4 Project description

4.1 Atlantic Marine Energy Test Site location

The Atlantic Marine Energy Test Site (AMETS) is located off the coast of west County Mayo near Annagh Head, which is approximately 7km from Belmullet. The site stretches offshore from Belderra Strand at the southern end of the bay south of Annagh Head. Access to the proposed landfall site at Belderra Strand is good. The main access is off the R313 which passes through Belmullet. From there the R5233 leads to Belderra Strand by tarmac road along the coast. A small hard stand parking area for recreational users has been provided by Mayo County Council near the southern end of Belderra Strand.

The immediate land side of the Bay is mainly within the Natura 2000 site Mullet / Blacksod Bay complex (cSAC Site Code 000470) and will be traversed for a short distance by the cable landing in the shore area at Belderra. The land side of the L5233 adjacent to Belderra strand is outside any designated site.

The following Special Protection Areas designated under the EU Birds Directive are within 15km of the area: Termoncarragh Lake, Cross Lough and Inishglora / Inishkerragh Islands. There are also cSAC areas such as Inishkea Island which is important for both its birds and grey seal breeding population.

The offshore test area locations associated with AMETS are shown in figure 4-1. Test areas A and B are located some 10.5km and 2.2km respectively from the nearest mainland at Annagh Head.

4.2 Wave resource at the test site

The wave resource off the west coast of Ireland has been internationally recognised as one of the most energy-intense in the world, and it is estimated at 70kW per metre of wave front in the vicinity of the proposed test areas. Annagh Head has also been monitored using wave buoys located in the 50m and 100m water depth areas since early 2010. An example of the max wave heights recorded at the 50m water depth test areas is shown in Figure 4-2.

Table 4-1indicates the peak, minimum, median and average wave height recorded at this location.

An example of the maximum wave heights recorded at the 50m water depth test areas is shown in Figure 4-2. Similar data has been collected at the 100m water depth test area (Table 4-2, Figure 4-3).

Table 4-1: 50m depth wave data from 29/12/2009 to 03/01/2011

Wave height	**Height (m)**
Maximum (HMax)	22
Minimum	2.8
Median	3.2
Average	3.6

The maximum wave height was recorded on the 11/11/2010 at 4.30 am.

Table 4-1: 100m depth wave data from 07/04/2011 to 10/08/2011

Item	Height (cm)
Maximum wave height	**17.4**
Minimum Hmax	0.7
Median	3.1
Average	3.6

4.3 Project components

The proposed development will involve deploying Wave Energy Converters (WECs) such as Wavebob, Pelamis, Ocean Energy Limited and Ocean Power Technologies in deep water (as described in 4.3.7 below). WECs will be anchored within the designated test areas and will be connected to the distribution electricity grid onshore via submarine electricity cables installed between the test areas and the proposed onshore electricity substation. The project will have the following components:

- Offshore test areas – two areas delineated by cardinal marker and other buoys: Test Area A with100m water depth and Test Area B with 50m water depth.
- Offshore submarine electricity cables in the subtidal environment (associated with Test Areas A and B);
- Cable landfall in the intertidal environment (associated with Test Areas A and B) at Belderra Strand. Four submarine electricity cables, two from each Test Area, will be landed at this location;
- For wave resource assessment purposes, oceanographic monitoring equipment will be located as follows:
    - At present at Test Area A a Met Ocean buoy is moored to record the waves and other data such as wind, pressure and direction. In addition an Acoustic Doppler Current Profiler (ADCP) is located adjacent to the weather buoy.
    - At present at Test Area B a Waverider buoy is moored to measure the wave resource at this location. It is intended to deploy a second Waverider here and a further ADCP.
    - In order to help prevent collision damage to these oceanographic buoys, each of the two test areas has a large Special Mark buoy moored close to them. The Special Mark buoys warn passing vessels to keep their distance. The Special Mark at Test Area B can be seen from the adjacent mainland on a clear day.
    - At the 20m water depth one ADCP may be deployed on the seabed to measure currents and wave resource.
- Land-side cable transition joint bay located adjacent to Belderra Strand to allow connection of the submarine electricity cables to land-side electricity cables.
- Land-side electricity cables from the transition joint bay to the substation.
- Land-side substation and access road with connection to the distribution electricity network using wooden poles and 10/20kV overhead line located outside the cSAC area near Belderra Strand.
- Office base in Belmullet.

- Wave Energy Converters (WECs) will be deployed within the test areas once these have been established.

These components are discussed in more detail in the sections 4.3.1 to 4.3.11.

4.3.1 Offshore test areas

The offshore test areas, Test Area A and Test Area B, were designed following consultation with WEC developers and marine users, and were based on Marine Institute survey data and other survey data for the area (ESBI 2011).

Test Area A consists of an irregular 'boot' shape designed to allow anchoring of the WECs on sediments ranging up to 7m in depth, while avoiding fishing ground in the area as much as possible. At the 50m water depth contour the test area consists of a box rectangular area, again located on sediments up to 7m in depth. The proposed areas are shown on Figure 4-1. The areas will be delineated by both cardinal marker buoys and other marker buoys in accordance with international regulations and in consultation with the Marine Survey Office (MSO) and the Commissioners of Irish Lights (CIL).

Test Area A, the furthest offshore, will be located in a water depth of 100m and will accommodate WECs such as Wavebob and Pelamis (described in Section 4.3.7). The physical dimensions of Test Area A are shown in Figure 4-4 and in Table 4-3 The total area is 6.9 km^2 (2.02 nautical square miles).

Table 4-3: Test Area A dimensions

Side	Kilometres	Nautical Miles
Side 1 – 2	1.95	1.05
Side 2 – 3	1.47	0.79
Side 3 – 4	1.31	0.71
Side 4 – 5	0.74	0.40
Side 5 – 6	3.09	1.67
Side 1 – 6	2.70	1.46

The coordinates of Test Area A are provided in Table 4-4.

Table 4-4: Coordinates of Test Area A

Minus sign added

Location	Longitude	Latitude
1	- 10° 18' 16"	54° 17' 25"
2	- 10° 16' 31"	54° 17' 23"
3	- 10° 16' 13"	54° 16' 37"
4	- 10° 15' 31"	54° 16' 2"
5	- 10° 15' 30"	54° 15' 39"
6	- 10° 18' 15"	54° 15' 59"

Test Area B will be located in 50m water depth and will accommodate WECs such as attenuators or Oscillating Water Column WECs (described in Section 4.2.11). The physical dimensions of Test Area B are 1.25 km by 1.2 km (0.67 nautical miles by 0.65 nautical miles). The total area is 1.5 km^2 (0.44 nautical square miles).

The coordinates of Test Area B are given in Table 4-5.

Table 4-5: Coordinates of Test Area B

Minus sign added

Latitude	Longitude
54 13′ 17″	- 10 09′ 21″
54 13′ 17″	- 10 08′ 15″
54 13′ 58″	- 10 08′ 15″
54 13′ 58″	- 10 09′ 21″

Coordinate corrected 17' to 13'

Submarine electricity cables

Wave energy converters (WECs) will be deployed within Test Area A and B and connected to the onshore electricity grid via submarine electricity cables.

The cable layout for the test site provides for two cable terminations at each of the two offshore test area locations. Two cables will run from the cable transition joint bay at Belderra Strand to Test Area A (approximately 16km in length. The cables will be installed to an optimum depth of 1m below the seabed where sandy substrate exists. Surveys have indicated that a stony substrate is likely to be encountered along about 4km of the cable route length and here the cables will be laid on the surface of the seabed and protected using suitable methods such as rock armour or concrete mattresses.

The cables will terminate within the test area. Within the test areas approximately 300m of each cable will consist of a dynamic cable riser, a flexible section of the cable which will allow connection to the WECs. This dynamic cable riser section will be capped and left on the seabed and protected as above. As the cable installation is likely to take place well in advance of the WECs deployment, the cable dynamic riser will need to be stabilised on the seabed until WEC deployment takes place. The location of the dynamic riser cable will be marked with a surface marker buoy.

Two further cables will run from the land-side cable transition joint bay to Test Area B. Each cable will be approximately 6.5km long. These cables will again be installed to a minimum depth of 1m below the seabed where substrate allows and suitably protected on the seabed where necessary – although surveys indicate that the route for these cables has sandy substrate all the way. These cables will have 150m sections of dynamic cable riser which will be laid on the seabed and temporarily protected until WECs are deployed. They will also be capped and marked with a surface marker buoy.

The cables will be deployed in corridor with maximum width of 200m and will converge as they near shore to the landing location at Belderra Strand.

Cable route

The four cables will follow a sandy substrate corridor over most of their length to the landing location on Belderra Strand. In sandy substrate areas the cable will be buried to a minimum depth of 1m below the seabed. The cable route corridor is shown on Figure 4-5.

Cable protection

Surveys indicate that the cable corridor will traverse rock substrate areas for a distance of 4km – see Figure 4-5. In these locations the cable will be laid on the seabed and may be protected using either rock armouring, matressing or other suitable protection method.

The actual requirement for cable protection will be determined at the detailed design stage by the cable laying contractor. Options for protection include:

Rock armour	A rock berm may be used to protect the cables from third party damage where the cables are installed in high risk locations (see Figure 4-6). In locations where rock is present along the seabed surface and alternative methods of mechanical protection such as rock placement is required, it may be desirable to converge the cable circuits together to minimise costs. The process of creating a rock berm involves the placement of inert graded rock above the sub-sea cables.
Cable mattresses	Alternatively, in more shallow waters where the overburden of sand above the rock is minimal it may be preferable to install a grout or concrete block mattress (see Figure 4-7). Here the mattress is bolted onto the seabed where it provides additional mechanical protection to the cable.
Protective shells and grout bags	It may also be feasible to install the cable directly onto the seabed at locations where embedment is not possible by surrounding the cables in polyurethane half shell mouldings or split cast iron shells – see Figure 4-8. Both of the above significantly reduce the risk of cable abrasion or fatigue from wave action, sand, moving rocks or third- party damage. This is particularly the case, as the cables would be installed parallel to the wave/ tidal action so that the longitudinal forces exerted on the cables should be tolerable. Furthermore if the voids between rock outcrops could be filled by grout bags or other similar materials then a more suitable seabed could be designed to accommodate the cables. However, placement of grout bags or shell protection requires pinning to the bedrock and is dependent on bedrock nature.

Cable design

Four separate sub-sea cables will be laid as part of this project – two cables will be laid from the cable transition joint bay at Belderra to Test Area A (the deep water 100m test area) and two cables from the cable transition joint bay at Belderra to Test Area B (the 50m depth test area).

The cable type will be 3-core extruded insulation, conductor size approximately 95-120mm^2 copper conductor. Overall cable diameter will be approximately 14cm. This conductor is typically surrounded by a triple-extruded, dry-cured, crosslinked polyethylene (XLPE) insulation screen. This insulation screen is a solid material which does not have any potential to cause environmental impacts. To the exterior of this screen is an inner sheath, which can be made of corrugated copper or corrugated aluminium. The cable is then surrounded by an outer serving of medium or high density polyethylene. No environmental issues are associated with the cable material itself.

Four separate land-side cable circuits will be installed from the cable transition joint bay to the land-side substation in a trench approximately 2m wide and 2m deep. These will be similar in nature to the submarine cables but of smaller diameter and different specification.

Cable lay vessels

Cable deployment will be performed by a dedicated cable-laying vessel, which will lay the cables onto the seabed. The same vessel may also have a device to bury the cable into the seabed as the cable is laid (Figure 4-9). Such an embedment technique would typically be associated with ploughing in the cables. Alternatively, a separate vessel may follow the cable-laying vessel to perform this task. This embedment method would be used when trenching the cables by water jetting. Cable burial can be performed by either trenching or ploughing.

Cable-laying may be performed on a 24-hour basis to ensure minimal impact on navigation and on other users and to maximise efficient use of suitable weather conditions and vessel and equipment time. In addition to the installation vessel(s), additional support, supply and guard vessels will be involved with the operation.

Cable burial

Cable burial is required as a safety measure to avoid damage and entanglement with third parties (for example with trawling gear or anchors), and to minimise the risk of 'free span' cable over gaps leading to cable fatigue. The optimum burial depth is 1m, although this will be confirmed by detailed sub-sea survey and burial assessment work as part of an Engineer, Procure and Construct (EPC) contract. Cable burial depths are likely to vary where seabed movement is identified and depending on how compacted different areas of the seabed are. For example, if the seabed is very hard, a burial depth of 0.5m may be acceptable. Where the cables pass through a test area as is the case at Test Area B, an increased burial depth of up to 2m may apply and this may be supplemented by rock berm protection to highlight the presence of the cables to prospective WEC deployments.

Cable burial will be by means of ploughing or water jetting, either simultaneously with, or after, cable deployment.

Ports and supply basis

Support vessels will operate from established ports that will also be used as supply bases. There are a variety of harbours and ports with varying capabilities available at Blacksod, Ballyglass, Belmullet, Killybegs, Shannon Foynes, Galway Port and Belfast. In an assessment of the Irish shipping and ports requirements for the ocean energy industry, Ireland is identified as having a vibrant ports sector which is well placed to service the needs of the offshore renewable energy industry (SEAI, June 2011). The ports are generally aware of the opportunities in this sector and in many cases are already actively marketing and engaging with developers and planning new and improved facilities to cater for this potential market.

During the construction phase cable laying vessels may use deep water ports for cable loading and as a supply base, or they may arrive preloaded with cable. Where a local port is used, space will be required on the quayside for mobilisation and storage of equipment, mobile offices and associated infrastructure. The construction contractor will determine which ports are required for any local support. Port facilities will also be required for maintenance of WECs.

Standard slipway access facilities are proposed for construction at Frenchport Bay nearby the test site.

4.3.2 Submarine cable landfall

The four cables will converge as they reach the proposed Belderra Strand landing area. The cables will run underneath the beach up to the cable transition joint bay located behind Belderra Strand. The cable corridor at the low water mark will be approximately 40m in width reducing to a 10m corridor as the route approaches the cable transition joint bay location. The cables will be installed at a minimum depth of approximately 1m in conduits under the beach surface between the low water mark and the cable transition joint bay. Conduits will be pre-installed and secured using lean mix at the bottom of the cable trench, which will be backfilled with beach material. The cables will cross the intertidal zone, and the works associated with their installation will temporarily affect the zone below the high water mark as well as above the high water mark near the existing car park area.

4.3.3 Cable transition joint bay

A cable transition joint bay will be constructed under ground at the car park location at Belderra Strand. The approximate dimensions of the cable transition joint bay will be 7m long by 6m wide and 2m deep (Figure 4-10). The area over the jointing bay will be reinstated post construction to its pre-construction condition.

A triangular area behind the car park will be used as a temporary lay down area and for a mobile cable pulling winch.

4.3.4 Land-side cable

Four land-side cables will be installed underground from the cable transition joint bay to the dedicated onshore substation located in Ballymacsherron townland. The cables will be trenched from the cable interface joint bay along the L5233 road to the substation field boundary and then through the field leading to the substation site.

4.3.5 Substation

The proposed substation will be constructed in the townland of Ballymacsherron, south of the L5233, which runs alongside Belderra Strand (Figure 4-11). An existing access track running parallel to a minor road will be used during construction and will be reinstated to its pre-existing condition or improved. A hardcore access road will be constructed off the existing track to the substation site.

The cable route from the cable interface joint bay to the substation is shown on Figure 4-12.

The substation control room building will be a single storey blockwork building on reinforced concrete foundations. The floor will be constructed of concrete and the roof will be pitched. The dimensions are 28.8 metres long, 7.15 metres wide, and 5.4 metres high. The footprint of the control building is 205.9 m^2. The control building, together with an external hard standing for vehicular access, transformer compound and overhead line interface compound, will be enclosed in a secure compound with palisade fencing to 2.6m in height. This will be screened by a landscaped earthen berm. The total footprint enclosed by the palisade fence is 1,343m^2 and the total site area is 2 acres. The substation compound layout is shown on Figure 4-13.

The site will be landscaped. Arisings from within the substation site and from other site works will be reused within the site for site restoration and landscaping berms where possible. The site entrance will be provided in accordance with NRA standards for road design / vehicular entrances and following discussion with Mayo County Council. Site elevations are shown in Figure 4-14.

Given that the substation will be unmanned and will be used on an infrequent basis, a sewage holding tank of storage capacity 30m^3 will be provided. Sewage waste will be removed from site for disposal by a licensed waste disposal operator.

The substation will be the interface point between the offshore wave energy converters and the onshore electricity network. It will contain an assortment of electrical equipment. ESB Networks will dictate the internal layout and functional design of the substation such that it complies with the Distribution System Operator grid code requirements. The planning and construction of the substation will be undertaken as part of this project with approval of the design by ESB Networks. A planning application for the substation will be lodged with Mayo County Council.

From the test site perspective, an electricity meter will be included on each electricity cable coming from Test Areas A and B for monitoring purposes. In addition, a small administration area will be included for meter reading purposes only.

The whole substation will be a locked unmanned facility having only occasional visits only. Monitoring and control of the test site and WECs will take place from the main office in Belmullet.

Electricity supply to the compound will be from the local mains network.

Water supply to the compound will be from the existing County Council water supply in the area. Water demand will be low and for domestic purposes only.

4.3.6 Office base

SEAI have initially established a Project Office at the Civic Centre premises in Belmullet. SEAI will establish a long-term project office base in Belmullet, possibly at the Civic Centre premises or at another location within the area. At this location a number of offices will be fitted out for the use of prospective developers and also for use as project offices incorporating communications links with the substation, the WEC devices, work vessels and measurement buoys.

4.3.7 Wave energy converters (WECs)

The range of wave energy converters (WECs) which may be deployed at Belmullet have been developed or are in the process of development. For completeness, examples of both offshore and nearshore WECs are shown although only offshore WECs are being considered for the test site. It is envisaged that a number of these, either singly or in combination, will be deployed within the Test Areas A and B for a defined period. A brief description of the main wave energy converters available is provided below.

WEC types

The energy extraction methods or operating principles can be categorised into three main groups.

Wave activated bodies (WAB) –	Waves activate the oscillatory motions of body parts of the device relative to each other or of one body part relative to a fixed reference. Primary heave, pitch and roll motions can be identified as oscillating motions. Energy is extracted from the relative motion of the bodies or from the motion of one body relative to its fixed reference typically by using hydraulic systems to compress oil, which is then used to drive a generator.
Overtopping devices (OTD)	Ocean waves are elevated into a reservoir which stores the water above the sea level. The energy is extracted by using the difference in water level between the reservoir and the sea and low-head Kaplan turbines.

Oscillating water column (OWC) — Waves cause the water column to rise and fall, which alternately compresses and depressurises an air column. The energy is extracted from the resulting oscillating air flow by using a Wells or impulse turbine. An OWC uses an enclosed column of water as a piston to pump air. These devices can be fixed to the seabed or floating.

Table 4-6 illustrates the diversity of types of WEC under development in Ireland and the UK.

Table 4-6: Diversity of WECs under development in Ireland and UK

Scheme	WEC type			Suitable location	
	WAB	OTD	OWC	Near shore	Off shore
Pelamis	●				●
Oyster	●			●	
Wavebob	●				●
Ocean Energy Ltd			●		●

The wave activated bodies (WABs) can be further categorised in sub-groups based on the energy extraction by the principle motion of the floating body (heave, pitch and roll).

Because they are usually attached directly to the seabed, the techniques to anchor nearshore devices could follow established engineering procedures. Each offshore device, however, requires an independent study to ascertain the extreme environmental loads that it must withstand. The moorings for offshore devices are more complex in that they impact significantly on both energy extraction and the orientation of the device to the mean wave direction, which can be critical for efficient power conversion.

The ability of a device to capture energy is a factor of its orientation in relation to the direction of the incoming wave front. It is possible to categorise the directional characteristics into three additional groups:

Point absorber — A point absorber is relatively small compared to the wave length and captures energy from the up and down motion of waves. It does not need large waves to capture energy.

Terminator — A terminator has its principal axis parallel to the incident wave crest. It captures energy from the wave's breaking force. The amplitudes of the reflected and transmitted waves determine the efficiency of the device.

Attenuator — An attenuator has its principal axis placed parallel to the direction of the incoming wave and converts energy as the wave passes along the device.

A point absorber does not have a principal wave direction and is able to capture energy from waves arriving from any direction, whereas the peak efficiency of a terminator or attenuator device is linked to their principal axis being respectively parallel or orthogonal to the incoming wave crest. As a consequence, the mooring or foundation for the terminator and attenuator (unlike that for the point absorber) has to allow the unit to weathervane into the predominant wave direction. The possible operating principles for the principal location and directional characteristics are given in Table 4-7 as follows:

Table 4-7: Possible Operating Principles

Principal location	Directional characteristic		
	Point absorber	Terminator	Attenuator
Nearshore	WAB	OWC, OTD, WAB	WAB
Offshore	WAB,OWC	OWC, OTD, WAB	WAB

At nearshore locations, point absorber or attenuator devices can only be wave-activated bodies. Offshore point absorbers can also include OWCs as well as WABs, although attenuator devices are likely to be just WAB devices. Terminator devices can be based on any one of the three operating principles.

Point absorber devices tend to require a deep second reference mass that is likely to have a long body of length up to 60m with a vertical axis. This body may be floated to location with a horizontal aspect and then up-ended on site. An example of a point absorber device (Wavebob) is shown in Figure 4-15.

The Ocean Energy OWC device is a terminator device rather than a point absorber, (Figure 4-16). It is fabricated in steel from stiffened flat panels using conventional shipbuilding technology. At full scale it would either be built on a slipway and launched as a ship or more likely assembled in a dry dock and floated out. Once afloat it can be towed to site.

Similarly, attenuator WABs are likely to be composed of several linked and hinged linear sub-sections that will have a length significantly greater than their width. These devices are likely to be joined afloat in harbour and then towed to site as a linear array with an overall length of typically 180m. An example is shown in Figure 4-17 (Pelamis).

the other hand, nearshore WAB terminator devices are likely to have equal width and length of about 20m and may be floated to site, or transported by barge prior to being lifted into location and attached to the seabed.

WAB-T device (Near shore device, not suitable for testing at AMETS, but shown for completeness, Figure 4-18). This type of device will not be deployed at the AMETS.

Delivery of wave energy devices to site.

All WECs will be constructed off-site and either shipped or towed to the test area. The WECs will be anchored to the seabed via rope, chain or cable riser to either suction piles, clump weights or drag anchors. These will also be delivered and installed by vessels operating from deep-water ports equipped with the necessary lifting gear to handle such equipment – these include Killybegs, Belfast, Shannon Foynes or Galway Port.

Good weather conditions are critical for the deployment of anchor systems and the WECs themselves. The likely period for installation of anchors and WECs is from June to September when conditions are favourable for such operations.

4.3.8 Ancillary works

Some ancillary works will take place related to project, but outside the direct control of the project. These include provision of an overhead line for grid connection and upgrading of pier facilities at Frenchport. Existing sub-sea infrastructure that could be affected by the project must also be considered.

Submarine cable crossing

The cable will not cross any existing cables along its route.

Overhead line

ESB Networks will be responsible for providing grid connection to the test site as the distribution system operator. This will be a 10/20kV feeder on wooden poles similar to existing lines in the area at Belderra. The substation electricity cables will be connected to the overhead 10/20kV line using a standard pole set within the substation compound area. The final design of the proposed 10/20kV transmission line back to Belmullet substation will be decided by ESB Networks.

Upgrading of facilities at Frenchport Bay

Mayo County Council are proposing to upgrade the existing pier at Frenchport Bay as a separate project. This will involve the construction of a slipway alongside the existing quay and extending the quay itself. This would facilitate the project, allowing small vessels such as rigid inflatable boats (RIBs), to be launched for inspection and maintenance operations of the WECs. It would also facilitate local fishermen who are using the existing pier.

4.4 Project construction

4.4.1 Construction activities

The following are the main activities that will be associated with the implementation of the project:

Phase 1 - Land-side works

- Construction of substation
- Construction of the cable transition joint bay
- Installation of land-side cable ducts
- Installation of land-side cable
- Installation of intertidal submarine cable ducts

Phase 2 – Subtidal works

- Marking of the designated test areas with cardinal marker buoys
- Deployment of the sub-sea cable including:
  - Cable landfall including sub-sea cable installation, via the intertidal submarine ducts installed in Phase1, to cable transition joint bay and winching of cables onshore
  - Offshore deep-water cable laying
- Offshore cable protection including cable burial or surface protection
- Commissioning of cable circuits and substation

4.4.2 Phase 1 – Land-side work

Substation construction

Construction of the substation will comprise civil and electrical elements, which will entail the following main activities:

- Construction of access road.
- Initial site development works, which will consist of the creation of construction lay-down areas, excavation of overlying topsoil to area of compound and (internal) site

roads, commencement of creation of landscaping berms, earthworks (excavation and filling) and site grading and preparation of bases for foundations.

- Removal of excess materials from site (estimated at 1,400m^3).
- Main civil works comprising construction of equipment foundations, cable ducts, control building, installation of an earth grid, site access roadway, perimeter fence and water and waste-water services.
- Erection of steelwork, high voltage equipment and installation of low voltage cables.
- Termination of all high voltage and low voltage equipment.
- Completion of landscaping berms.
- Landscaping of the site on completion of civil and electrical works.

Construction of cable transition joint bay

The landfall works comprise the construction of one cable transition joint bay behind Belderra Strand. It will be located beneath the road and car park.

The jointing bay is to be constructed with concrete floors and sidewalls. Once the cables are connected to the relevant joints within the jointing bay, compact cement-bound sand is put into the bay to surround the cables and joints. Additional sand and excavated material is then backfilled into the bay, following which the ground over the jointing bay is reinstated to match existing ground levels.

Construction of the land-side cable ducts

Four electricity cables will be installed into conduits which will have been pre-installed by an open trench method from the cable transition joint bay at the car park to the proposed substation. The trench will also be used to accommodate 4 fibre optic cables in two separate ducts.

Construction of the intertidal submarine cable ducts

Due to the sheltered location of Belderra Bay and the gently sloping gradient of the seabed towards the shoreline which consists of sandy sediment, Belderra Strand presents a technically favourable environment to install the four sub-sea cable circuits.

Belderra Strand is approximately 400m wide and has a low to high water length from front to back of around 200m (Figure 4-19).

The beach has a regular gentle rising slope from front to back and sits between outcrops of the local rock formation. Behind the beach a low dune system extends for a short distance between the beach and the road.

The position of Belderra Strand also presents a number of suitable locations for setting up a temporary construction site during cable installation works. Both the car park immediately adjacent to Belderra Strand and the parcel of land directly behind the beach may be utilised for the purpose of a temporary lay-down area during the works (Figure 4-20). A traffic management plan will be implemented during these works to ensure the smooth flow of traffic during construction. This may entail intermittent temporary closure of the road and car park over a period of days or weeks.

Intertidal Works – options

The offshore submarine electricity cables will be installed at a minimum depth of 1m below the sandy sea bed in the approach to the beach. On the basis that the preferred cable installation depth remains within the beach deposits then a number of installation options are possible including trenchless directionally drilled installations or open trenching. The proposed route across the beach is shown in Figure 4-21.

Option 1: trenchless horizontal directional drilling

A low-depth horizontal directional drill or drills could be feasible for the installation of the required cable conduits, depending on the location of the rock head. A typical HDD drill is shown in Figure 4-22. Drill length would be approximately 300 to 350m depending upon the required punch-out position above or below low water mark. In this configuration, drilling would be assumed to take place from the land parcel behind the beach to the south of the road. Using this method, four conduits would be drilled under the beach to the low water mark. For a cable installation through a HDD, the internal diameter of the pipe should be 2.5 times the diameter of the cable. Each conduit would be approximately 35cm in diameter. The drilling operation would generate approximately 135m^3 of rock-based waste arisings.

Installation of the works by drilling carries certain risks. These include possible interference from the underlying rock head and/or contamination of the ground or ground surface and the beach from drilling material (drilling mud) escape. There would also be potential drilling mud losses to the marine environment at punch-out of the drill head. The envisaged length of time for completing the installations by drilling would probably be significantly longer than for traditional methods such as open trenching, particularly if drilling difficulties are encountered.

Option 2: installation by open trenching (preferred option)

This option involves laying the cable ducts through the beach by open trenching. Four separate cable trenches will be constructed. These will be 200m long and will be buried 1–2m deep. The cable conduit will be laid in these trenches. The trenches will be spaced approximately 10m apart at the low tide area and will converge to a corridor approximately 10m wide on approach to the cable transition joint bay.

Where a conventional excavator is used, the trench will be dug on a receding tide. During the falling tide, it is envisaged that the contractor will dig the trench and line it with sand. Once the conduits are installed the trench is to be back filled using a mix of sand and beach material. The material that is initially excavated to construct the trench is therefore reused during backfilling.

The working corridor is not likely to exceed 40m in width for the intertidal works.

Open trenching is the least costly solution and presents the least risk. Excavation and placement of the cable conduit below the beach can be achieved quickly with the minimum of disruption. Once backfilled, the trench area would be expected to be indistinguishable from the surrounding area after a few tide cycles. Damage to the existing dune system behind the beach will be mitigated entirely as the cable landfall position will be at the existing small car park at the southernmost point of the beach. A rock breaker may be required to excavate this last portion of trench above the beach.

Waste arisings

Any excess spoil (estimated at 400m^3) that is generated through land-side cable duct construction works, transition joint bay construction works or intertidal cable duct construction works will either be reused for the substation berms or will be transported in a covered vehicle by an appropriately permitted waste contractor to an appropriately licensed waste site in accordance with requirements under the Waste Management Acts 1996–2006.

Taking into account bulking of the excavated soil, approximately 600m^3 of excavated material requires removal from site.

Construction traffic

The estimated quantity of movements for the main civil works is shown in Table 4-8. The calculations are based on a construction programme of 6 months with operations deemed mutually exclusive. An allowance of 9m^3 per tipper truck for offsite disposal and drawing in of material has been assumed. Concrete trucks are assumed to deliver 6m^3 each. The quantities are based on planning drawings and subject to detailed design, a 20% contingency in traffic movements has been included.

Table 4-8: Estimates of construction traffic movements

Description	Number of trucks	Duration (days)	Trucks per day	Trips per day
Site Preparation				
Site Strip to formation level	67	10	7	14
General Building / Civil Engineering				
Control Building	75	35	3	6
Ancillary site structures- Electrical switchgear bases	12	5	3	6
Site fencing	14	5	3	6
Roads & paths	105	35	3	6
Surface & foul drainage	9	5	3	6
Electrical ducting.	15	5	2	2
Landscaping	5	5	3	6
Sundries	20	10	1	2
Subtotal	255	115		
Contingency @ 20%	51	10		
Total	**373**	**135**		

4.4.3 Phase 2 – subtidal construction works

Design and installation methods have undergone considerable improvement since the earliest installations of submarine cables, with the latest vessels deploying sophisticated dynamic positioning systems (as opposed to manually deployed anchors) and a variety of burial techniques (jetting, ploughing, and so on) which ensure that the cable installation technique selected is appropriate to the type of cable and the seabed conditions. The contract to provide and install the cable is an Engineer, Procure and Construct (EPC) contract which means that the design details will be finalised by the client engineer and the contractor selected through a tender process to undertake the EPC contract. It is therefore expected that some variation may be made to the cable and installation methods proposed. However, the descriptions of the proposed installation techniques are based on typical cable lay methodologies used by the industry and reflect a worst-case scenario for the purposes of the assessment of environmental effects.

The marine cable installation will typically comprise:

- Pre-cable lay grapnel run

- Cable landing at the beach
- Offshore deepwater cable lay
- Post-lay cable survey

Pre-cable lay grapnel run

Before cable laying commences, a suitable vessel will undertake a pre-cable lay grapnel run along the cable route to remove any discarded materials that could snag the submarine cable as it is being laid or interfere with the cable protection process.

Cable landing at beach

Before the cable landing operation, the seaward end of the pre-installed ducts are exposed using an excavator.

Where the cable is to be buried in shallow water, the shallow-water vessel will either deploy plough or jetting techniques to bury the cable as it is laid to the optimal target depths.

Shallow-draft vessels will be used for cable-lay operations in the shallow water immediately adjacent to the intertidal landing area. The cables are floated in to the cable ducts from the cable laying vessel. Normally as the cable is pulled from the vessel floats are attached to it to enable it to stay on the water surface, making it easier to pull. At the water's edge the floats are removed by divers and it is pulled over running blocks into the duct and onwards to the cable transition joint bay. An example of this operation for the 220kV cable landing at Cork Harbour is shown in Figure 4-23.

The running blocks are subsequently removed, the ducts and their seaward ends are sealed and the area around the ends of the conduits backfilled with sand and excavated material.

The ducts may be filled with bentonite mud on completion of cable pulling to dissipate heat effectively. Depending on the specific properties of the substrate on-site, it may be necessary to use engineered sand (i.e. graded sand with specific thermal properties) at the bottom of the cable trench to enhance heat transfer away from the cables.

Cable winch

A winch will be used to pull the cables from the vessel and from the substation into the cable conduits to the cable transition joint bay. A typical winch for this purpose will weigh up to 20 tonnes and may be a double-drum capstan winch with a separate reel winder for the wire. The winch will be driven hydraulically and powered by electricity or diesel motors. This will be stationed temporarily in the lay-down area at Belderra. A hauling wire or rope will be attached directly from the winch to each cable through the cable conduit and the cable will be winched through the conduit to the cable transition jointing bay.

Offshore deepwater cable deployment

Special cable deployment vessels are used to deploy marine cables. The offshore cable-lay vessel will arrive on site with a turntable loaded with the cable. The cable is transported via cable wheels from the turntable to the laying wheel at the stern of the ship from where it is to be paid out. Under tension, it is guided into the water (Figure 4-24). The cable is paid out from the back of the ship through the chute. Where installations are carried out in deep waters the cable is laid directly onto the seabed in a defined catenary line from the cable-laying barge to the test area.

Each cable will terminate in one of the two test areas with a dynamic riser tail which will not be buried but will be stabilised on the seabed by a suitable protection methodology and its location marked with a surface buoy. The two dynamic risers in Test Area A will be 300m long and the two in Test Area B will be approximately 150m long.

Two cables of 16km and two of 6.5km will be laid, necessitating four separate cable-laying runs by the cable vessel. The cable-lay operation may be performed on a 24-hour basis to ensure minimal navigational impact on other users and to maximise efficient use of suitable weather conditions and vessel and equipment time. Notifications, such as Notices to Mariners, will be issued in accordance with statutory procedures to ensure navigational and operational safety. Some additional vessels such as safeguard vessels may be used in addition to the main cable-laying vessel.

Offshore cable protection

As the laws of the High Seas do not grant a safety zone around submarine cables every effort must be made during design and installation stage to adequately protect the cable circuits. It is also essential that each cable circuit is marked up on Admiralty charts.

The most common protection method today is trenching – that is the burial of the cable under the sea floor. This is necessary to avoid damage and entanglement with trawling gear and anchors and to minimise the risk of the cable movement on the seabed where there may be a risk of damage due to cable fatigue. There is a variety of different trenching methods, and new equipment is being developed as the amount of submarine infrastructure increases. The cables at the test site will be buried to an minimum depth of 1m. Where the cables pass through the inner Test Area B en route to Test Area A they will be buried to a depth of up to 2m and a rock berm will be installed to further protect the cables but also to highlight the route location to ensure that WEC moorings do not damage the cables. There is approximately 4km of the cable route where rocky substrate cannot be avoided. In these areas the cable will be laid on the seabed surface and protected with suitable "armouring" material, such as rock protection, split shells or 'mattresses' to protect the cable from scouring by tidal currents.

Typically a remotely operated vehicle (ROV) with supporting camera unit is deployed by the vessel to check cable touch-down positions at selected locations.

The cable within the marine area will be installed either by post-lay burial (PLB) or directly as the cable is deployed. Burial in the sea bed may be undertaken by water jetting or by ploughing. The final choice of cable protection will be determined by the EPC contractor.

Water jetting

The cable is installed by a post-lay burial water jetting system. Jetting devices tend to be used where the seabed is relatively soft. Water jetting systems use a controlled jet of pressurised water to create a trench. A sword carrying a row of water nozzles is pushed down into the seafloor. The high-pressure water flow from the nozzles fluidises the seafloor. Typical water flow is around 1,100m^3/h at 5.5 bar pressure. While the water-jetting unit is moved along the cable route, the cable sinks down through the sediment. Soon after, the sediment resolidifies. Different carrier systems are available for the water-jetting unit. For example, the water-jetting unit can be assembled into a purpose-built ROV with own propulsion, and can move along the sea floor on wheels or caterpillar wheels. An umbilical cable connects the ROV to the surface vessel to provide a power supply and data communication.

As the operation of such systems is limited in time, in area of work and in the size of the open trench created, they are regarded as among the most environmentally sensitive. The water jetting burial system offers a number of advantages including:

- The potential for rapid trenching.
- Easy and cost effective operation from most dynamically positioned vessels without A-frame or other specially designed launching arrangement.
- More controlled operation whereby disturbance of sediment is minimised and the disturbed sediment is then used immediately to backfill the trench.

This cable-laying operation typically proceeds at speeds of between 200–1000m per hour depending on the conditions.

Ploughing

Ploughing-in submarine cables is also a common method of installation within the industry. An underwater cable plough has a horizontal framework that can travel over the seafloor either on four sledges (one in each corner) or on wheels or caterpillar wheels. In the centreline of the framework, there is a plough share reaching down into the seafloor.

In contrast to an agricultural plough, the cable burying plough is not designed to turn over the soil but to cut a narrow slit with as little resistance as possible. As the plough opens a slit in the seabed the cable is guided down directly behind the ploughshare or through a hollow slot inside the ploughshare.

Ploughs are towed after the surface vessel and can require high tow forces. In deeper water, the plough requires long heavy tow cables and control of the position of the plough can become difficult.

More sophisticated ploughing systems employ vibration or water jets to support the ploughing process.

Ploughing down cables is a method mostly suitable for soft to medium strong soils and shallow waters for example, less than 100m deep)). Many ploughs are passive systems with a good reliability, which makes ploughing one of the most economic cable burial methods.

Ploughing is used widely, as the technology is relatively simple and, provided the geology, bathymetry and soil mechanics allow, it can be used to minimise environmental impacts.

Post-lay burial survey

Following cable burial operations, a geophysical survey will be undertaken to provide information on burial depths throughout the length of the sub-sea cable. This survey will last for approximately 10 days, and use standard geophysical techniques and possibly an ROV.

Installation of land-side cables

The land-side cables from the substation will be installed by pulling them through the ducts which were pre-installed by trenching the cable route to the cable transition jointing bay. The submarine cables and land-side cables are jointed at the cable joint bay, which is then backfilled. This completes the cable landfall operation.

Marking of test areas

Subject to statutory sanction, Test area A will be marked typically as follows:

- Cardinal marker buoys (marked with directional arrows) will be placed at the corners marked 1, 2, 5 and 6.
- Special Marker buoys (marked with St Andrews Cross) will be placed at corners 3 and 4 (Figure 4-4).

Cardinal marker buoys indicate the safe side of a danger to navigation. The cardinal marker buoy at Corner 5 will be larger in size, approximately 4m wide and 6m high. It will be fitted with an antenna and an automatic identification system (AIS) transmitter. This will allow data transmission from the test site to shore-based facilities and identify the test area location to shipping and other traffic by electronic and visual means.

Test Area B will be marked as follows:

- Cardinal marker buoys (marked with directional arrows) will be placed at the corners on the west side of the test area.
- Special Marker buoys (marked with St Andrews Cross) will be placed at corners on the east side of the test area.

The marker buoys will be anchored to the seabed using either catenary mooring systems or gravity anchors. These will be maintained by SEAI throughout the lifetime of the project. The operation to deploy the cardinal marker buoys will take approximately one week and will require one vessel such as the *Celtic Explorer* present on site.

Temporary site facilities and construction materials

Plant items and materials for the landfall cable transition joint bay and the substation will be delivered by road along the R313 and L5232. Temporary direction notices will be erected for construction traffic.

It is envisaged that the works area would be compact. There will be a limited number of vehicles associated with the works. The plant and equipment required to build the jointing bay and to remove any excess spoil are expected to consist of a tracked excavator or JCB, a standard ready-mix concrete mixing truck and a tractor with a tipper-trailer.

The plant and equipment required to build the substation and access road are expected to consist of a tracked excavator or JCB, a standard ready-mix concrete mixing truck, a surface grader and a tractor with a tipper-trailer. Spoil from the substation construction will be reutilised in the construction of the screening berms around the substation compound. Should additional materials be needed for this purpose they will be imported from approved quarries by road to the substation site. Road making materials will be imported from a licensed quarry in the area.

There will be no significant storage facilities/depots located near the shoreline.

Any construction materials required will be stored in such a manner and location that they do not to pose any risk to the surrounding environment.

When the project is completed, all temporary facilities will be fully removed upon project completion and the respective areas will be reinstated.

The diesel generator required for the power supply to plant and machinery during the construction phase will be bunded. Adequate absorbent material will be held on site to contain possible spills.

In order to prevent littering and contamination incidents, general collection facilities will be provided at the sites for all other wastes, including non-hazardous wastes.

Other than surface water no discharges will arise during construction works.

Duration and phasing

It is envisaged that the works will commence in early 2013. The total duration of the works has been estimated at approximately six months. Over this period, a number of activities will be carried out consecutively or concurrently:

- Construction of cable joint bay and land-side cable duct installation is anticipated to take approximately two months over a number of separate periods.
- Closure of the L5233 may occur at intermittent periods of up to three days to one week.
- The cable landing at Belderra will take approximately 6 weeks to complete but operations will not occur continuously. It is expected that they will occur over a number of periods.
- Construction of the substation will take up to up to 6 months.

Working hours on the substation construction, cable joint bay construction and intertidal area will normally be from 8.00 a.m. to 8.00 p.m. Monday to Saturday and potentially Sunday. At certain times, contractors may be required to work extended hours to meet the project programme or to use suitable tides.

There may be unavoidable delays and changes to the project programme because of weather and sea conditions. These delays are to be minimised where possible and interested parties are to be kept notified where possible or necessary.

Test site infrastructure commissioning phase

Sub-sea cable commissioning will take place after all four sub-sea cables have been installed. It will require consultation between the client engineer and the cable installer to determine the optimum solution. The cable testing will not have any impact on the surrounding environment.

Construction phase vessel movement

An estimate of duration of construction phase and operational phase vessel movement is provided in Table 4-9 and Table 4-10 respectively.

Table 4-9: Estimated duration of construction phase vessel movement

Vessel	Duration (days)
Cable vessel cable collection	90
Pre-lay grapnel run	14
Cable lay vessel -offshore cable laying	30
Guard vessel	30
Cable burial	20
Rock armouring	20
Post-lay survey	4
Total	**208**

4.5 Deployment of WECs

The deployment of WECs will be the responsibility of WEC developers and will take place under strict conditions governed by a deployment protocol set up by SEAI to which all developers must adhere. The test site is designed to allow both single WECs and arrays of WECs to be deployed and tested.

The overall capacity of the test site, including both test areas, is limited to a maximum export of 10MW. Various combinations of WECs can be considered subject to this maximum export capacity.

A further consideration in assessing the likely combinations of WECs on the test site is the likelihood of deployment. Based on discussions with WEC developers, a minimum of one 5MW array of WECs may deploy at Test Area A. Indications are that the remaining 5MW of capacity will be either a second array of 5MW at Test Area A or an array at Test Area B.

The possible configurations of WEC arrays and potential anchoring systems are discussed below.

4.5.1 WEC arrays deployed at Test Area A (100m)

Test Area A (100m water depth) has been designed based on discussions with prospective users of the site. It is currently envisaged that the test area should allow for the deployment of up to two WEC arrays of approximately 5MW each. An example of the layout of such deployment, based on arrays of five Wavebobs and five Pelamis WECs, is shown in Figure 4-25.

It can be seen that the overall test area is greater in size than the actual footprint of the arrays shown. There are a number of reasons for this including;

- Additional equipment such as wave and current measuring devices deployed within the test area.
- Remaining uncertainties regarding number of WECs planning to deploy.
- Uncertainties over final anchor, mooring and foundation designs and the need to account for this by accommodating some additional area.
- Flexibility to adjust arrays and install other equipment such as noise monitoring sensors in the test areas.
- Remaining uncertainties over the size of the WECs themselves.
- Requirement to provide a safety zone around deployed WECs and WEC arrays while still facilitating transit of vessels in the vicinity of the test areas.

A 400m safety zone around the arrays is incorporated in the design. The main factors that are considered when sizing the safety zone are the collision risk from vessels, the mooring and foundation design of the deployed WECs, the submarine electrical cable configuration and connection design and the minimisation of impact on fishing activities in the area.

4.5.2 WEC arrays deployed at Test Area B (50m)

Test Area B (50m water depth) can accommodate a variety of deployment layouts, Figure 4-26. A small array of WECs or a number of single WECs are envisaged. For example an array of two OWCs such as Ocean Energy's WEC could be deployed. Alternatively some mix of OWC and alternative WECs could be accommodated such as a small array of Ocean Power Technologies' (OPT) WECs. The size of the useable test area is limited in the north-south direction due to the unsuitable nature of the seabed for mooring of WECs beyond the limits of the existing test area.

4.5.3 Mooring of WECs

While some full-scale commercial WEC units have been deployed to date, mooring systems are still largely at the developmental stage. Although the experience gained from deployed mooring systems is limited, a number of anchoring solutions are in development. These take into account the size and needs of different WECs as well as seabed substrate type, mooring depth, static and dynamic forces, and economic factors. The experience gained from existing deployed WECs and from other offshore applications such as wind farms, ship anchoring, general marine construction and the offshore oil industry has also been considered.

The potential anchoring systems that are likely to be used at the test site are discussed below.

WECs are required to operate in high-energy environments where they can maximise the potential to generate commercial outputs of electricity. The design of mooring systems must therefore take into account the typical requirements of such conditions with a view to ensuring the survivability of the WEC device and the optimisation of commercial power output.

The major requirement of a mooring system for an offshore unit is to withstand the loads from wind, wave and current to keep the unit in position at all times, in all weather conditions, and in a cost effective manner. In general mooring system consist of three main parts;

- The mooring line or riser
- The connections
- The anchor / foundation

4.5.4 Mooring configurations

Mooring can be achieved by either a single or spread mooring systems. Mooring type is generally WEC specific with most floating units using spread mooring systems due to safety factors and redundancy. Some techniques demand a mooring solution that allows the WEC to weathervane in the predominant wave direction. A sketch of single and spread mooring solutions is shown in Figure 4-27.

Floating systems such as Wavebob and Pelamis do not generate the wave energy relative to the sea floor and therefore may have spread mooring systems. They also have the choice between catenary or taut mooring systems (smaller footprint), Figure 4-28 and Figure 4-29.

4.5.5 Anchoring systems

There are a number of likely anchoring systems for WECs which would be suitable for use at the designated test areas. These include gravity anchors, drag embedment anchors (including vertical load anchors) and suction piles; these are described below.

Gravity anchors

Gravity anchors (Figure 4-30) keep the unit in place solely by the weight of the anchor. In medium to soft seabed sediment, the friction force between the foundation surface and the surrounding sediment will add to the holding capacity. The weight of the foundation must be sufficient for it to withstand horizontal forces and it must also remain stable and not tilt over when exposed to forces that present at an angle.

Gravity foundations are mostly concrete or concrete and steel shells filled with ballast and are suitable for all soil conditions with sufficient bearing capacity. Gravity foundations are the most suitable for hard soils or rocky seabeds where drilling or blasting need to be avoided. They are also suitable for both seabed-mounted and floating WECs and for both catenary and taut mooring configurations. In areas with strong current, scour protection might be necessary to prevent soil erosion around the gravity anchor.

Drag embedment anchors

Drag embedment anchors are used with mooring systems without vertical loads, such as catenary mooring systems (Figure 4-31). When installed the anchor is embedded in the seabed substrate and the connector is attached at the seabed surface to the catenary mooring line. Drag embedment anchors are only suitable for floating WECs that use a catenary mooring line system. They are suitable for most soft and medium seabed substrate conditions where it is possible to lower the anchor into the substrate at installation (Vryhof, 2005).

Vertical load anchors

Vertical load anchors (VLA) are embedment anchors designed to withstand forces at angles of up to 50 degrees, depending on the design parameters (Figure 4-32). The anchor is embedded several meters into the ground at installation. This type of anchor is suitable for tension leg moorings and can be used in most soft and medium soil conditions where it is possible to lower the anchor into the soil at installation. VLAs are suitable for floating WECs that use a taut mooring line configuration.

Suction bucket anchors

A suction bucket anchor is designed as a kind of 'bucket' that is lowered onto the seabed (Figure 4-33) and then kept in place by suction created by the difference in pressure inside the bucket and in the surrounding area. The design of the bucket depends on the frictional forces of the seabed sediment. Suction anchors have been used for anchoring in the oil industry for several decades, and they are suitable for most soft to medium soil conditions. They do, however, require thorough investigation of the site to establish its suitability. Suction bucket solutions are suitable both for seabed-mounted and floating WECs and can be used both for catenary and taut mooring configurations.

4.5.6 Mooring at Test Areas A and B

The mooring systems that may be used at the test site locations reflect current understanding of potential deployments as presented to the project by technology developers and prospective users of the site. They are also based on the results of vibrocore samples taken at the test site locations. Soil profile logs from the vibrocoring indicate that the predominant soil type within the test areas is both fine and coarse sand often mixed with varying degrees of silt or shell fragments. Thus the test area seabed substrate would in general be suitable for gravity anchors, embedment anchors or suction bucket anchors where sufficient depth of soft sediment is available.

Clearly the actual deployments will depend on a whole range of factors that cannot all be determined until technology-specific design work is undertaken by prospective users of the site. Almost all of the technologies proposing to utilise the test site are at different stages of prototype development and numerous challenges are likely to impact on their future deployment strategies and designs.

Only floating WECs will be deployed in Test Areas A and B. These will use either a catenary mooring line (see Pelamis mooring layout) or a taut mooring line system (see Wavebob mooring layout). WECs that are likely to be deployed at the 100m water depth test area include Wavebob and Pelamis. Pelamis may also be deployed at the 50m water depth test area.

See Figure 4-34 for details of Wavebob mooring layout for a single WEC in 100m-deep water.

It is anticipated that in the 100m water depth test area an array of up to five Wavebob WECs could be deployed for testing. The likely configuration of such an array is shown in Figure 4-35 in plan and elevation.

Mooring of Wavebob devices will most likely utilise suction bucket anchors.

Pelamis is held on station by a catenary mooring spread consisting mainly of steel chain and synthetic tethers, with the connection point to the machine being near the nose via a yoke attachment structure, as shown in Figure 4-36.

The mooring system is an integral component of the Pelamis WEC installation, and it needs to allow the machine to rotate so that it can point into the predominant wave direction and to allow for surge motions from the swell. Both of these functions help minimise loading within the moorings and machine, especially in heavy swell conditions. The Pelamis moorings are designed for water depths greater than 50m. Embedment anchors (as used for floating oil rigs) are the preferred anchors for Pelamis. These require sites with sedimentary cover. If site conditions are not conducive for embedment equipment, Pelamis Wave Power (PWP) may employ alternatives such as gravity or suction anchors.

Figure 4-37 shows how an array of five Pelamis WECs could be deployed in the 100m test area.

4.5.7 Scour protection

Currents and tidal movements can give rise to erosion around seabed structures and create 'scour holes'. Where the seabed substrates are sandy (as in Belmullet), there is a higher risk of scour holes around foundations than in areas where the substrate is clay or mud. Protection may therefore be required to protect the anchoring structures from scour, but the need for this will depend on the anchoring system chosen.

4.5.8 Commissioning of WECs

Once the WEC unit is anchored in position, the dynamic cable riser will be lifted from the seabed and connected to the WEC unit. This will give rise to a small amount of seabed disturbance as the temporary cable protection is removed.

Once connected to the land-side substation, electrical testing will be undertaken to ensure that power generated by a WEC can be transmitted to the substation and into the grid system and measured.

4.5.9 Duration and phasing

The likely period for the deployment of WECs will be after 2013 and will likely occur during the months April to September. As this is a test site WECs will be deployed initially for short periods and will be periodically removed for adjustment and maintenance purposes. This is likely to occur monthly in the initial six-month period. Thereafter, the period when WECs are on-site will increase until such time that maintenance will occur on a six monthly or less frequent basis. Actual deployment of WECS will occur over a two- to three-day period and will initially involve deployment of the anchoring system, towing of the WEC to the site, tethering of the WEC to the anchoring system and connecting the WEC to the submarine electricity cables. However, deployment and commissioning of WECs will be very weather-dependent and bad weather could extend the timeframe for these operations.

4.5.10 Estimated duration of operational phase vessel movement

An estimate of the duration of vessel movement during anchor and WEC deployment is provided in Table 4-10. Anchors may be deployed by special anchor handling tugs (AHT). WECs will be deployed by multi category vessels capable of undertaking a range of different tasks.

Table 4-10: Estimated duration of operational phase vessel movement

Vessel	Duration (days)
Cable survey	5
Vessel mobilisation from home port	30
Mooring deployment –anchor handling tugs	65
WEC deployment – multi-category vessel	20
WEC recovery – multi-category vessel	20
	140

4.6 Overall project timescale

It is anticipated the AMETS project test site will be fully commissioned and operational in 2014. The site will be maintained in an operational capacity for 15 years from the date of commissioning

4.7 Decommissioning

Experience is that a lifespan of 50 years or more is possible for submarine transmission cables. This is in line with the Commission for Energy Regulation's direction on material assets, which suggests that assets such as submarine cables have an operational lifetime of 50 years.

The proposed development has a design life of 15 years, although refurbishment could extend this if necessary.

Decommissioning of the sub-sea portion of the cable will be subject to agreement between SEAI, the Minister for Communications, Energy and Natural Resources, and other appropriate authorities, and will be in line with relevant legislation and industry best practice at the time.

Decommissioning of the onshore (landfall) substation will be subject to agreement between SEAI and the Mayo County Council, and impacts will be assessed based on best-practice techniques in place at the time of decommissioning.

Decommissioning of wave energy converters will be the responsibility of the WEC developer and will be subject to agreement between SEAI, the Minister for Communications, Energy and Natural Resources, and other appropriate authorities, and be in line with relevant legislation and industry best practice at the time.

A full assessment of the impact of decommissioning will be undertaken. This will include the options of recovering the submarine electricity cables or leaving them *in situ*.

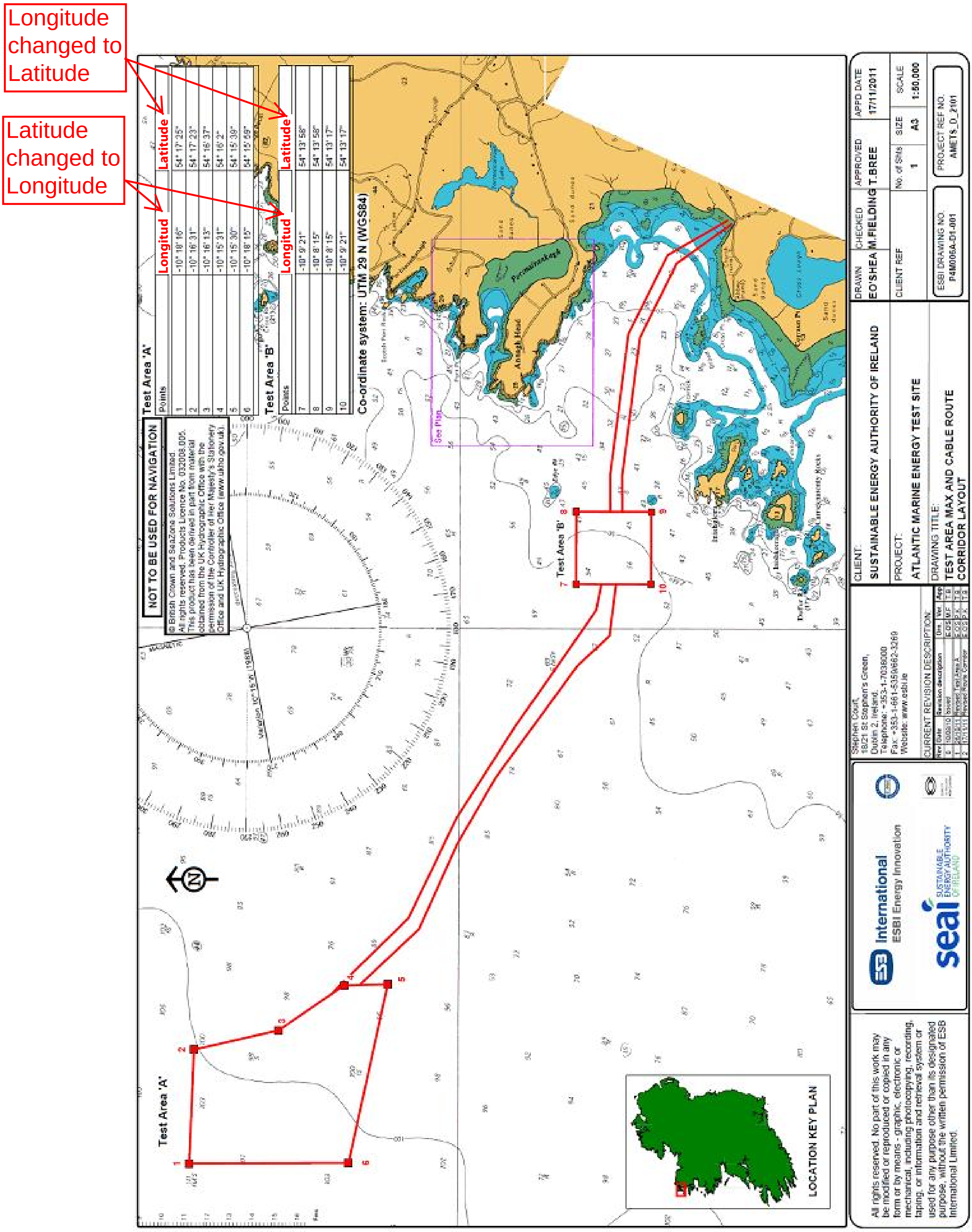


Figure 4-1: Location of offshore test areas

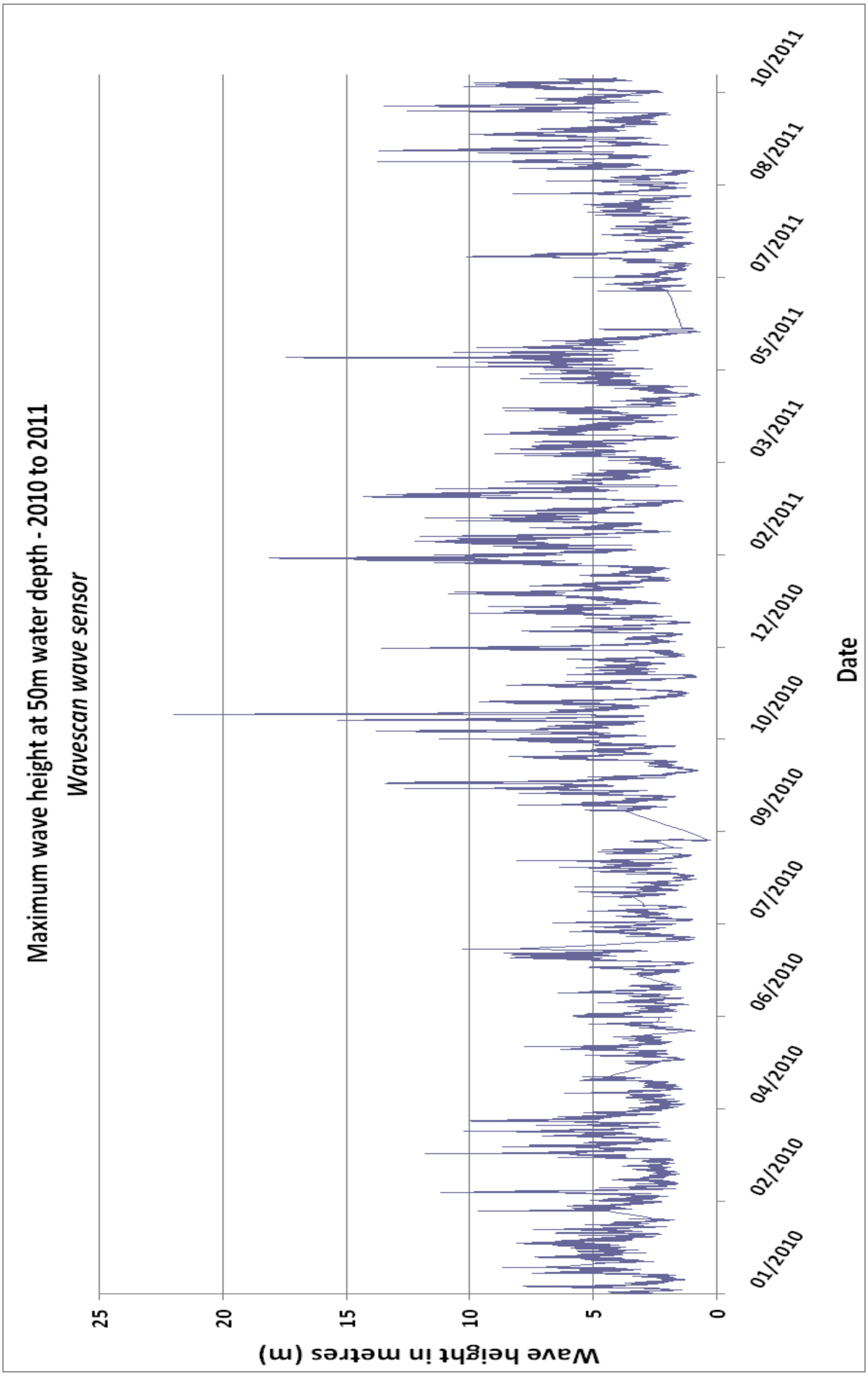


Figure4-2: Maximum wave height recorded at the 50m water depth test area (Hmax in cm)

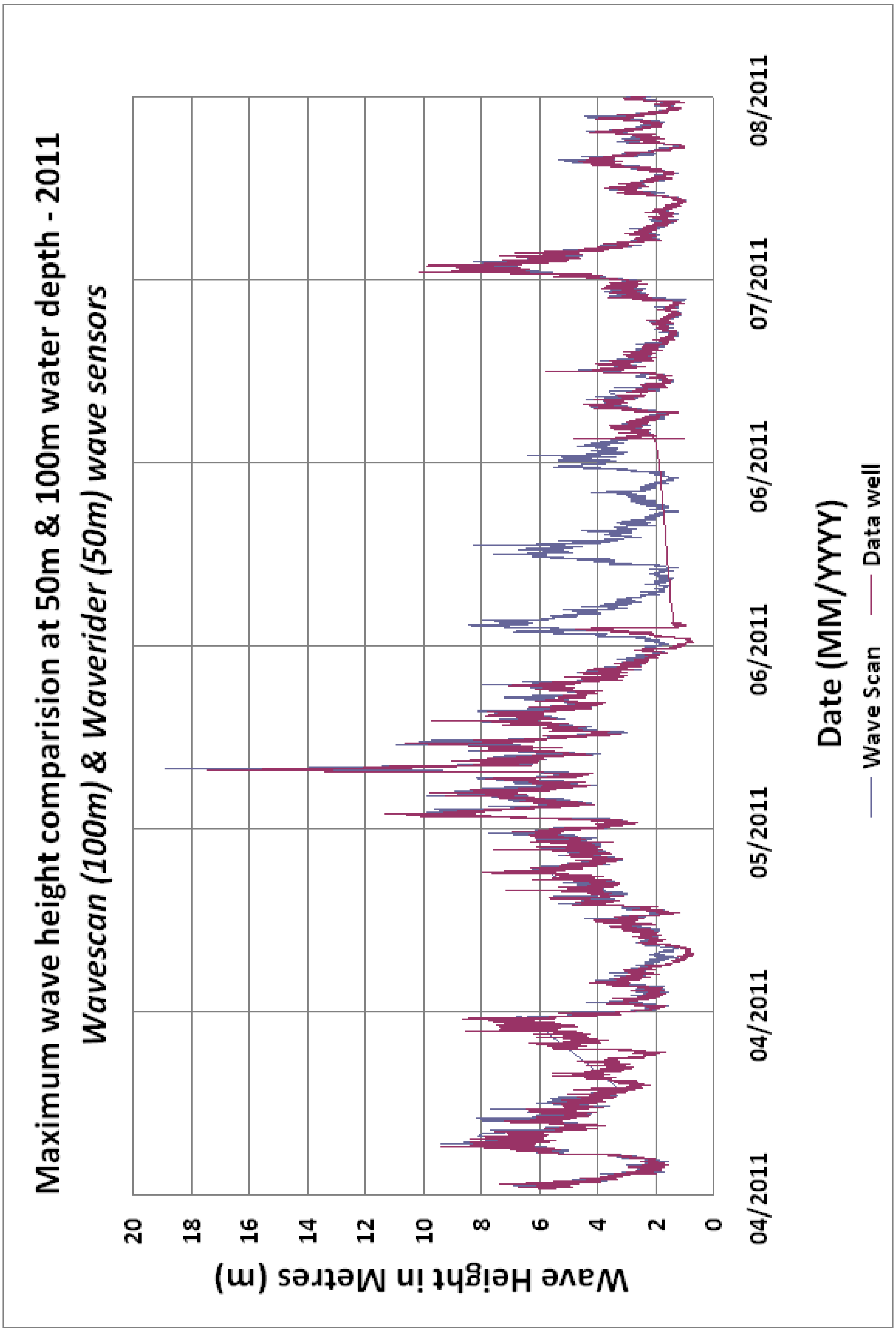


Figure 4-3: Comparison of maximum wave heights at Test Area A and Test Area B as recorded by a Wavescan Buoy and a Waverider buoy respectively

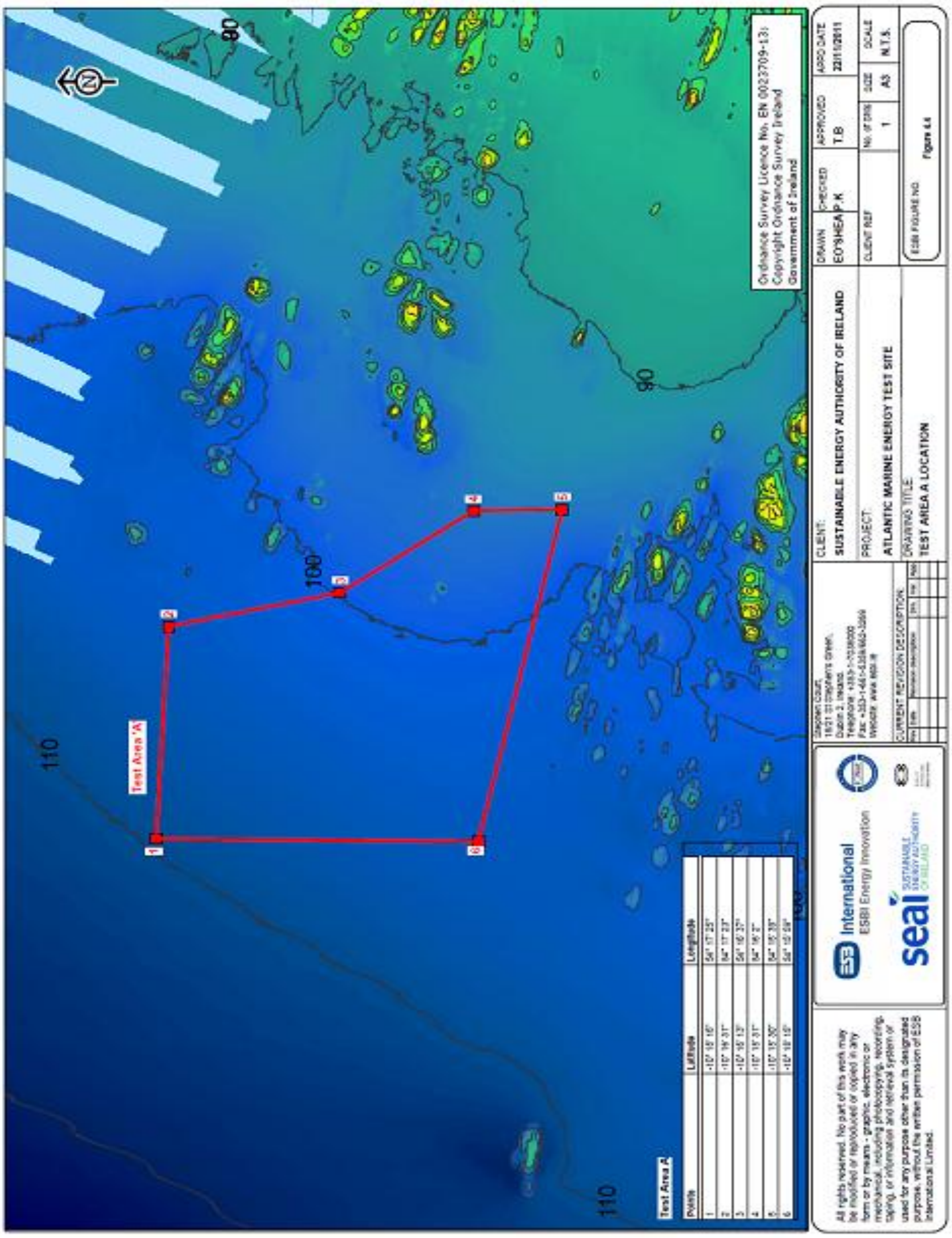


Figure 4-4: Test Area A shape

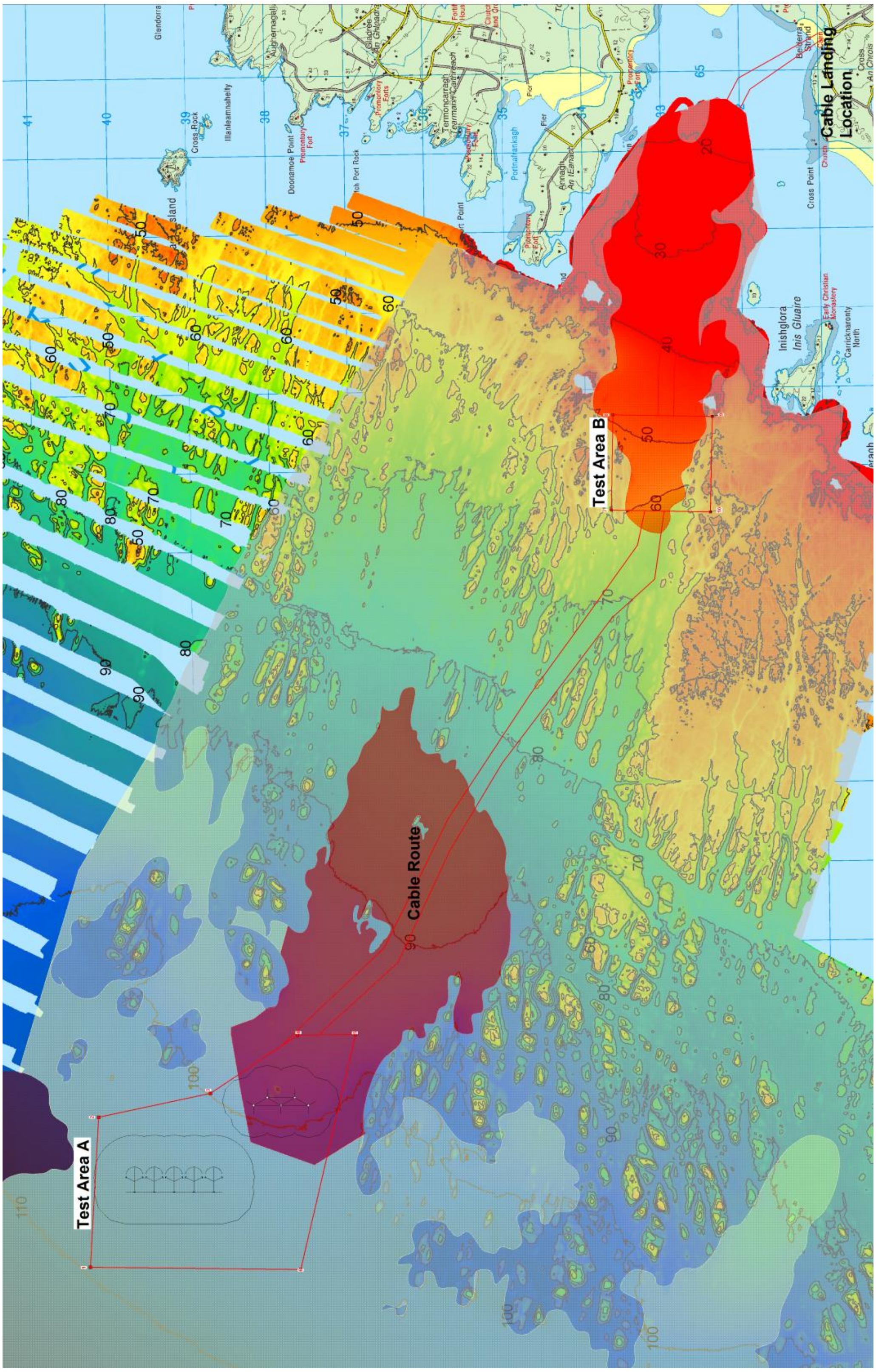


Figure 4-5: Cable route corridor

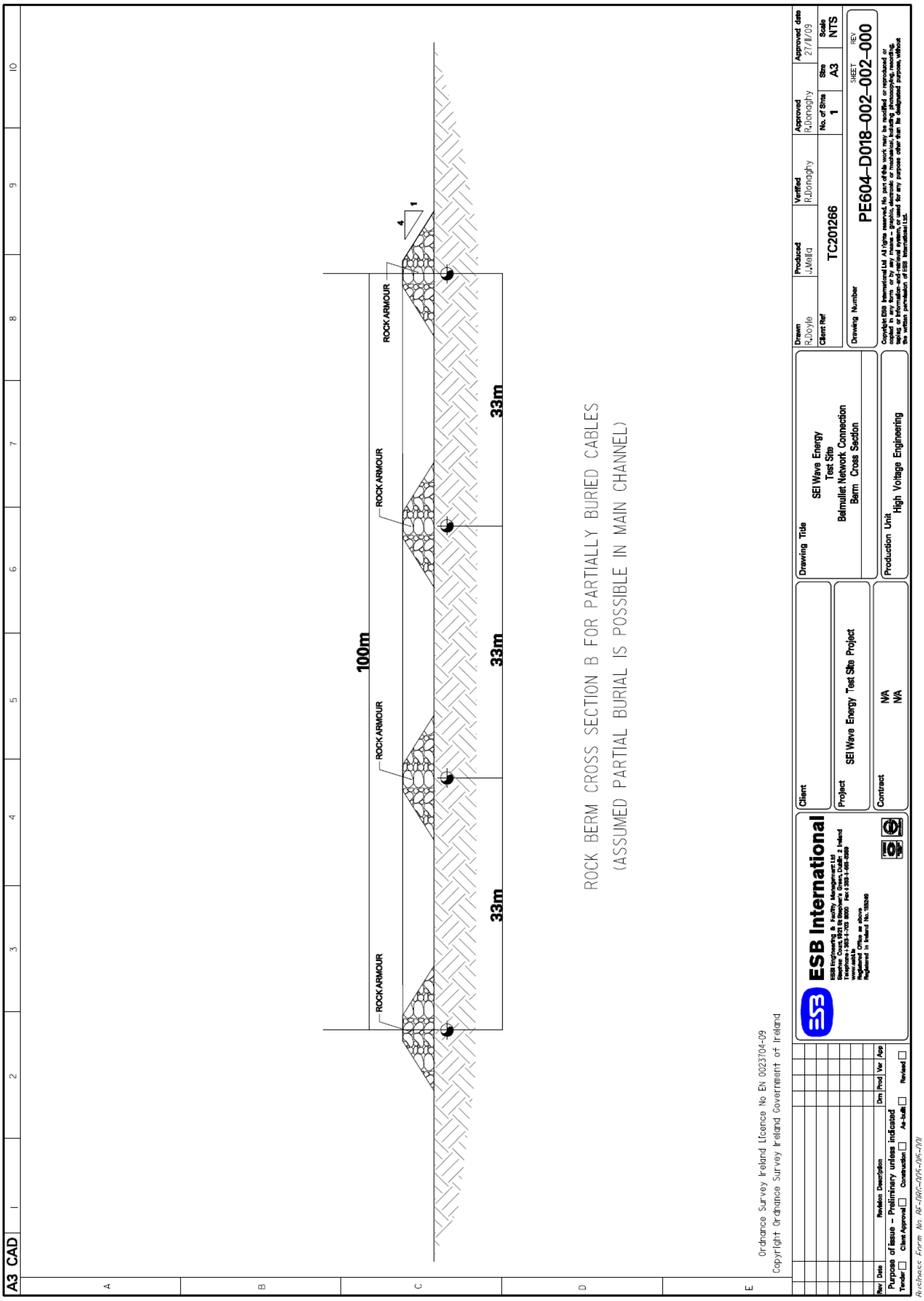


Figure 4-6: Typical submarine cable protection - rock berm

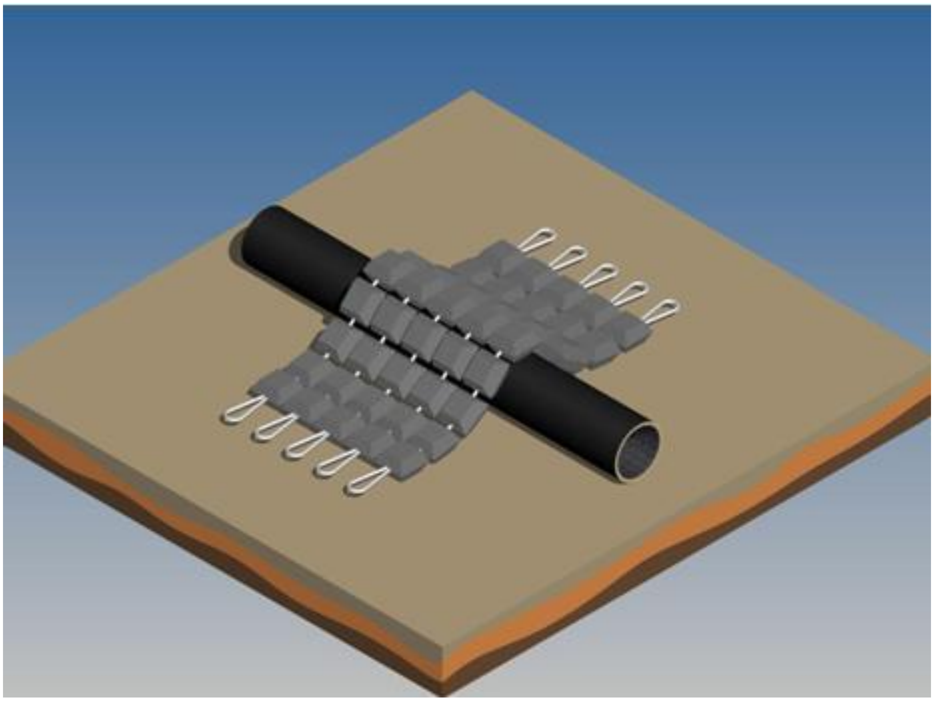


Figure 4-7: Cable mattress protection

Figure 4-8: Split shell cable protection

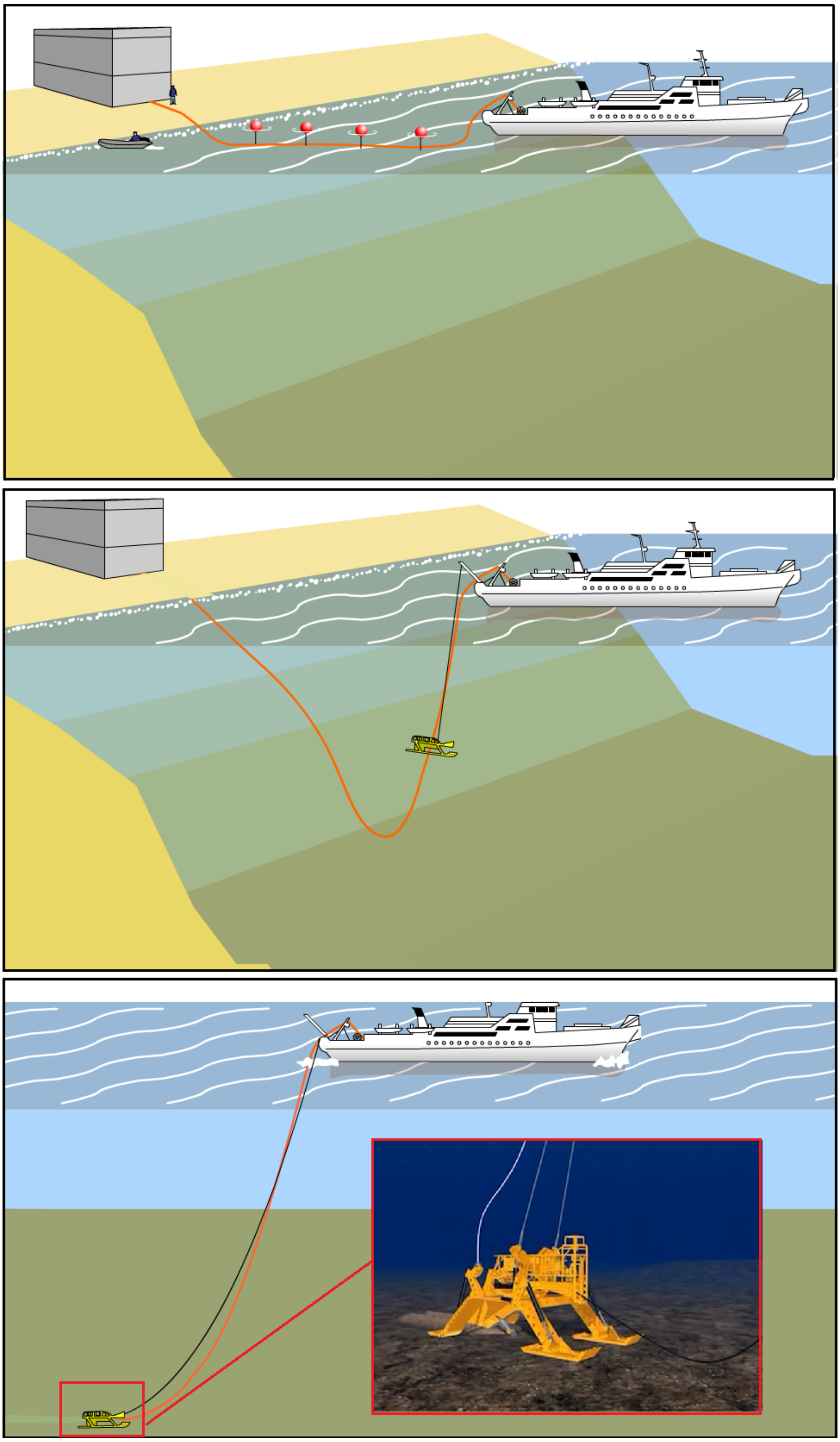


Figure 4-9: Schematic of typical off-shore cable laying operation

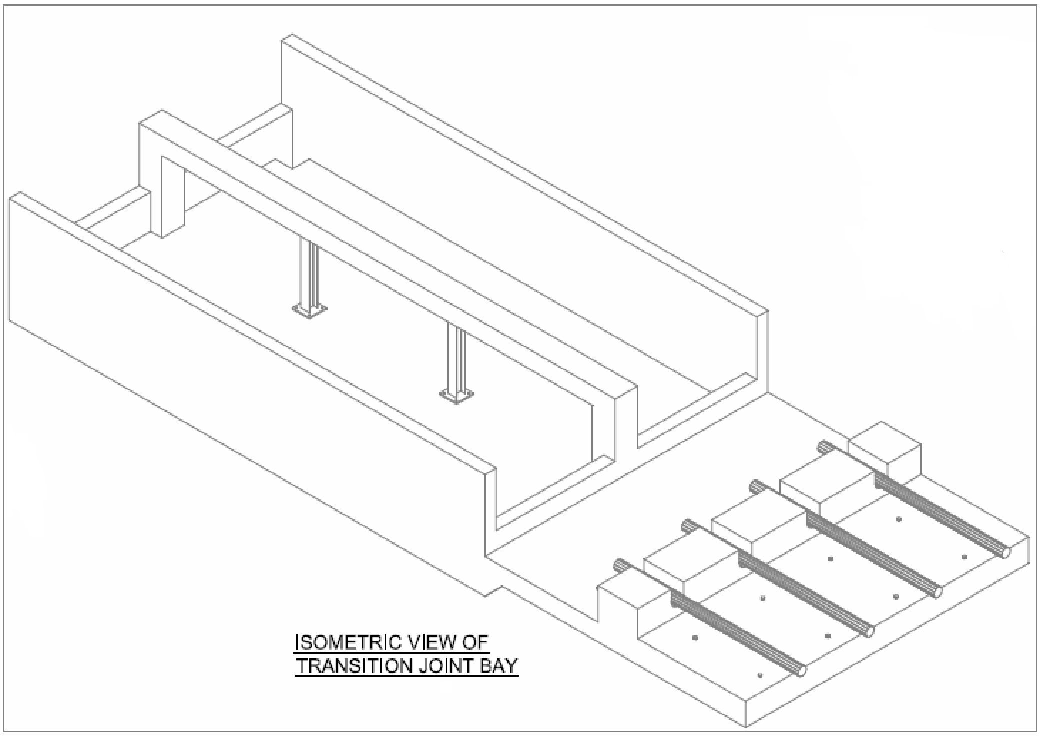


Figure 4-10: Isometric view of transition joint bay

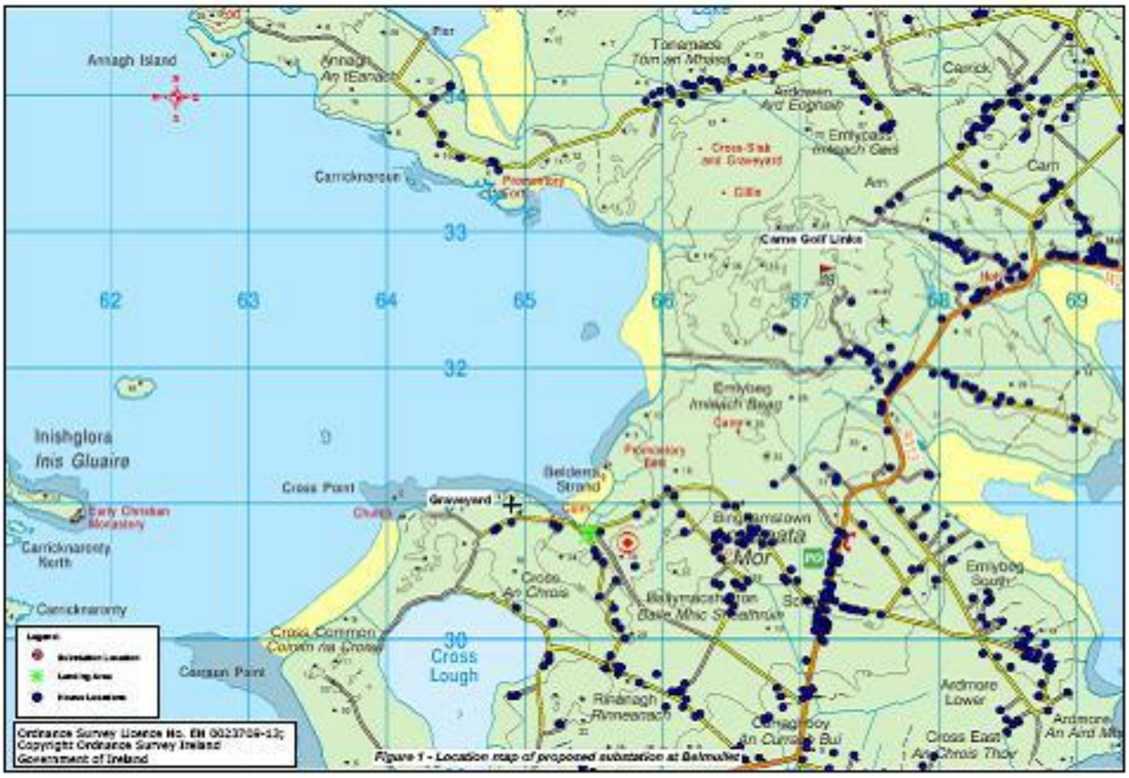


Figure4-11: Proposed substation location at Ballymacsherron townland

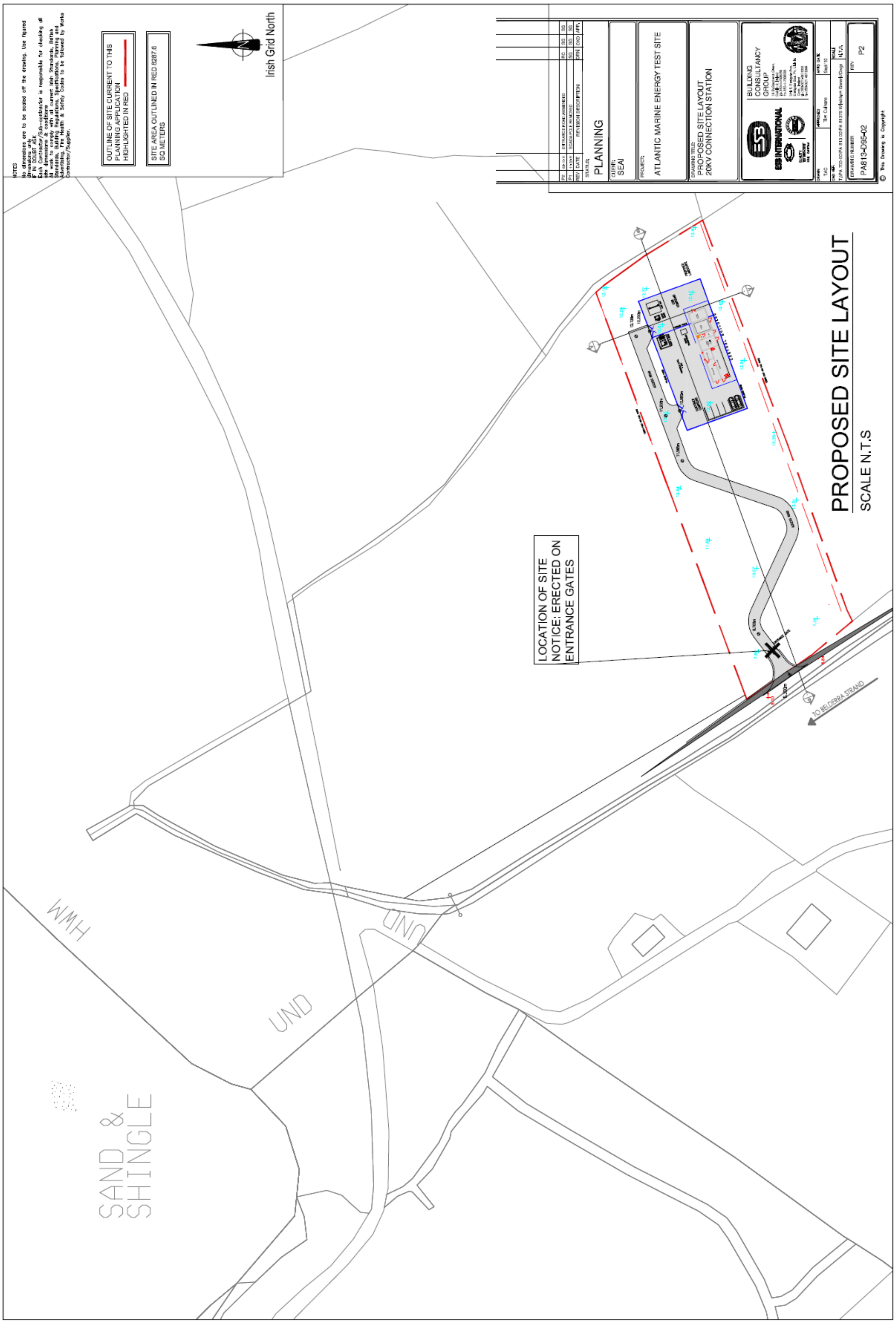


Figure 4-12: Land cable route to substation

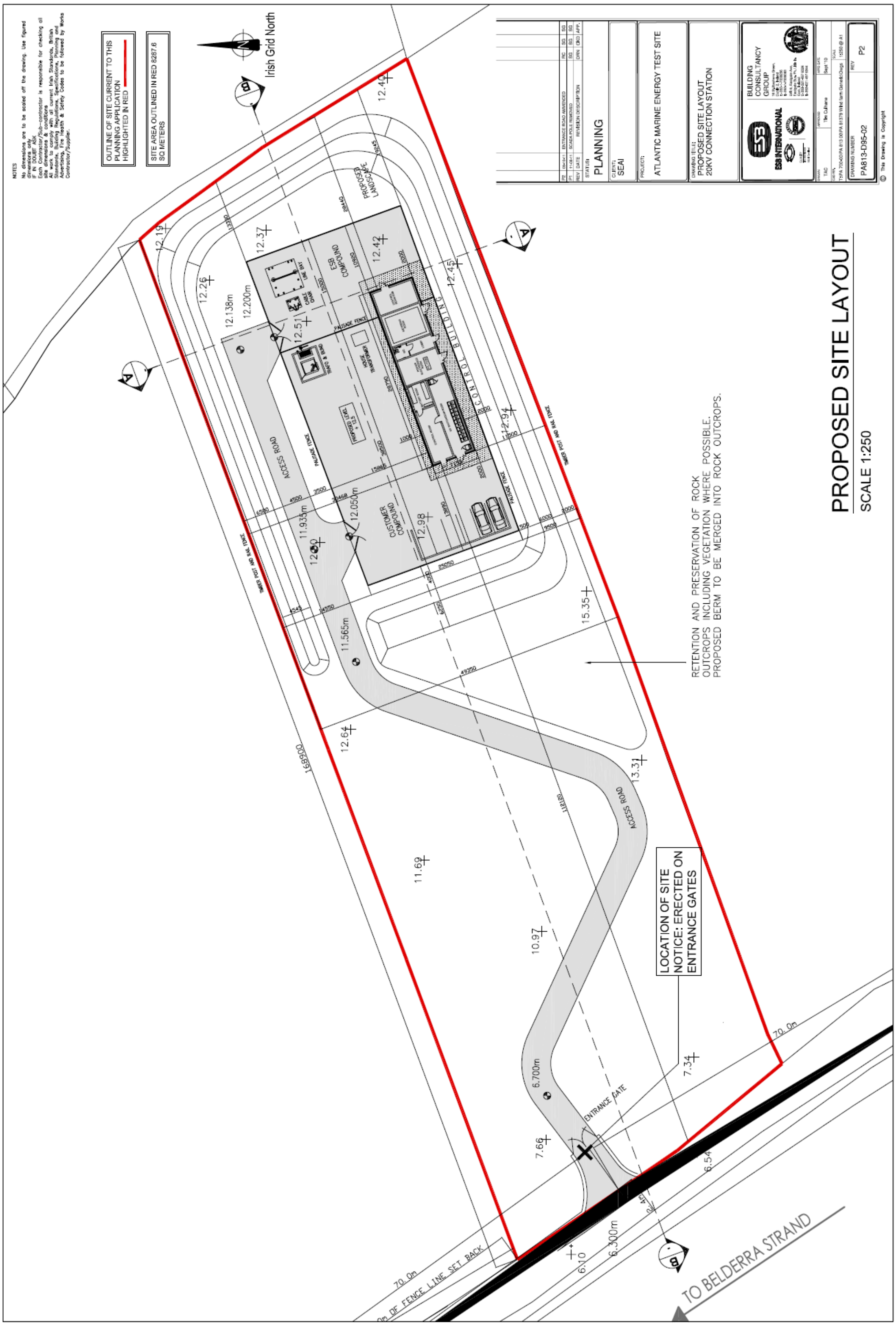


Figure 4-13: Proposed substation layout and access road

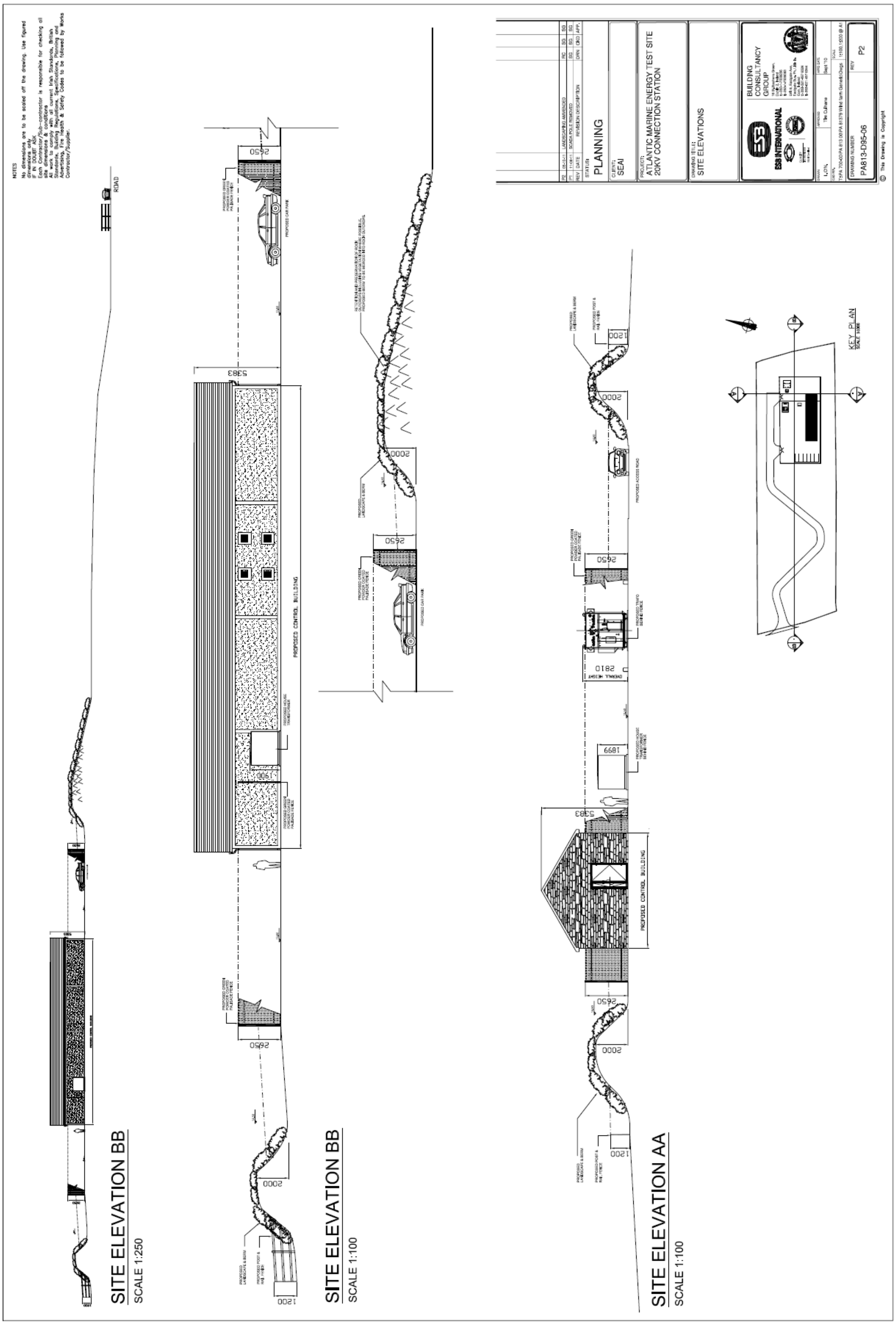


Figure 4-14: Plan and elevation of proposed substation control building

Figure 4-15: Quarter scale Wavebob WAB-PA device

Figure4-16 : Quarter scale Ocean Energy OWC device

Figure 4-17: Full scale Pelamis deployment WAB-A device

Figure 4-18: Full Scale Oyster during construction

Figure4-19: Belderra Strand, Belmullet Co. Mayo

Figure 4-20: Proposed location of temporary construction site

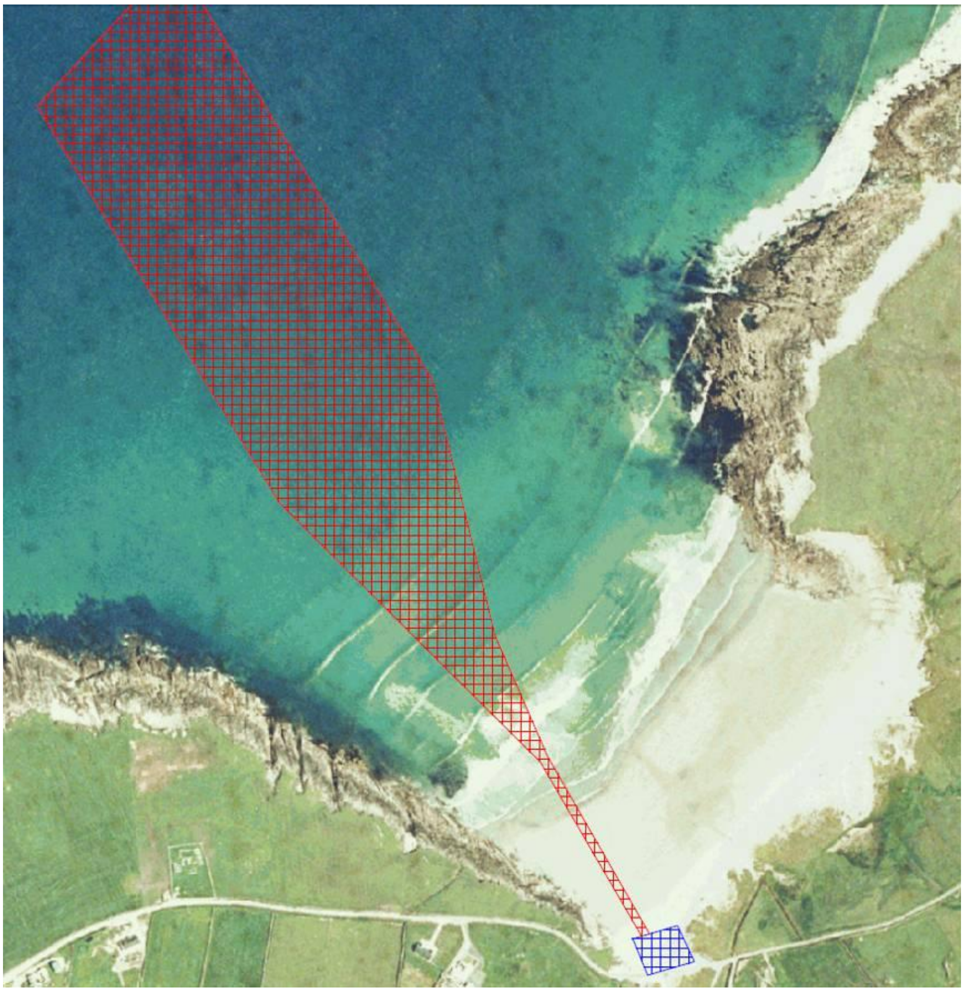


Figure 4-21: Proposed route of cable trench across Belderra Strand

Figure4-22: Typical horizontal directional drill

Figure 4-23: Shallow water cable deployment

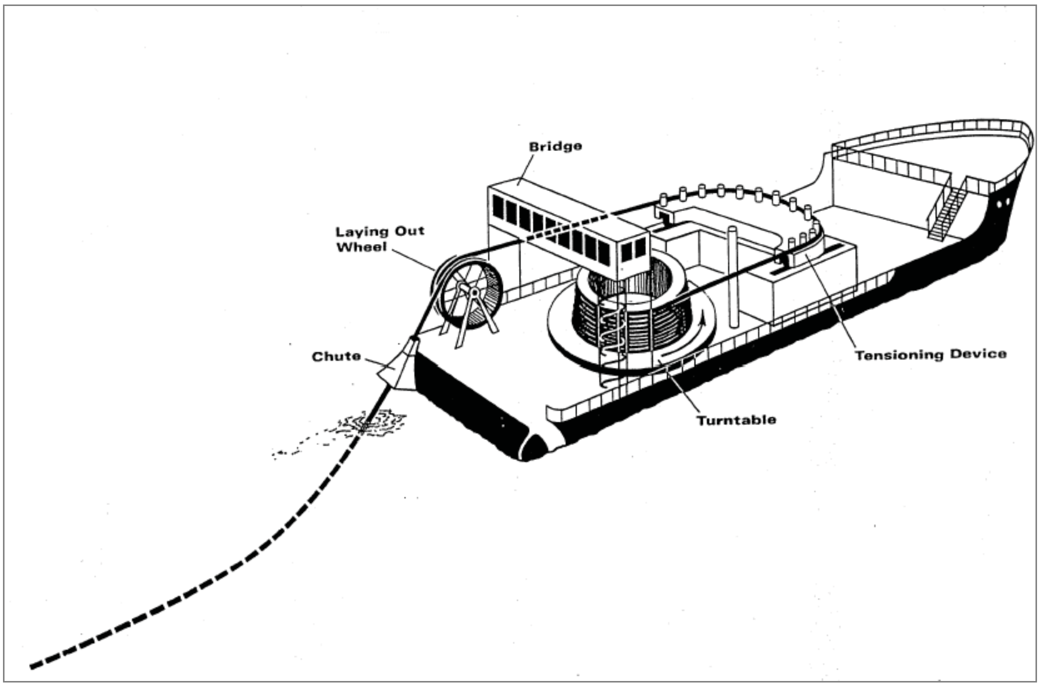


Figure 4-24: Sketch of typical cable lay vessel

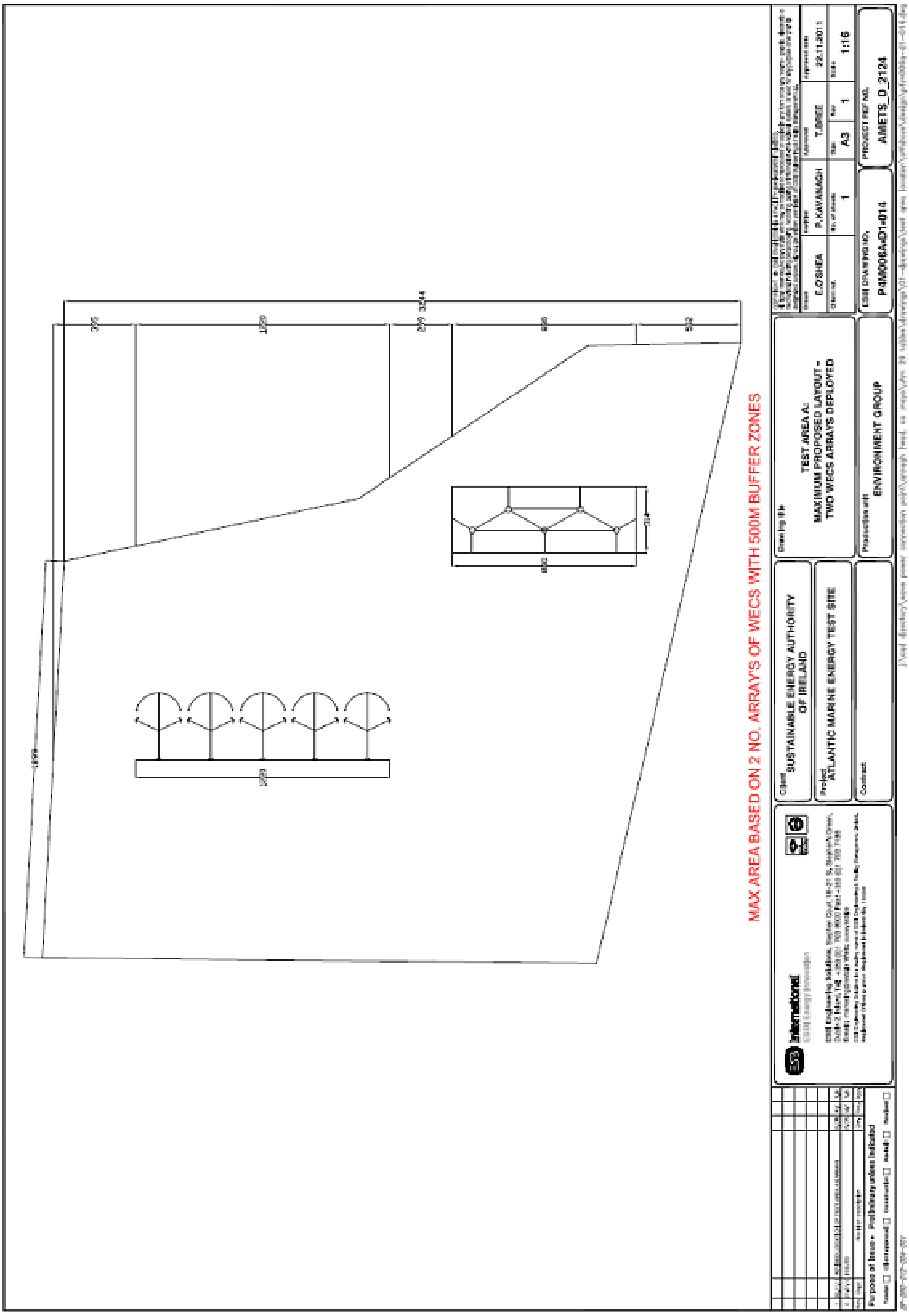


Figure 4-25: Test Area A with possible array layout

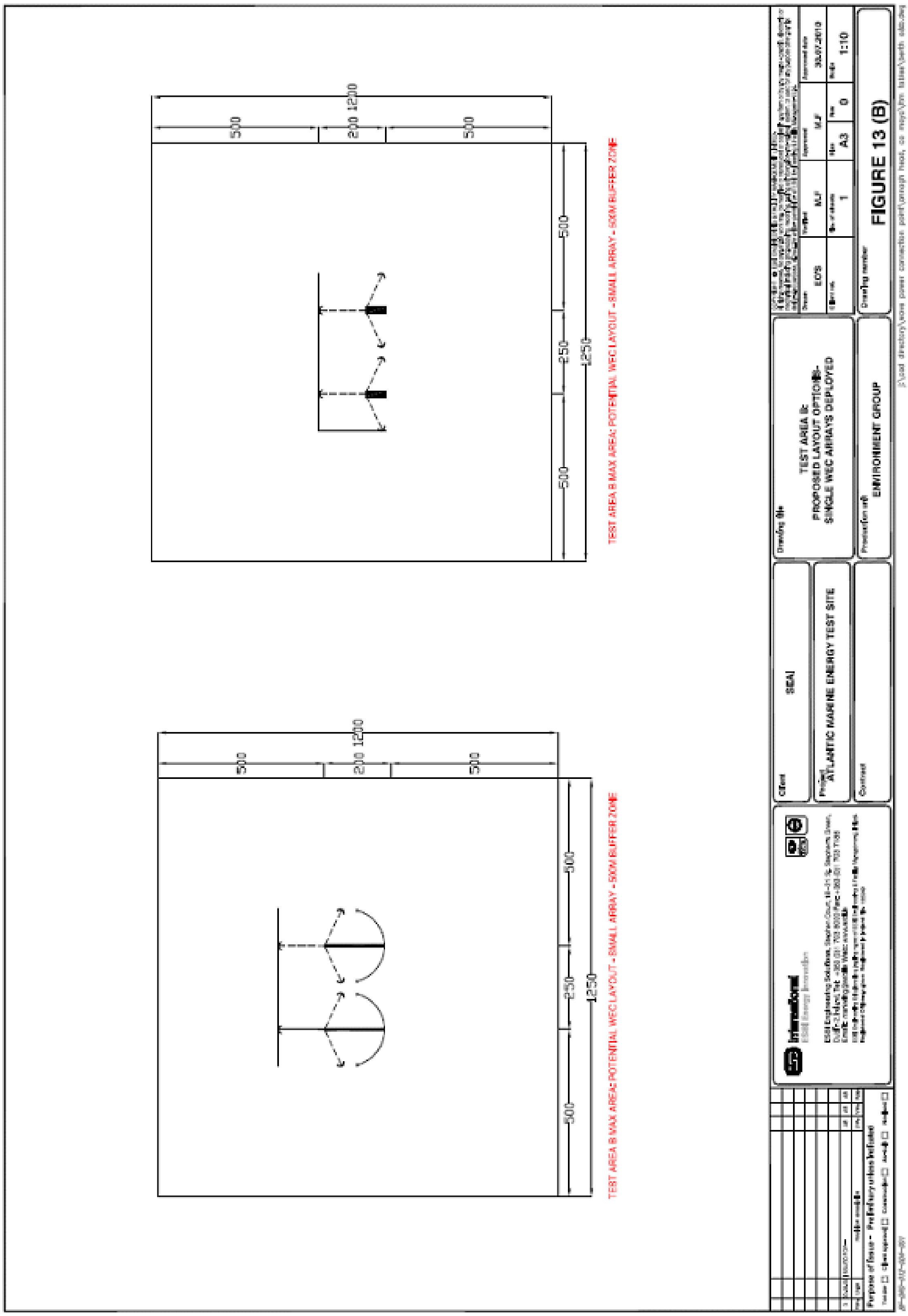


Figure 4-26: Test area B with possible array layout

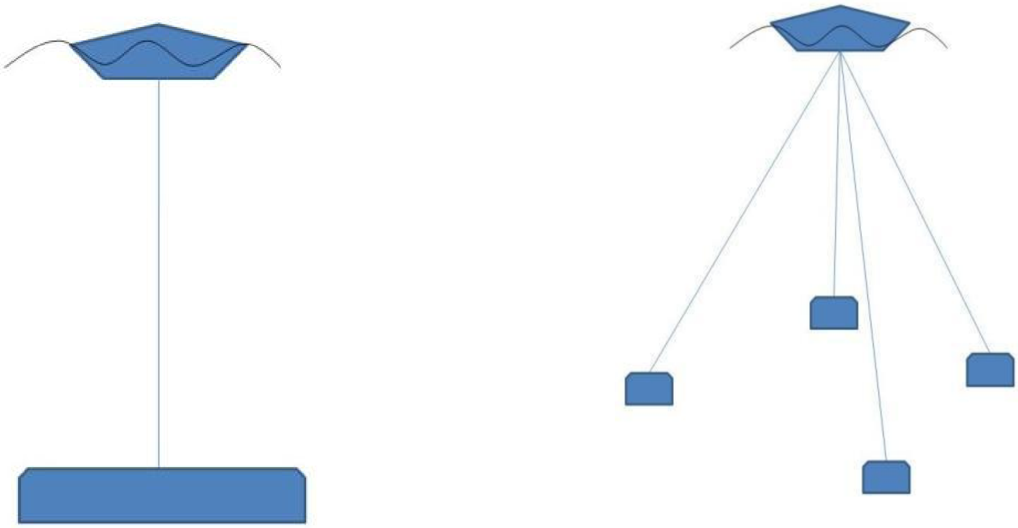


Figure 4-27:Typical single and spread mooring system

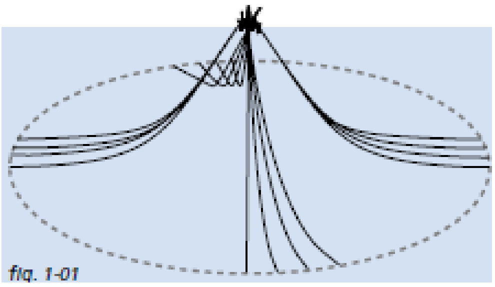


Figure 4-28: Example of catenary mooring system

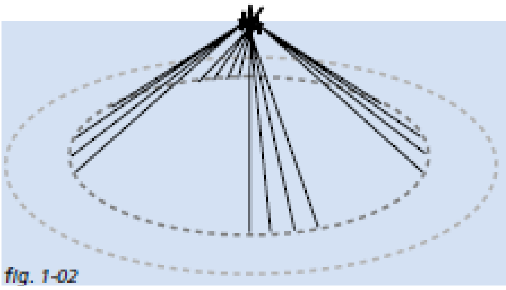


Figure4-29: Example of taut leg mooring system

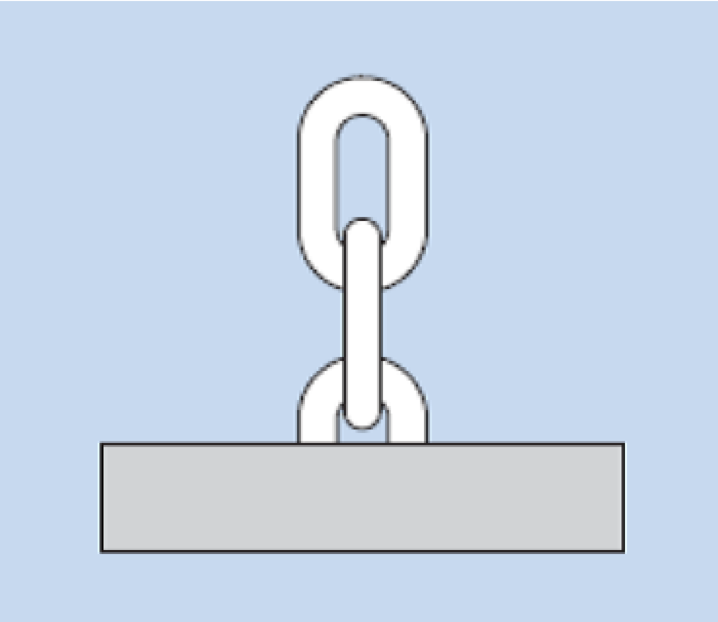


Figure 4-30: Sketch of typical gravitation anchor

Figure 4-31: Sketch of a drag embedment anchor

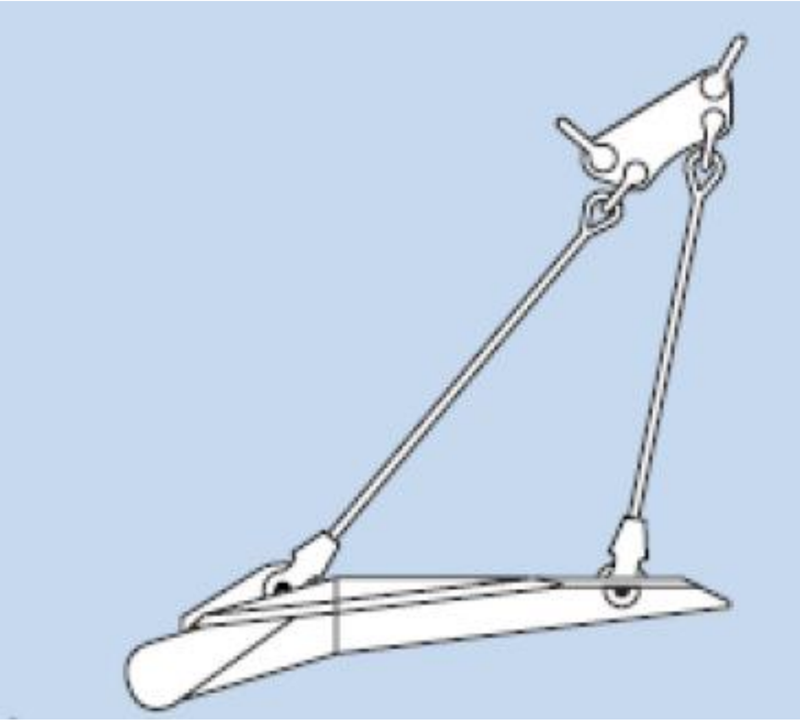


Figure 4-32: Sketch of a vertical load anchor

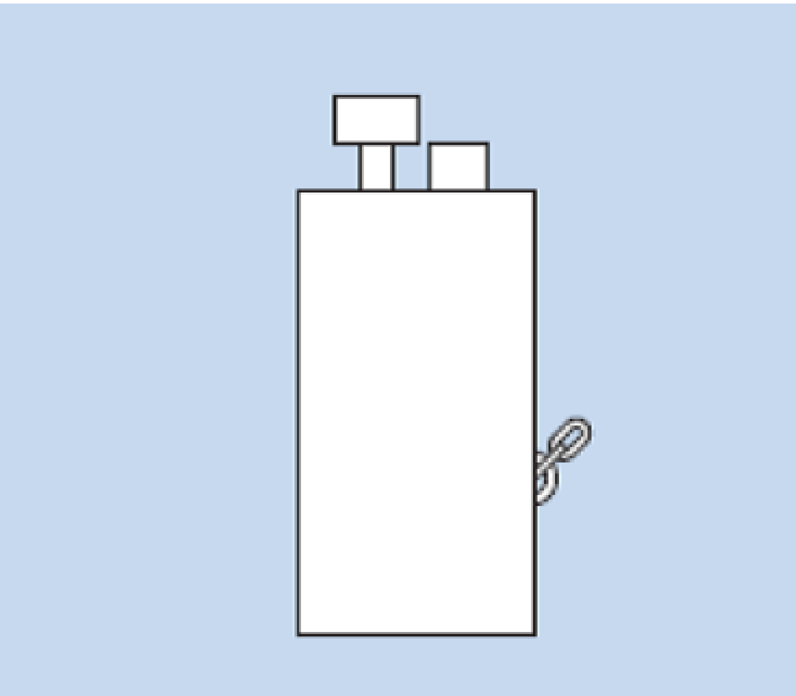


Figure 4-33: Sketch of a suction bucket anchor

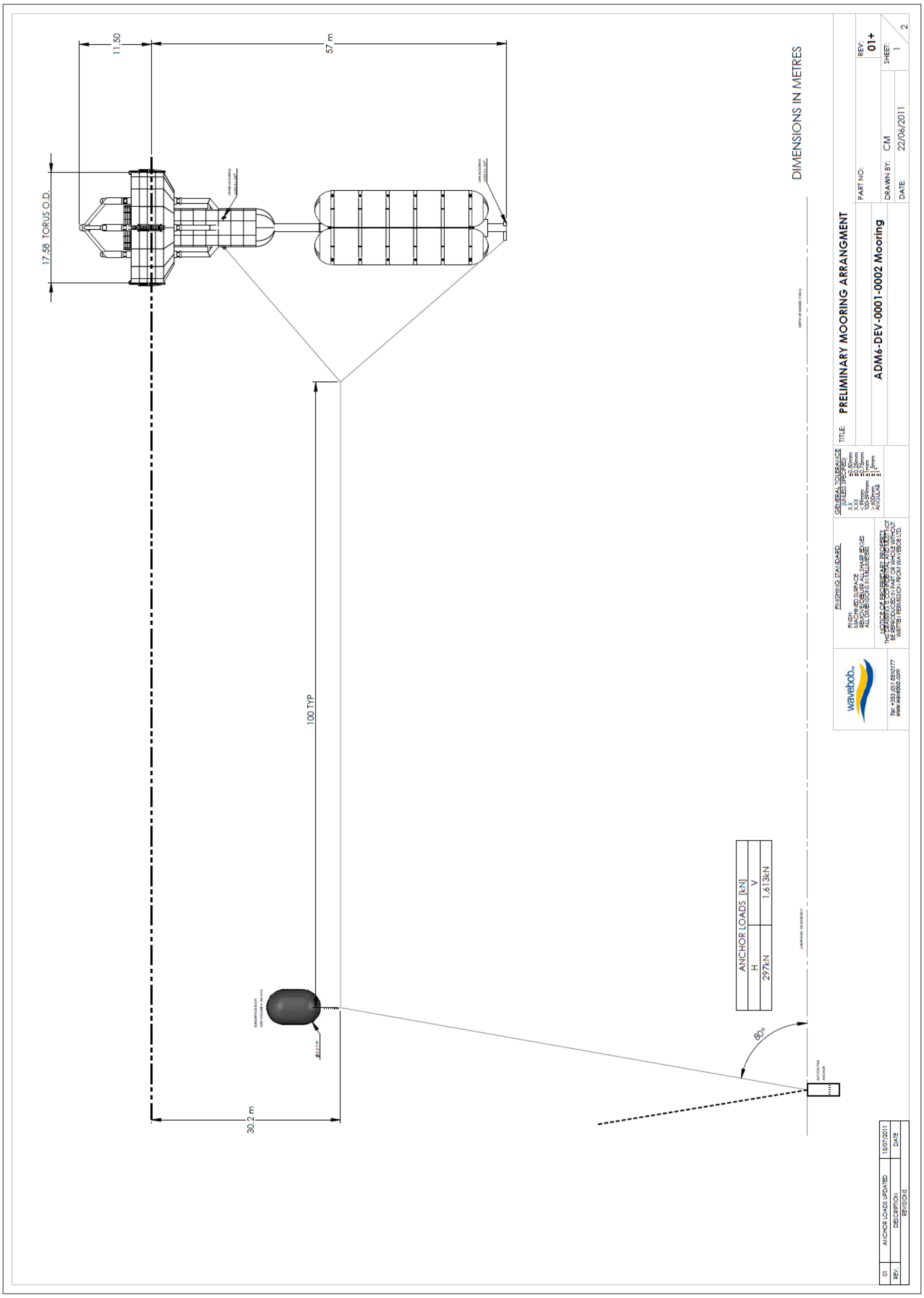


Figure 4-34: Possible Wavebob WEC mooring arrangement (courtesy of Wavebob)

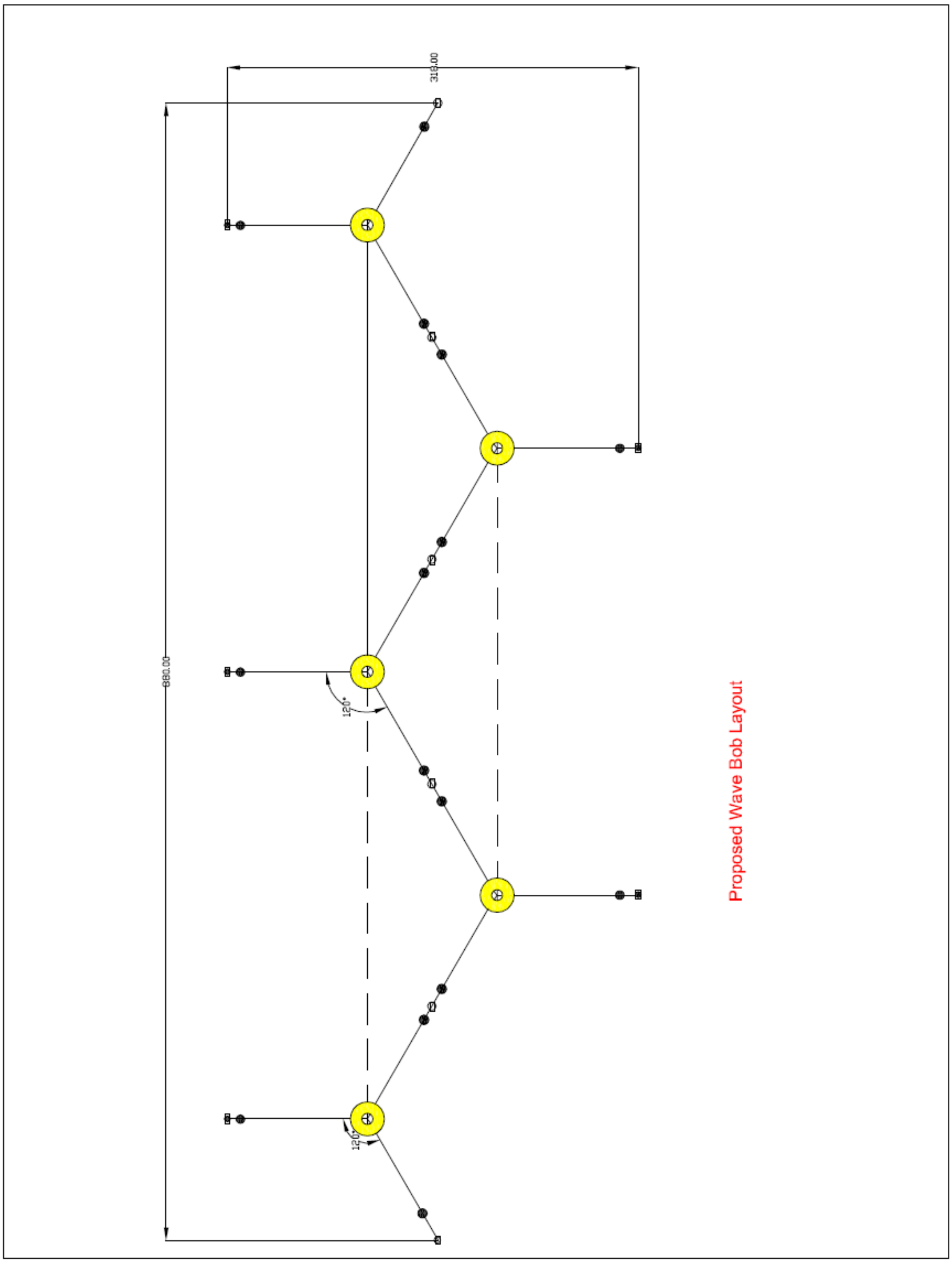
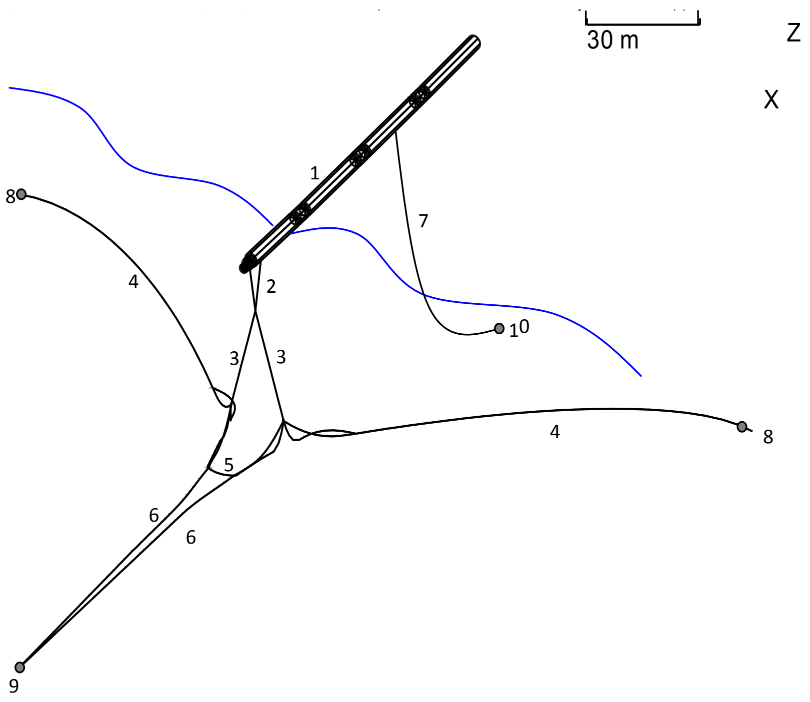


Figure 4-35: Likely Wavebob array



Component	Description
1	Pelamis P2 – 180m
2	Yoke
3	Tether lines
4	Rear lines – studlink chain, 130m long
5	Front connection line
6	Front lines – studlink chain, 140m long
7	Yaw restraint Line
8	Rear embedment anchors – 4T
9	Front embedment anchor – 7.5T
10	20T clump weight anchor

Figure 4-36: Possible Pelamis mooring system

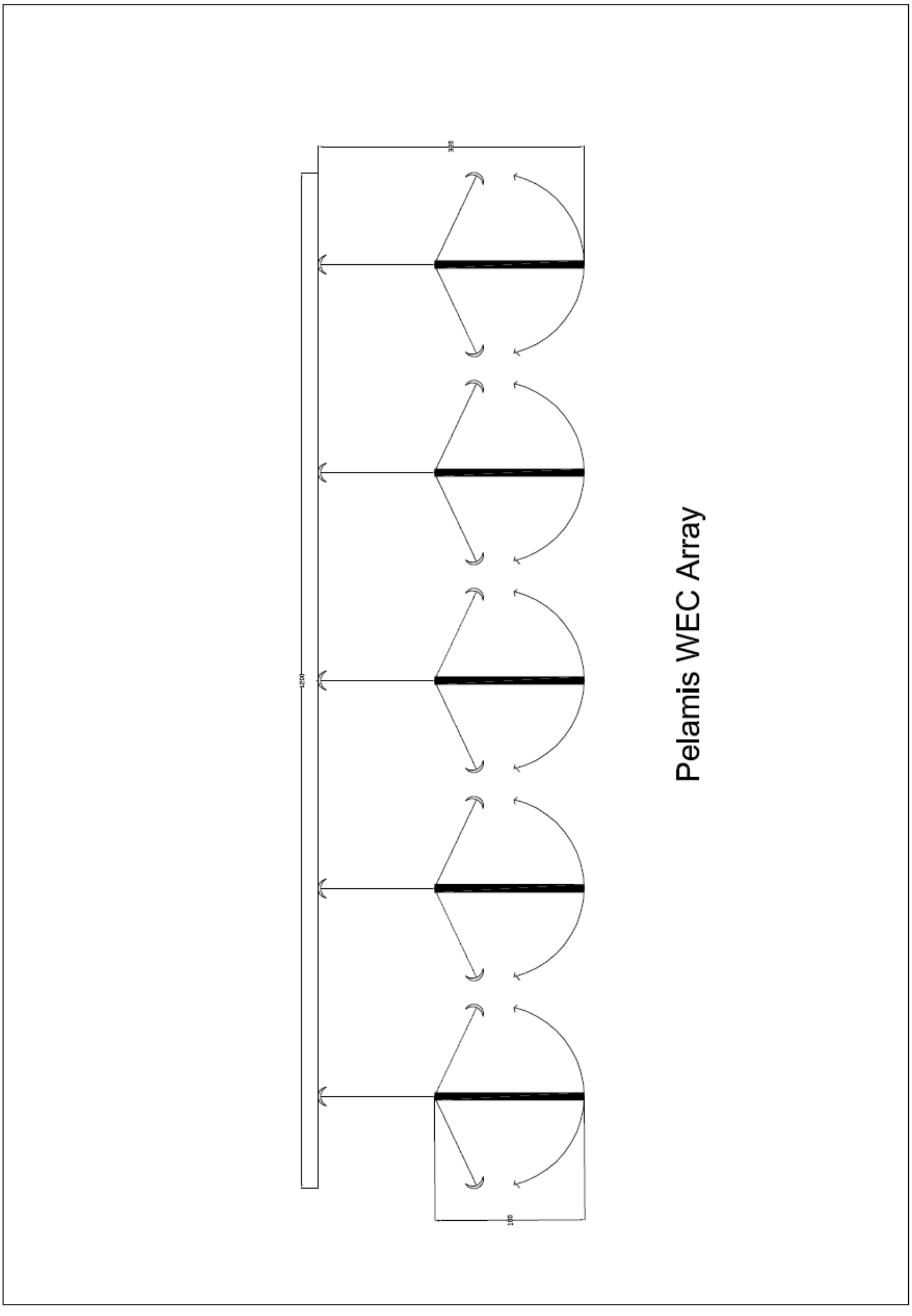


Figure 4-37: Likely Pelamis array configuration