

Marine Traffic

NOAA

NIWA

Neptune Canada

Nexans

OSPAR Commission

Statoil

Transpower NZ and Seaworks

UK Cable Protection Committee

University Washington

Wikipedia

International Cable Protection Committee

ICPC - Sharing the seabed in harmony