

Arklow Bank Wind Park, Phase II

Cable Landfall: Feasibility Study

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Executive Summary

Project Background and Objectives

Sure Partners Ltd ('SPL'), a subsidiary of SSE Plc ('SSE') are investigating the engineering feasibility of progressing with the second phase (Phase 2) development of the off-shore Arklow Bank Wind Park ('ABWP') development, located on the Arklow Bank some 11.50km off the east coast of Ireland in the Irish Sea. This is in response to the success of the Phase 1 project co-developed by Airtricity and GE Energy, which is now owned and operated by GE Energy.

The export circuit will comprise of 2No. 220kV cables with each cable having a nominal Outside Diameter (OD) of 266mm. A representative cable data sheet is contained in Appendix A although the final cable details are unconfirmed at the date of issue.

Two potential cable landfall sites have been consented within the projects Foreshore Lease, termed the 'northern' and 'southern' landfalls.

Waterman Infrastructure & Environment Ltd ('WIE') have been appointed by SPL to undertake a Feasibility Study to determine suitable cable landfall methods, and the preferred landfall site, through a process of Options Appraisal.

The primary objective of the appointment is to establish the most appropriate cable landing technique for each landfall site and offer a recommendation on the preferred site. This shall be based on technical considerations only.

Engineering Assessment: Northern Landfall

Through a process of options appraisal Horizontal Directional Drilling ('HDD') is determined as the favoured technique for the cable landfall at the Northern Site.

Option	Advantages	Disadvantages
Open-cut Trench	Accuracy of installation operations. Generally of lower cost than Trenchless Techniques.	Steep cliffs (approximately 9m high) in conjunction with an exposed location susceptible to stormy sea conditions will preclude the use of open cut trenching. This option should be discounted from further consideration.
Micro-tunnelling / pipe jacking	Suitable for geological conditions. Accuracy of installation operations (vertical ±25mm horizontal ±100mm). Speed of installation operations. Minimum impact to environment. Pre-Cast Concrete sections installed with the advancing tunnel drive providing immediate shoring support Suitable for installation below groundwater level.	Typically, cannot be curved when drill length <1km. Typical maximum single drive of 300m to 500m (intermediate thrust jacking stations may be required). Relatively expensive. Temporary sheet piles required for Launch and Reception Pits.

Horizontal Directional Drilling	Suitable ground conditions. Minimum impact to environment. Reasonable accuracy of installation operations (+/- 1m to 2m horizontally dependant on geological conditions) Speed of installation operations Continuous monitoring and control during the operations	Additional space required for stringing out / laydown if required. Minor earthworks cut and fill required to create level area at proposed entry compound.
Direct Pipe	Suitable ground conditions. Minimum impact to environment. Accuracy of installation operations (vertical ±25mm horizontal ±100mm). Speed of installation operations.	Insufficient bending radii to account for topography / need to pass below cliff line. Temporary sheet piles required for Launch and Reception Pits.

Engineering Assessment: Southern Landfall

Through a process of options appraisal Direct Pipe is determined as the favoured technique for the cable landfall at the Southern Site.

Option	Advantages	Disadvantages
Micro-tunnelling / pipe jacking	Suitable for geological conditions. Accuracy of installation operations. Speed of installation operations. Minimum impact to environment. Pre-Cast Concrete sections installed with the advancing tunnel drive providing immediate shoring support Suitable for installation below groundwater level.	Typically, cannot be curved when drill length <1km. Typical maximum single drive of 300m to 500m (intermediate thrust jacking stations may be required). Relatively expensive. Temporary sheet piles required for Launch and Reception Pits.
Open-cut Trench	Accuracy of installation operations. Relatively Low Cost when compared to trenchless techniques.	Excavation required through erosion protection revetment requiring significant temporary works. Significant temporary works required on the foreshore. High risk of downtime due to exposed coastal location (storm damage to existing erosion protection revetment). Buried high voltage electrical cable (existing Arklow Phase 1 export cable) runs below the erosion protection revetment. Likely requirements for shallow groundwater control.

Horizontal Directional Drilling	Minimum impact to environment. Accuracy of installation operations Speed of installation operations Continuous monitoring and control during the operations	Unsuitable ground conditions (thick layer of granular deposits). Kentledge likely to be required within launch pits. Additional space required for stringing out / laydown if required. Disposal of potentially contaminated arisings.
Direct Pipe	Suitable ground conditions. Minimum impact to environment. Accuracy of installation operations. Speed of installation operations.	Limited bending radii to avoid existing/ proposed utilities along the route. Temporary sheet piles required for Launch and Reception Pits. Disposal of potentially contaminated arisings.

Conclusions and Recommendations

Northern Landfall

Through a process of Options Appraisal this study concludes that, on technical grounds only, the Northern Landfall site using a method of Horizontal Direction Drilling would be the preferred location and option for the cable landfalls.

The following recommendations are made in relation to developing detailed design of the northern cable landfall:

- A supplemental bathymetric survey should be completed, using suitable vessels with a low draught, to cover the data gap in the existing survey;
- A campaign of onshore and nearshore intrusive ground investigation is required;
- For the onshore ground investigation, it is considered that trial pits and cable percussive boreholes with rotary core follow-on would be required. All boreholes should be marginally offset from the proposed bore paths to avoid the creation of potential weak zones that may impact “frac-out”;
- Boreholes should be sunk to a minimum 5m below the proposed bore path depth;
- A suite of suitable laboratory testing should be completed, including rock strength testing and soils classification testing, with all results to be presented in a Ground Investigation Factual Report;
- For the nearshore ground investigation, it is considered likely that the extents of the geophysics completed to date have been limited by water depths and therefore further nearshore geophysics is not considered appropriate. It is recommended that the offshore ground investigation comprises cable percussive boreholes with rotary core follow-on, interspersed with CPTu data from a jack-up (or similar) barge in order to ascertain the ground conditions from the proposed exit point back to the beach/ base of cliffs; and
- Although accessible to farm traffic, due to the narrow nature of the access road (R750) it would be prudent to undertake a route study which includes a swept path analysis, a review of any culvert/ bridge crossings and overhead utilities.

Southern Landfall

The following recommendations are made in relation to developing detailed design of the southern cable landfall:

- A campaign of onshore and nearshore intrusive ground investigation is required;
- Prior to any site works a UXO contamination survey should be completed to clear all excavation positions. This should be undertaken by an experienced Explosives Engineer;
- UXO awareness briefing should be carried out for site workers by a suitably qualified UXO expert;
- For the onshore ground investigation, trial pits and cable percussive boreholes with rotary follow-on boreholes to prove

rockhead and gather soil samples. Groundwater and ground gas monitoring standpipes should be installed and monitored included as part of the ground investigation;

- A suite of suitable laboratory testing should be completed, including soils classification testing, rock strength, contamination testing and soil aggressivity testing (BRE SD1) all results to be presented in a Ground Investigation Factual Report;
- For the nearshore ground investigation, further nearshore geophysics should be completed utilising a shallow draft vessel.
- It is recommended that the offshore ground investigation comprises cable percussive boreholes with rotary core follow-on (if shallow rock is determined), interspersed with CPTu data from a jack-up (or similar) barge in order to ascertain the ground conditions from the proposed onshore/ offshore transition bay back to the coastal erosion revetment;
- Flood Risk Assessment (FRA) should be completed given the area is within a historic flood plain from the adjacent Avoca River;
- A Ground Penetrating Radar Survey is recommended to identify all utilities below any areas of excavation are and should include the revetment in order to identify the Arklow Phase 1 cable route.

1. Introduction

1.1 Scope and Objectives of Report

Sure Partners Ltd ('SPL'), a subsidiary of SSE Plc ('SSE') are investigating the engineering feasibility of progressing with the second phase (Phase 2) development of the off-shore Arklow Bank Wind Park ('ABWP') development, located on the Arklow Bank some 11.50km off the east coast of Ireland in the Irish Sea. This is in response to the success of the Phase 1 project co-developed by Airtricity and GE Energy, which is now owned and operated by GE Energy.

The export circuit will comprise of 2No. 220kV cables with each cable having a nominal Outside Diameter (OD) of 266mm. A representative cable data sheet is contained in Appendix A although the final cable details are unconfirmed at the date of issue.

Two potential cable landfall sites have been consented within the projects Foreshore Lease, termed the 'northern' and 'southern' landfalls.

The proposed northern landfall site is located approximately 5.0km northeast of the town of Arklow, close to Ennereilly Beach. The landfall area consists of undulating pasture fields located behind sea cliffs, of approximate 10m height, which fall down to a steeply sloping shingle beach.

The proposed southern landfall is located within the town of Arklow on a parcel of land to the north of the Avoca river, and immediately west of the coastline with the Irish Sea which is formed of a coastal erosion protection embankment at this location.

Waterman Infrastructure & Environment Ltd ('WIE') have been appointed by SPL to undertake a Feasibility Study to determine suitable cable landfall methods, and the preferred landfall site, through a process of Options Appraisal.

Under separate contract WIE have previously undertaken a Desk Study for the completion of a cable landfall by means of Horizontal Directional Drilling ('HDD') at the northern landfall. This is reported within WIE Report WIE12731-113-R-1-3-3, Arklow Bank Wind Park, Phase 2: HDD Desk Study, dated December 2018 [1].

WIE's current appointment includes a Desk Study for the southern landfall, which is reported in WIE Report LF100034-WIE16435-100-R-1-1-3, Arklow Bank Wind Park, Phase 2: Arklow Cable Landfall: Southern Site: Desk Study, dated December 2019 [2].

The findings of the above Desk Study reports are incorporated within this Feasibility Study, the objectives of which are set out below:

- Develop understanding of likely subsurface conditions from statutory data sources;
- Report on the findings of a Site Walkover Survey;
- Identification of hazards and constraints that may affect each cable landfall site;
- Production of a Geotechnical Risk Register;
- Options Appraisal of potential cable landfall techniques at each landfall;
- Development of Conceptual Designs including plans, long sections and indicative compound layouts;
- Documentation of design risk appraisal in support of the above, and presentation of Designers Risk Assessments;

- Conclusions outlining, on technical grounds, the preferred landing site and method; and
- Recommendations for further work required.

Notwithstanding the foregoing, the primary objective of the appointment is to establish the most appropriate cable landing technique for each landfall site and offer a recommendation on the preferred site. This shall be based on technical considerations only.

1.2 Limitations

The information contained in this report is based on 3rd party information sources, the accuracy of which WIE can accept no liability for.

The ground conditions presented are based solely on published information, examination of photographs and the findings of a Site Walkover Survey. Correspondingly, the conclusions presented in this study, including Conceptual Designs, are based on information available during the course of review and may require to be revised in light of additional information obtained from further investigations to be undertaken at both sites including intrusive ground investigation and laboratory testing.

Detailed consideration of ecological, cable rating impacts, environmental and archaeological constraints are beyond the scope of this report, which relates to a desk-based review of ground information to determine geotechnical ground risks and suitability of existing information supplemented with a site walkover.

WIE has endeavoured to assess all information provided to them during the course of this study, but makes no guarantees or warranties as to the accuracy or completeness of this information.

2. Data Correction

2.1 Geodetic Data

The topographical and bathymetric data sets used in the study were obtained in a variety of co-ordinate systems. All data sets have been converted to Irish Transverse Mercator (ITM) 1995 with ETRS89 Datum. Levels converted further to m AOD (Malin Head). The level conversions are presented in Table 1 below. The conversion factor between Chart Datum (CD) and Malin Head (OD) is -1.13m.

Lowest Astronomical Tide (L.A.T) is considered most relevant for offshore elements of the works, representing the minimum water depth and hence limiting the draught of offshore support vessels.

Table 1: Levels Conversion Table*

Arklow Harbour	Chart Datum (m CD)	Malin Head (m OD)
HAT	1.60	0.47
MHWS	1.40	0.27
MHWN	1.20	0.07
MSL	1.03	-0.10
MLWN	0.90	-0.23
MLWS	0.60	-0.53
LAT	0.20	-0.93

*From Admiralty Tide Table UK & Ireland, NP201B, Volume 1B, 2019, Page xxxix

3. Northern Landfall

3.1 Site Location and Description

The proposed northern landfall site is located approximately 5.0km northeast of the town of Arklow, in the Republic of Ireland, close to Ennereilly Beach and can be centred by an approximate Ordnance Survey Ireland Grid Reference N726779, E677108.

The boundary between the off-shore and on-shore works are defined by the high water mark, which is broadly in line with the Highest Astronomical Tide (H.A.T) level, located on the foreshore below steep coastal cliffs. For a trenchless technique, the proposed site compound is located within a field on flat agricultural land located behind the cliffs, to the west of the R750 single track road. The site location is shown in Figure 1.

Figure 1: Site Location



Imagery from Google Earth accessed 29/01/20

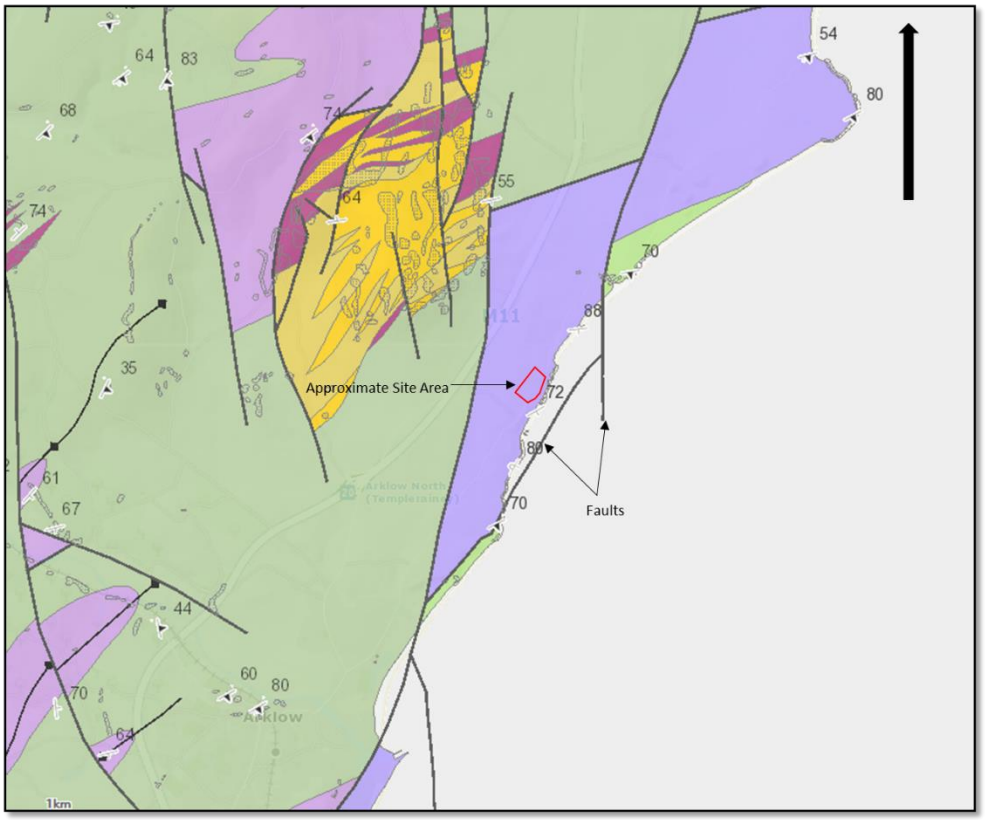
The field is at an elevation of approximately 15m Above Ordnance Datum (m AOD) and is roughly trapezoidal in shape with a length of approximately 250m and width of approximately 200m at the northern end narrowing to approximately 100m at the southern end. Access is provided by means of a gate, directly off the R750 which is a single-track road of around 4m in width. A pond is located in the north western corner.

The foreshore, located below the cliffs, comprises of sand and shingle storm beach deposits which overlie steeply dipping foliated metamorphic rocks. The rock outcrops at isolated locations on the foreshore and forms the cliffs which bound the foreshore to the west.

3.2 Geology

The Geological Survey of Ireland (GSI) interactive mapping tool [3] has been accessed to ascertain the geological conditions below site and the 1:100,000 scale geological map and accompanying memoir [4] purchased from GSI. An extract of the GSI map is presented as Figure 2. The map aligns with the information obtained from the 1:100,000 scale geological map. It should be noted that the geological memoir contains a sketch map which indicates the area around the site to be underlain by the Oaklands Formations consisting of red purple slate and siltstone. This is at odds with the GSI online mapping tool [3] and the accompanying geological map to the memoir. The memoir presents the geology in a regional context and as such the 1:100,000 geology map and GSI mapping tool [3] indicate a higher level of detail and should be given preference until actual conditions are confirmed through intrusive ground investigation.

Figure 2: GSI Geological Map Extract



Geological Survey Ireland (GSI) is free for use under the conditions of Creative Commons Attribution 4.0 International license.

3.2.1 Onshore

The foreshore and most of the land to the east of the R750 road is noted as bedrock with no superficial deposit. The land to the west of the R750 is recorded as being underlain by Irish Sea Till derived from lower Palaeozoic sandstones and shales. Beach areas to the north and south are noted as Marine Sand.

1: 100,000 scale mapping indicates the solid geology below site to consist of dark grey-blue grey slate, phyllite and schist of the Maulin Formation. Bands of siltstone, granite and orthoquartzite are also common.

Strike and dip information available from the geological map indicates that the Maulin Formation is very

steeply dipping (72° to 88°) to the south and southeast, which appears to be validated by review of photographs freely available on Google Maps [5] and further confirmed by a Walkover Survey reported within Section 3.

An anticline axis is located approximately 15km west of the site trending southwest to northeast. The Courtown – Tramore fault line, also trending southwest to northeast, is located approximately 25km to the south of site.

3.2.2 Offshore

The Marine Environmental Mapping Programme (MAREMAP) [6] was accessed in order to ascertain the nearshore geology which indicates Marine Deposits of silt, sand and gravel over Mudstone, Siltstone, Slate and Volcanoclastic igneous rock.

Two faults are shown off-shore to the east striking north - south approximately parallel to the shoreline at distances of 0.30km and 0.70km respectively. These are shown on the 1:100,000 scale geological map and are not in an area where seismic activity is considered a risk.

3.3 Historical Mapping

Historical mapping accessed through the GeoHive online mapping portal [7], has been reviewed and is presented in Table 1 below.

Table 2: Historic Mapping

Source	Site	Surroundings
1837 - 1842, 6 - Inch	Site consists of a single field of same shape and size as current field. A road is on shown on similar alignment to existing R750.	Three buildings to the south of site forming the hamlet Johnstown South.
1888 - 1913, 25 - Inch	Drainage channel shown along northern boundary and passing below road. Three ponds are indicated on the western field boundary. One pond is within the site boundary, one straddles the boundary and one is just beyond the site boundary.	No significant changes.
Latest Aerial Photography	The ponds appear to have been replaced with semi mature trees and vegetation however, the vegetation may just be obscuring the ponds.	More buildings in Johnstown South (approximately 9 in total).

3.4 Hydrology and Hydrogeology

3.4.1 Rainfall

Review of the “climate and weather” website [8] indicates the average total rainfall for Arklow is approximately 885mm per year with the lowest rainfall averages falling April to July.

3.4.2 Watercourses

No watercourses are visible on aerial photography however, the GSI interactive mapping tool [3] has been accessed to ascertain any surface water data at site. There is a stream shown to the north of site flowing west to east which discharges on Ennereilly Beach. Two streams are also located approximately 500m to the west of site, one flowing to the north and the other to the south.

A pond in the western portion of site is present as noted in Section 3.1.

3.5 Flood Risk

The National Flood Hazard Mapping resource for Ireland [9] was accessed and indicates that the site area is not at risk of flooding from rivers or the sea nor is there any historical records of past flooding at site.

3.5.1 Aquifers and Water Resources

The GSI interactive mapping tool [3] has been accessed to ascertain the information regarding the hydrogeology below site and confirms the following:

- The bedrock is a locally important aquifer which is moderately productive only in local areas;
- There are two groundwater extraction boreholes close to the site boundaries to the north and south, the locations are given as 327340,177640 and 326700,177130 respectively. It should be noted that the locational accuracy of the northern well is within 50m and the southern to within 1km. The distance from the site boundary is therefore difficult to ascertain but they could be within 50m of the site boundaries. The northern well was drilled in 1899 and the southern 1971. Both are noted as poor yield;
- It is not within a public supply protection area; and
- Groundwater vulnerability is low to extremely high (becoming lower towards the west of the R750, which is likely attributable to the fact that to the west of the R750 the superficial deposits are expected to be clay (low permeability) as opposed to the increasingly permeable beach deposits to the east).

3.6 Mining and Mineral Extraction

The GSI interactive mapping tool [3] was accessed to confirm any mineral or active quarrying occurrences below site. None are identified. The bedrock is not of coal bearing strata and as such underground coal mining is not considered a risk.

3.7 Contaminated Land

As the site has not been previously developed, any potential risk may be associated with unknown hazards or historical use. However, from the available information, the risk is currently considered low. This should be further assessed as part of an intrusive ground investigation.

3.8 Unexploded Ordnance

An Unexploded Ordnance (UXO) Pre-Desk Study Assessment has been undertaken by Zetica Ltd which concludes that a detailed desk study is not necessary in the case of the northern landfall (see Appendix B).

3.9 Archaeological Sites

The Irish National Monuments Service was accessed in order to access the Historic Environment Viewer [10]. There are no historic points of interest noted for site however it would be prudent for SPL to confirm any specific archaeological requirements or restrictions with the relevant local authorities prior to undertaking works.

3.10 Environmental and Ecological Consultation

Detailed consideration of environmental and ecological constraints is beyond the scope of this report. As part of subsequent design development and pre-construction works, a Construction Phase Environmental Management Plan (or equivalent) should be prepared and adhered to. However, an online search of the National Parks and Wildlife Service [11] website which includes links to National Heritage Areas, Special Areas of Conservation, Special Protection Areas, OSPAR Sites, National Parks and Nature Reserves did not indicate any conflicts within the site location. The Buckroney - Brittas Dunes and Fen area is, however, located approximately 500m north and is a Special Area of Conservation which extends north for a distance of some 8.50km.

3.11 Previous Ground Investigation and Interpretative Reports

Two previous ground investigation reports were downloaded through the GSI mapping tool [3] however, these were from sites between 3.5km and 4km north of site.

- GSI Report 1957: European Golf Clubhouse (approximately 3.8km north of site)
- GSI Report 6724: Brittas Bay Commercial/Residential (approximately 4.2km north of site)

The data contained within the reports is limited to basic soil strata descriptions and given the distances from site are of limited relevance.

Nonetheless, the closest historical borehole records available are located 3.8km to the north of site and were sunk in association with another ground investigation (GSI Report 1957: European Golf Clubhouse). Whilst of limited relevance to the site location, this indicates that rockhead is between 4.70m and 7.30m below surface and is overlain by clay. Similar conditions might be expected at the site location and should be confirmed through intrusive ground investigation.

3.12 Topography

Preliminary Digital Terrain Model (DTM) data was initially obtained through the Irish Ordnance Survey and incorporated into the AutoCAD Civil 3D model in order to progress initial outline designs.

A topographic survey was subsequently undertaken by Murphys Survey Ltd ('Murphys') to WIE's specification. The works comprised both land-based GPS surveying and aerial surveying using an Unmanned Aerial Vehicle (UAV). Land-based GPS methods were undertaken to an accuracy of ±25mm in the horizontal and ±10mm in the vertical for hard details and the UAV to an accuracy of ±50mm in the horizontal and ±75mm in the vertical. The survey works were undertaken between 9th and 20th December 2019. The UAV survey was undertaken in accordance with Irish Aviation Authority (IAA) rules and regulations with appropriate flight plans submitted by the UAV operator and utilising a suitable weather window. The land-based survey was undertaken following the UAV survey. The topographic data obtained by the survey updates the DTM data and has been used to inform Concept Design.

3.13 Bathymetry

Off-shore bathymetric survey data supplied by SPL from the consented cable route investigation

Ultrabeam Hydrographic, [12] (see Appendix C) and from GSI [3] has been incorporated with the topographic data acquired by Murphys in AutoCAD Civil 3D to form a combined seabed and topographical profile along the proposed bore path. The bathymetric data was captured from survey vessels and as such a near shore data gap of approximately 120m exists due to insufficient water depths for the draught of survey vessel employed.

3.14 Existing Infrastructure & Utilities

Existing infrastructure is limited to that associated with houses belonging to the hamlet of Johnstown at the junction of the R750 and the L95115, the two houses above Ennereilly Beach, and the R750 road (single track) itself. Copies of utilities plans obtained are presented in Appendix D and indicate no utilities the vicinity of the site, however overhead (possibly phone lines were identified during site walkover.

4. Site Walkover Survey (Northern Landfall)

The site walkover survey was undertaken on the 5th December 2019 by two engineers from WIE's geotechnical team. The primary purpose of the site walkover was to;

- Confirm the ground conditions as reported previously as steeply dipping Oaklands Formation;
- Obtain geological data such as the dip and dip direction of the bedding planes; and
- Identify and measure the trend lines of faults which may affect the proposed bore path.

Secondly there was a requirement to assess the suitability of an area of land for the provision of a site compound beyond the sea cliffs to the west of the R750 road.

The weather at the time of the survey was overcast, rainy and breezy. Temperatures were commensurate with the time of year.

The feasibility routes previously considered utilise two separate bays within the Northern site area as indicated on Figure 3.

Figure 3: Northern Site Location Plan indicating two considered bays



Imagery from Google Maps accessed 29/01/20

4.1 Foreshore Geology

Inspection of the foreshore cliffs was limited due to the absence of an accessible route in to either the northern or southern bays therefore structural geology measurements were obtained from outcrops immediately adjacent to the northern bay (see Figure 4).

The sea cliffs vary in height from approximately 3m in the northern bay up to around 10m in the southern bay (Figures 5 and 6).

From inspection of available outcrops, a thin layer or topsoil (up to 300mm) overlies Glacial Till of firm, reddish brown, slightly sandy gravelly Clay with occasional cobbles and boulders overlying bedrock of the Oakland Formation, of predominantly steeply dipping schist (see Figure 7).

A number of quartzite veins were present within the schist (see Figure 8) at the outcrop exposure to the

north and were also visible in the northern and southern bays. A probable igneous intrusion was visible in the southern bay (possibly rhyolite), which are visible due to differential erosional rates and colour change, unfortunately, due to the height and steepness of the cliffs, it could not be inspected in detail (see Figure 9).

Figure 4: Rock outcrops from adjacent land to northern bay (looking east)



Figure 5: Northern bay sea cliffs (≈3m height) looking south



Figure 6: Southern bay sea cliffs (≈10m height) looking north



Figure 7: Ground composition identified from adjacent land to northern bay (looking southwest)



Figure 8: Quartzite veins seen from adjacent land to northern bay (looking west)



Figure 9: Potential igneous intrusions seen within southern bay (looking north)



4.2 Structural Geology

The schist bedrock typically dips towards the south and southeast at between 70° and 90° although due to folding within the rock structure there is potential for further variation. A secondary fracture set was mapped further north towards Ennereilly Beach as northwest at 20°.

A number of minor faults were noted trending in a north easterly direction close to vertical (see Figure 10) with a number of small cross cutting faults noted trending in a southerly direction (see Figure 11). Larger faults may exist in the cliff faces however, due to the inaccessible nature of the bays this could not be confirmed.

A cave was noted in the southern bay and is estimated to be 1.5m wide and 1m high (see Figure 12).

Figure 10: Minor faults identified near to northern bay (looking north)



Figure 11: Small cross cutting faults near to northern bay (plan view)



Figure 12: Cave seen within the southern bay (looking south)



4.2.1 Proposed Compound Area

The proposed compound area consists of two undulating grazing fields bounded to the north, west and south by hedgerows and to the east by the R750 road. The fields are separated by a west to east flowing burn edged with hedge rows (see Figure 13). The fields were very wet underfoot at the time of inspection.

Each field is accessible via gates from the R750 (see Figures 14 and 15) and is of suitable size for the construction of a site compound however due to their undulating nature it is likely that some levelling

works may be required (see Figure 16) comprising of minor earthworks cut and fill.

Figure 13: Watercourse running in between the two fields



Figure 14: Access gate to northern field (looking southwest)



Figure 15: Access gate to southern field (looking east)



Figure 16: Undulating fields (taken from southern field looking north)



5. Conceptual Geological Model (Northern Landfall)

From the information obtained by Desk Study review and the Site Walkover Survey, a conceptual ground model has been developed.

5.1 Onshore Conceptual Ground Model

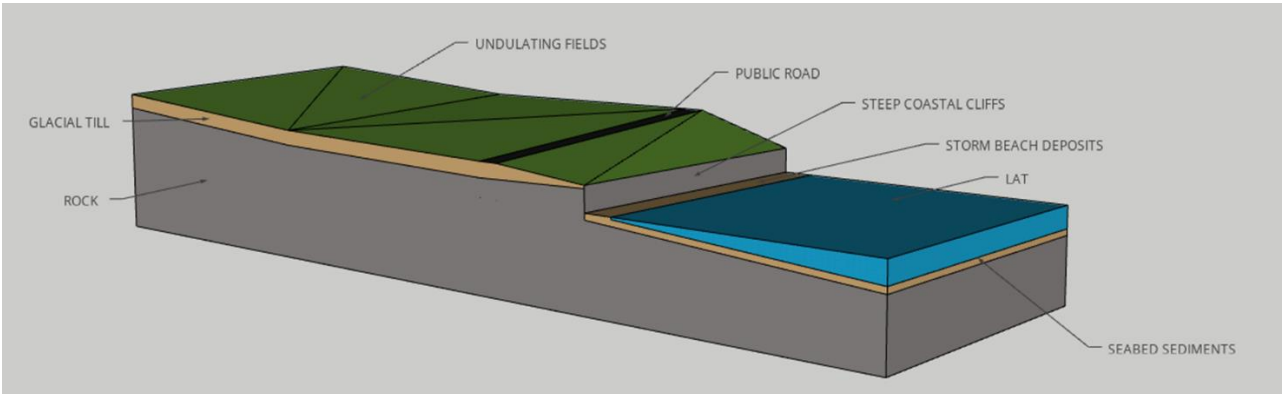
Table 3: Conceptual Landfall Geological Model

Stratum	Area Covered	Estimated Thickness	Typical Description
Topsoil	West and East of R750	0 – 0.30m	Topsoil
Glacial Till	West and East of R750	3.00 – 10m	Sandy gravelly Clay
Beach Deposits	East of R750	0.00 – 5.00m	Gravelly Sand
Maulin Formation	Entire Site	Unknown	Slate, Phyllite & Schist with bands of orthoquartzite, siltstone and granite

The thicknesses tabulated above are estimated from available exposures and will require to be confirmed through intrusive ground investigation.

A schematic ground model is presented in Figure 17 below.

Figure 17: Northern Landfall: Schematic Ground Model



5.2 Offshore Conceptual Ground Model

Drawing No. UHC19004-REV00-05, as presented in the Ultrabeam Hydrographic [12] report, shows the interpreted geophysics around the area of the consented cable route junction and proposed punch out location. This indicates approximately 1.50m of Sand is expected to sit above approximately 2.00m of Till which sits on rockhead. This therefore indicates a maximum sediment thickness in the order of 3.50m but would require to be confirmed through intrusive ground investigation.

6. Geotechnical Risk Register (Northern Landfall)

6.1 Geotechnical Risk Evaluation Matrix

Based on information available, a specific review of the geotechnical risks associated with the landfall installation works has been undertaken and the risks evaluated using a risk evaluation matrix.

The risk register, detailed in the following tables, lists the anticipated ground hazards associated with the works and the associated consequences of those hazards in order to determine the level of risk presented. The risk before control of the hazard has been assessed quantitatively and following the implementation of specific control to each risk. The register should remain a 'live' document, updated as construction works progress.

The level of risk is calculated to be up to a value of 25 (Critical Risk). The maximum value can be reduced to 5 (Medium Risk) and with implementation of the recommended controls during construction may be reduced further.

Probability (P) x Impact (I) = Risk Rating (R)

PROBABILITY OF OCCURRING		IMPACT ON PROJECT COST / PROGRAMME
Very Likely	5	Substantial (>50% Cost/ Programme increase)
Likely	4	High (30% to 50% Cost/ Programme increase)
Probable	3	Moderate (10% to 30% Cost/ Programme increase)
Unlikely	2	Minor (< 10% Cost/ Programme increase)
Highly Unlikely	1	Negligible (0% Cost/ Programme increase)

PROBABILITY (P)	IMPACT (I) 5	4	3	2	1
5	25	20	15	10	5
4	20	16	12	8	4
3	15	12	9	6	3
2	10	8	6	4	2
1	5	4	3	2	1

1 to 4	Low Risk
5 to 10	Medium Risk
11 to 16	High Risk
≥ 17	Critical Risk

Geotechnical Risk Register

Arklow Northern Landfall										
No	Hazard	Consequence	Risk before Control			Recommended Mitigation Measures to be implemented	Risk after Control			Comments
			P	I	R		P	I	R	
1	No ground investigation data available for any part of the site with the exception of geophysics.	No rock strength data, high strength rock may impact entry angles due to the tendency of the HDD to skip over the hard surface after drilling through the soil. Potential for igneous intrusions which could impact on steering and progress due to changing rock strengths. Encountering unforeseen ground conditions and incorrect design leading to impact on progress, programme and costs. Bore path may need to be abandoned and re-drilled leading to programme and cost impacts. Potential for “Frac-out” to occur leading to programme and cost impacts. Damage/ environmental incident	5	5	**25**	Ground investigation must be undertaken to sufficient depth across the site ensuring robust design. This should include both onshore and nearshore investigation.	2	5	**10**	

Arklow Northern Landfall										
No	Hazard	Consequence	Risk before Control			Recommended Mitigation Measures to be implemented	Risk after Control			Comments
			P	I	R		P	I	R	
2	Unknown thickness and composition of marine sediments.	Encountering unforeseen ground conditions and incorrect design leading to impact on progress, programme and costs. Bore path may need to be abandoned and re-drilled leading to programme and cost impacts. Depending on offshore sediment thickness drilling from offshore to onshore may be required. Potential for "Frac-out" to occur leading to programme and cost impacts. Damage/ environmental incident	5	5	**25**	Further investigation required through nearshore GI including boreholes and tight grid of CPT's at proposed punch-out.	2	5	**10**	
3	Very steeply dipping rock strata in cliff face and outcropping around beach.	Potential for "Frac-out" to occur along foliation planes leading to programme and cost impacts. Damage/ environmental incident.	4	5	**20**	Ground investigation required to investigate rock at depth. Ground investigation to include detailed rock mapping, such as downhole CCTV, to accurately record and map all discontinuities.	2	5	**10**	
4	Offshore geological faults approximately 300m and 700m from the shore.	Potential for "Frac-out" to occur along fault planes leading to programme and cost impacts. Damage/ environmental incident.	4	5	**20**	Design route to exit before faults, if possible, so as to mitigate risk of frac-out / bore collapse associated with heavily brecciated fault rock.	2	5	**10**	

Arklow Northern Landfall										
No	Hazard	Consequence	Risk before Control			Recommended Mitigation Measures to be implemented	Risk after Control			Comments
			P	I	R		P	I	R	
		Potential for chocking / collapse of bore in unstable rock.								
5	Risk of 'break-out' of HDD due to incorrect cover levels at base of beach cliffs.	Impact to progress, with programme and cost increases. Damage / environmental incident. Bore path may need to be abandoned and re-drilled leading to programme and cost impacts.	4	5	20	Additional topographic survey completed over the compound and foreshore areas providing data required to undertake outline design. Further nearshore bathymetric survey required.	2	5	10	Final hydro-fracture calculations to be undertaken using ground parameters to be confirmed through ground investigation.
6	Public Utilities	Risk of death or injury. Potential costs and programme impacts.	5	5	25	Initial utilities search completed as part of Concept Design. Up to date enquires to be submitted at Construction Stage. Any contractors employed on site should undertake their own searches and satisfy themselves that all utilities have been identified and cleared.	1	5	5	Utility plans should be updated every 3 months. Private landowners should be approached for details of any private utilities.
7	Extraction Wells	Contamination of drinking water resource.	4	5	20	Undertake detailed hydrogeological investigations.	1	4	4	
8	Potential for UXO unknown.	Risk of death or injury. Programme delays and cost increases.	3	5	15	Specialist UXO pre desk study has been undertaken and risk considered Low.	1	5	5	Risk after UXO Desk Study completed is Low.
9	Shallow Groundwater	Temporary works stability. Influence on HDD duct design (buoyancy).	3	4	12	No groundwater monitoring information to date. Groundwater monitoring rounds required as part of Ground Investigation to appreciate long term groundwater	1	4	4	

Arklow Northern Landfall										
No	Hazard	Consequence	Risk before Control			Recommended Mitigation Measures to be implemented	Risk after Control			Comments
			P	I	R		P	I	R	
						levels and variances, and hence allow consideration within design.				
10	Contaminated Soils	Health risk to construction personnel. Increased disposal costs of any materials going off-site.	3	3	**9**	Ground Investigation and testing required.	1	3	**3**	
11	Aggressive Soils	Sulphate attack on buried concrete.	3	3	**9**	Ground investigation undertaken with appropriate testing to BRE SD1	1	3	**3**	

7. Southern Landfall

7.1 Site Location and Description

Three main site areas were initially considered, however two were quickly discounted at an early stage of the study:

- Due to the proposed Waste Water Treatment Works already securing planning permission, together with likely utility interfaces and lack of existing working space this area was discounted.
- A brownfield area to the north of the proposed Waste Water Treatment Works was considered however, it was understood from SPL that no agreement was in place for access to this parcel of land as planning permissioned was granted 5th April 2019 under application number 19368 for the construction of a 3 storey office building with associated roads, car parks and areas of soft landscaping.

In comparison, the existing large, open, and flat area occupied by a public running track and with an existing access route is preferable. This location also maximises the distance between the cable landfall location and outfall of the Avoca River, where active scour of sediments is more likely.

The proposed southern cable landfall site is located approximately 400m to the northeast of Arklow town centre, in County Wicklow, to the north of the Avoca river, and can be centred by an approximate Ordnance Survey Ireland Grid Reference N725173, E673568.

The site is bordered by the Irish Sea to the east, with a prominent coastal erosion protection embankment forming the coastline at the site location.

The boundary between the off-shore and on-shore works are defined by the high-water mark, which is broadly in line with the Highest Astronomical Tide (H.A.T) level, located on the foreshore below the coastal erosion revetment. The proposed cable landing site is located on an area of flat playing fields used as a running track, which sits behind and to the west of the coastal erosion revetment. The site location is shown in Figure 18.

Figure 18: Site Location



Imagery from Google Earth accessed 29/01/20

The landfall site lies at an elevation of approximately 2m (m AOD) and is approximately trapezoidal in shape, having a length of approximately 150m and width of 250m at the southern end which narrows to approximately 140m at the northern end. Access can be gained directly from Seaview Avenue which forms the northern site boundary.

7.2 Geology

The Geological Survey of Ireland (GSI) interactive mapping tool [3] has been accessed to ascertain the likely geological conditions below site, together with a review of British Geological Survey (BGS) Geological map 1:63,360 Arklow Sheet 139 Solid with Drift Edition (1901) [4].

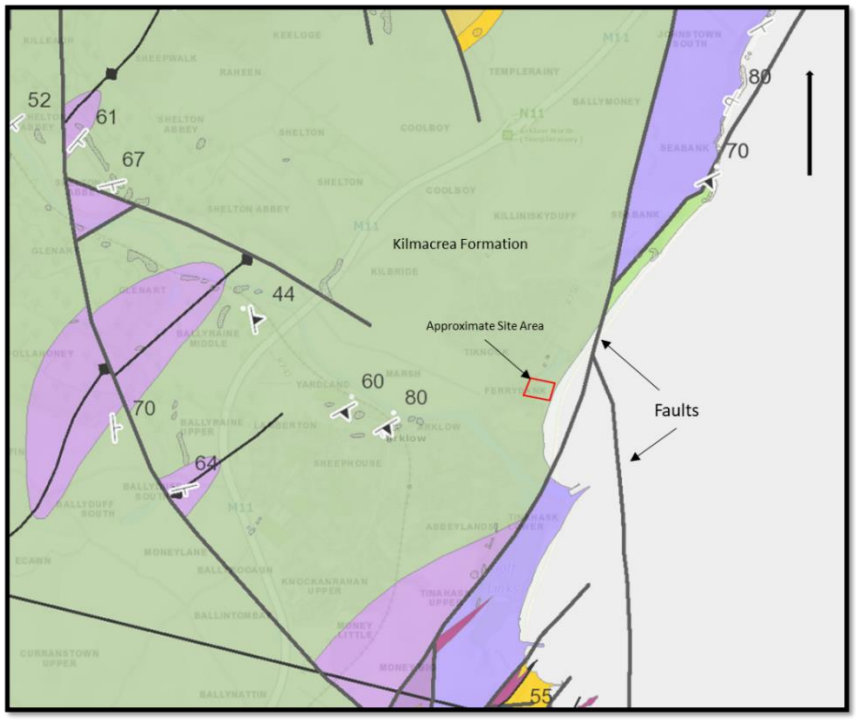
7.2.1 On-shore

Historically, the site area consisted of sand dunes and the flood plain and tributaries of the Avoca River (1840) and therefore although not mapped, a significant thickness of alluvial deposits are expected to be present below site. Mapping from around 1909 suggests that the site area is marshland, commensurate with alluvial deposits being present.

The GSI mapping tool [3] indicates that the site is underlain by Made Ground, which would be expected given its town centre location and various phases of historical development.

GSI 1: 100,000 scale mapping [3] indicates the solid geology below site to consist of the Kilmacrea Formation, which typically consists of dark grey slate, with minor pale sandstone (see Figure 19). It would be expected that this may lay at some depth, with the Avoca River channel creating a localised channel feature in the rockhead profile. This would however need to be confirmed by further surveys including intrusive ground investigation.

Figure 19: GSI Solid Geology Online Viewer Excerpt



Geological Survey Ireland (GSI) is free for use under the conditions of Creative Commons Attribution 4.0 International license.

Review of the GSI mapping tool [3], confirms that the closest historical borehole records available are located 450m south of Site. These records only state that bedrock was not met when drilling stopped at approximately 20m bgl but no indication of the ground composition was noted.

7.2.2 Off-shore

MAREMAP [6] was accessed in order to ascertain the nearshore geology which indicates Marine Deposits of silt, sand and gravel over Mudstone, Siltstone, Slate and Volcanoclastic igneous rock.

Two faults are shown off-shore to the east striking north - south approximately parallel to the shoreline at distances of 270m and 560m respectively. These are shown on the 1:100,000 scale geological map and are presented in Figure 18 above.

In addition, a Waste Water Treatment Works (WWTW) outfall pipe ground investigation was undertaken between 29th August and 7th November 2017 and is discussed further in Section 7.10.

7.3 Historical Mapping

Historical mapping accessed through the GeoHive online mapping portal [7], has been reviewed and is summarised in Table 3 below.

Table 4: Historic Mapping

Source	Site	Surroundings
1840 Historic 6" first edition B&W sheet	Site consists of sand dunes, with a watercourse running north south through the centre of Site.	South of Site is the Avoca river. South west of site, across the river is original town of Arklow. North of Site is agricultural land.
1909 Historic 25" maps	Site is part of the Kynoch munitions factory. Magazine huts are indicated, a tramline running north south is also indicated.	South of Site is a chemical works associated with the munitions factory and tramline, hydraulics pumps are also indicated which are likely associated with transporting chemicals though underground pipes. South west of site is the town of Arklow. West of Site (north of the river) is housing associated with the expansion of Arklow. North of Site is Explosive Works, Brick and Tile Works and a children's play park
Aerial Photography (2005)	Playing fields, with athletic running track. Coastal path runs north south along coast.	Southern boundary of Site now has a road running parallel, Mill Road. Beyond this is housing and abandoned buildings from the previous chemical works. West of Site is a construction site, for the construction of Bridgewater Shopping Centre. North of Site is a sport centre associated with the playing fields and running track. Public car park, housings and Arklow Bay Hotel.

7.4 Hydrology and Hydrogeology

7.4.1 Rainfall

Review of the "climate and weather" website [8] indicates the average total rainfall for Arklow is approximately 885mm per year with the lowest rainfall averages falling April to July.

7.4.2 Watercourses

No watercourses are present on-site however the Irish Sea is located on the eastern site boundary and the Arklow duck pond is located adjacent to the northern site boundary. The Avoca River is located 350m to the south of site flowing in a west to east direction.

7.4.3 Flood Risk

The National Flood Hazard Mapping resource for Ireland [9] was accessed and indicates that the site area is within the flood extents of the Avoca River, with one flood event recorded in August 1986.

7.4.4 Aquifers and Water Resources

The GSI interactive mapping tool [3] has been accessed to ascertain the information regarding the hydrogeology below site and confirms the following:

1. The bedrock is a locally important aquifer which is moderately productive only in local areas;
2. A locally important gravel aquifer is present in the approximate western half of Site;
3. There are four groundwater extraction boreholes indicated to be within 2km of the site, however their specific locations are not provided. Three of the wells were drilled in 1996 with the other in 1983. The yield class is noted as moderate for three wells and good for one well;
4. The site is not located within a Drinking Water Protection Area; and
5. Groundwater vulnerability is low.

7.5 Mining and Mineral Extraction

The GSI interactive mapping tool [3] was accessed to confirm any mineral or active quarrying occurrences below site. None are identified. One historic quarry is located approximately 450m north of Site. The likelihood of mining is deemed as negligible given the published geological information records geology which is not coal bearing and is unlikely to contain significant mineral reserves.

7.6 Contaminated Land

As the Site was part of the Kynoch Munitions Factory, with an associated chemical works, there is a moderate potential that pockets of contamination may exist on site. This can only be confirmed through ground investigation and an appropriate programme of laboratory testing.

7.7 Unexploded Ordnance

A Pre-Desk Study Assessment completed by Zetica Ltd recommended that a further detailed UXO Desk Study be completed. WIE subsequently appointed Zetica to undertake a detailed UXO Desk Study, a copy of which is presented in Appendix B and summarised below.

The assessment identified that the Kynoch Munitions Factory, established in 1895 and which was located 200m south of site, manufactured large quantities of explosives until shortly after WWI. The proposed Site area itself had no manufacturing processes present however had tracks running through it for transportation of explosives between buildings associated with the factory. Furthermore, several bombing runs by the Luftwaffe between August 1940 and July 1941 within the Republic of Ireland have been identified with 2 No. High Explosive bombs being recorded to have fallen on Arklow.

Zetica therefore recommend that the site be considered medium risk of UXO contamination.

Consideration should also be given to the marine environment, for both UXO's and military wrecks on the seabed. Any intrusive or construction works, including ground investigation, would have to take due allowance of the medium risk potential for UXO contamination with appropriate controls in place.

7.8 Archaeological Sites

The Irish National Monuments Service was accessed in order to access the Historic Environment Viewer [10]. There are no historic points of interest noted for site however it would be prudent for SPL to confirm any specific archaeological requirements or restrictions with the relevant local authorities prior to undertaking works.

7.9 Environmental and Ecological Consultation

Detailed consideration of environmental and ecological constraints is beyond the scope of this report. As part of subsequent design development and pre-construction works, a Construction Phase Environmental Management Plan (or equivalent) should be prepared and adhered to. However, an online search of the National Parks and Wildlife Service [11] website which includes links to National Heritage Areas, Special Areas of Conservation, Special Protection Areas, National Parks and Nature Reserves did not indicate any conflicts with the site location.

7.10 Previous Ground Investigation and Interpretative Reports

Two previous onshore ground investigation reports were downloaded through the GSI mapping tool [3] however, these were from sites 450m south and 1.7km west of site respectively.

- GSI Report 6924: South Quay (450m south of Site)
- GSI Report 1736: Marshland surrounding the M11 (1.7km west of Site)

The data contained within the reports is limited to depth and whether bedrock was confirmed. Report 6924 indicated that 4No. of boreholes were sunk and that bedrock was not recorded within a depth of 20m bgl. Report 1736 indicates that 15No. boreholes were sunk to depths of up to 15m bgl and that bedrock was only encountered in one borehole where bedrock was confirmed at 9.3m bgl.

SPL provided WIE with two offshore investigations:

- Causeway Geotech: Arklow Sewerage Scheme - Marin Outfall Site Investigation, December 2017
- Ultrabeam Hyrdographic: Arklow Bank Wind Park - Export Cable Routes, Volume 2, July 2019

The Causeway Geotech [13] investigation was undertaken to investigate the route of a proposed Waste Water Treatment Works outfall pipe. The eastern end of the proposed Waste Water Treatment Works outfall pipe is close to the consented cable route. Boreholes BH06 and BH08 are of most interest as these are within 20m of the proposed cable landfall route and indicate that the seabed deposits consist of sand, gravel and clay deposits of at least 25.20m thick in borehole BH06 (not proven). Bedrock was encountered in borehole BH08 at a depth of 23.50m below seabed (m bsb) and cored to 26.50m bsb.

In addition, a number of reports were provided by SPL for the offshore realm however, these are generally associated with the seabed export cable route and do not extend to the nearshore area of interest. The reports do however provide insight to the geology and seabed profile around the seabed "punch-out" location.

The Ultrabeam Hydrographic [12] investigation consisted of geophysics along the route of the consented export cable routes. Data from the start position of Cable Route 3, which is closest to the landfall location, has been reviewed as part of this report and the digital data has been incorporated into the AutoCad Civil 3D model.

It is noted that the geophysics interpretation does not correlate well with the factual records from BH06 or BH08 where the geophysics indicates that superficial deposits are in the order of 7.50m thick, against a proven thickness in excess of 20m as presented on drawing LF100034-16435-WIE-ZZ-XX-DR-C-90003.

7.11 Topography

Preliminary Digital Terrain Model (DTM) data was initially obtained through the Irish Ordnance Survey and incorporated into the AutoCAD Civil 3D model in order to progress initial outline designs. A topographic survey was subsequently undertaken by Murphys Survey Ltd ('Murphys') to WIE's specification. The works comprised land-based GPS surveying and was undertaken between 9th and 20th December 2019. The topographic data obtained by the survey updates the DTM data and has been used to inform Concept Design.

7.12 Bathymetry

Off-shore bathymetric survey data supplied by SPL from the subsea cable route investigation [Ultrabeam Hydrographic, 12] has been incorporated with the topographic data acquired by Murphys in AutoCAD Civil 3D to form a combined seabed and topographical profile along the proposed route. The bathymetric data was captured from survey vessels and as such a near shore data gap, of approximately 500m, exists due to insufficient water depths for the draught of survey vessel employed.

Bathymetry data available through GSI [3], does not cover any additional area from that provided by SPL.

7.13 Existing Infrastructure

The primary existing infrastructure which poses a constraint to the development of the southern cable landfall is a running track and use of the area as public space. In addition, there is a high voltage electrical cable which runs below the coastal erosion protection revetment and is the export cable from the Phase 1 Arklow Windfarm. The export cable is also present offshore however is beyond the subsea Cable Route 3 exit point.

A proposed Waste Water Treatment Works (WWTW), located immediately south of the site area, has recently been granted planning permission. The alignment of the WWTW outfall pipe is also shown to conflict with the cable landfall alignment and would need considered within the design of the cable landfall.

8. Site Walkover (Southern Landfall)

A walkover survey was undertaken on the 4th December 2019 by 2No. engineers from the WIE geotechnical team. The primary purpose of the walkover survey was to validate assumptions made at desk study stage and ascertain if any geological outcrops were visible for inspection. In addition, the walkover survey facilitated assessment of the suitability of the area to set-up a site compound and stringing out areas, plus any apparent access restrictions.

The weather at the time of the survey was overcast, rainy and breezy. Temperatures were commensurate with the time of year.

8.1 Foreshore Geology

The foreshore geology could not be ascertained due to the presence of a coastal erosion protection revetment (see Figure 20).

Figure 20: Southern Site (Coastal Erosion Protection Revetment) looking north



8.2 Proposed Site Compound Suitability

The proposed area for the Site Compound consists of relatively flat playing fields, a running track and public park (see Figure 21). The size of the site area is approximately 180m long by 160m wide. The site is bound to the north by Seaview Avenue and the existing sports centre and associated carpark (see Figure 22), to the east by a coastal erosion protection revetment approximately 5m in height (see Figure

23), to the south by Mill Road (see Figure 24) and to the west by the Bridgewater Shopping Centre and associated carparks and roads (see Figures 25 & 26).

Direct access can be gained from Seaview Avenue via playing field access gates approximately 3.50m wide located to the west and east of the sports centre (see Figures 27 & 28).

A 2m height restriction applies, and is enforced by a barrier, although these appear to be demountable and could therefore be removed for temporary access. It is noted that there are a number of overhead cables which cross Seaview Avenue at various locations (see Figure 29 & 30), plus a high likelihood of underground services associated with existing street lighting.

Access from Mill Road on the southern boundary is possible but would require the temporary removal of a low height wall to allow vehicles to drive on-site.

The proposed area for the site compound is considered to be of suitable size, and the height restriction barriers could be removed prior to site works commencing. Overhead cables would require to be checked for height but given that they cross an existing public road are considered likely to provide sufficient clearance for standard road going Heavy Goods Vehicles.

Figure 21: Proposed Site Location Compound (playing fields, park and running track) looking northwest



Figure 22: Northern Boundary (Seaview Avenue, sports centre and associated car parking) looking west



Figure 23: Eastern Boundary (Coastal Erosion Protection Revetment, approximately 5m height) looking east



Figure 24: Southern Boundary (Mill Road) looking east



Figure 25: Western Boundary (Bridgewater Shopping Centre Carpark) looking west



Figure 26: Western Boundary (Carpark) looking southwest



Figure 27: Field Access Gate (west of sports centre) looking south



Figure 28: Field Access Gates (east of sports centre) looking south



Figure 29: Seaview Avenue (height restriction barrier) looking west



Figure 30: View along Seaview Avenue (overhead cables) looking west



9. Conceptual Geological Model (Southern Landfall)

From the information obtained by Desk Study review and the Site Walkover Survey, a conceptual ground model has been developed.

9.1 Onshore Conceptual Ground Model

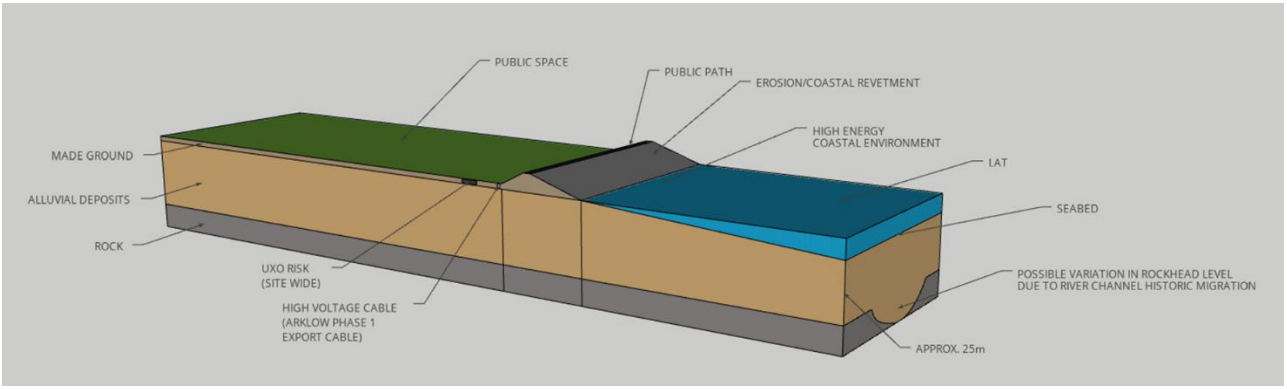
Table 5: Conceptual Landfall Geological Model

Stratum	Area Covered	Estimated Thickness	Typical Description
Topsoil	Site Compound	0 –1.00m	Topsoil/ Made Ground
Alluvial Deposits	Site Compound	20m +	Soft alluvial deposits (Clay, Silt, Sand and Gravel)
Kilmacrea Formation	Site Compound	Unknown	Typically consists of dark grey slate, with minor pale sandstone

The thicknesses tabulated above are estimated from available limited borehole information 450m south of the proposed compound area and will require to be confirmed through intrusive ground investigation.

A schematic ground model is presented in Figure 31.

Figure 31: Southern Landfall: Schematic Ground Model



9.2 Offshore Conceptual Ground Model

Table 6: Conceptual “Punch-Out” Location Geological Model (Geophysics)

Stratum	Area Covered	Estimated Thickness
Sand	“Punch- Out”	2.50m
Sand and Gravel	“Punch- Out”	5.00m
Rock	“Punch- Out”	Unknown

The above is based on Drawing No. UHC19004-REV00-05 presented by Ultrabeam Hydrographic [12] (see Appendix C) which shows the interpreted ground conditions from the geophysics around the proposed punch out location.

However, 2 No. boreholes sunk in association with the Causeway Geotech: Arklow Sewerage Scheme-Marine Outfall Site Investigation [13] report are within a 20m offset of the proposed cable landfall route

and are considered representative of ground conditions within the nearshore area. Borehole BH08 is located 100m of the cable route and is summarised in Table 7 below.

Table 7: Conceptual "Punch-Out" Location Geological Model (Boreholes)

Stratum	Area Covered	BH06 Estimated Thickness	BH08 Estimated Thickness	Typical Description
Alluvial Deposits	"Punch- Out" area	6.20m	4.50m	Medium dense gravelly SAND
Till	"Punch- Out" area	19.00m	19.00m	Stiff to very stiff gravelly CLAY and dense to very dense GRAVEL.
Rock	"Punch- Out" area	-	3.00m +	Weak blueish grey SLATE

9.3 Summary Conceptual Ground Model (Southern Landfall)

The above tables indicate that the depth of superficial deposits is likely to be significant (>20m) below the proposed landfall cable route. However, this is not confirmed by the geophysics data from around the subsea cable route "punch-out" location, where superficial deposits are inferred as being considerably thinner at approximately 7.50m.

This may be a result of very stiff and very dense materials being interpreted as rock, or there is a sudden change in superficial deposit thickness at the "punch-out" location. However, caution would be advised in the geophysical survey interpretation until conditions can be factually proven through intrusive ground investigation specific to the landfall location.

10. Geotechnical Risk Register (Southern Site)

10.1 Geotechnical Risk Evaluation Matrix

Based on information available, a specific review of the geotechnical risks associated with the landfall installation works has been undertaken and the risks evaluated using a risk evaluation matrix.

The risk register, detailed in the following tables, lists the anticipated ground hazards associated with the works and the associated consequences of those hazards in order to determine the level of risk presented. The risk before control of the hazard has been assessed quantitatively and following the implementation of specific control to each risk. The register should remain a 'live' document, updated as construction works progress.

The level of risk is calculated to be up to a value of 25 (Critical Risk). The maximum value can be reduced to 5 (Medium Risk) and with implementation of the recommended controls during construction may be reduced further.

Probability (P) x Impact (I) = Risk Rating (R)

PROBABILITY OF OCCURRING		IMPACT ON PROJECT COST / PROGRAMME
Very Likely	5	Substantial (>50% Cost/ Programme increase)
Likely	4	High (30% to 50% Cost/ Programme increase)
Probable	3	Moderate (10% to 30% Cost/ Programme increase)
Unlikely	2	Minor (< 10% Cost/ Programme increase)
Highly Unlikely	1	Negligible (0% Cost/ Programme increase)

PROBABILITY (P)	IMPACT (I) 5	4	3	2	1
5	25	20	15	10	5
4	20	16	12	8	4
3	15	12	9	6	3
2	10	8	6	4	2
1	5	4	3	2	1

1 to 4	Low Risk
5 to 10	Medium Risk
11 to 16	High Risk
≥ 17	Critical Risk

Geotechnical Risk Register

Arklow Landfall (Southern Site)										
No	Hazard	Consequence	Risk before Control			Recommended Mitigation Measures to be implemented	Risk after Control			Comments
			P	I	R		P	I	R	
1	Limited ground investigation data available for the site.	Encountering unforeseen ground conditions and incorrect design leading to impact on progress, programme and costs. Incorrect drill head selection based on insufficient ground investigation data. Bore path may need to be abandoned and re-drilled leading to programme and cost impacts. Potential for shallow rock or hard dig conditions which could impact on steering and progress due to changing material strengths. Potential for “Frac-out” to occur leading to programme and cost impacts. Damage/ environmental incident.	5	5	**25**	Ground investigation must be undertaken to sufficient depth across the site ensuring robust design. This should include both onshore and nearshore investigation.	2	5	**10**	Direct Pipe considered most suitable technique for conditions likely to be encountered, but this should be confirmed on completion of ground investigation.

Arklow Landfall (Southern Site)										
No	Hazard	Consequence	Risk before Control			Recommended Mitigation Measures to be implemented	Risk after Control			Comments
			P	I	R		P	I	R	
2	Potential of encountering relict river channel during drilling.	Potential for “Frac-out” to occur leading to programme and cost impacts.	4	5	**20**	Ground investigation required throughout site area including compound and nearshore. Use of Direct Pipe which reduces “frac-out” risk.	2	5	**10**	
3	Unknown thickness and composition of marine sediments.	Encountering unforeseen ground conditions and incorrect design leading to impact on progress, programme and costs. Incorrect drill head selection. Bore path may need to be abandoned and re-drilled leading to programme and cost impacts. Potential for “Frac-out” to occur leading to programme and cost impacts. Damage/ environmental incident	5	5	**25**	Ground investigation required through nearshore GI including tight grid of CPT’s at proposed punch-out. Use of Direct Pipe which reduces “frac-out” risk.	2	5	**10**	
4	Offshore geological faults approximately 270m and 560m from the shore.	Potential for “Frac-out” to occur along fault planes leading to programme and cost impacts. Damage/ environmental incident.	4	5	**20**	Offshore ground investigation to ascertain fault zones.	2	5	**10**	

Arklow Landfall (Southern Site)										
No	Hazard	Consequence	Risk before Control			Recommended Mitigation Measures to be implemented	Risk after Control			Comments
			P	I	R		P	I	R	
		Potential for chocking / collapse of bore in unstable rock.								
5	Risk of 'punch-out' or 'break-out' of drill due to incorrect cover levels.	Impact to progress, with programme and cost increases. Damage / environmental incident. Bore path may need to be abandoned and re-drilled leading to programme and cost impacts.	4	5	20	Additional topographic survey completed over the compound and foreshore areas providing data required to undertake outline design.	2	5	10	Further nearshore bathymetric survey required.
6	Risk of scour around the "punch-out" zone.	Impact to progress, with programme and cost increases. Damage / environmental incident.	4	5	20	Undertake detailed seabed survey at the "punch-out" zone to assess the likelihood of impact and design adequate protection measures.	2	5	10	
7	Existing/ Proposed infrastructure - notably existing windfarm cable (On and Offshore) and proposed waste water treatment works outfall pipe.	Risk of death or injury. Potential costs and programme impacts.	5	5	25	Utilities search underway.	1	5	5	Utility plans should be updated every 3 months.
8	Extraction Wells.	Contamination of drinking water resource.	4	5	20	Not within a groundwater drinking protection area, however, 4 wells are recorded within 2km of site and as such	1	4	4	

Arklow Landfall (Southern Site)										
No	Hazard	Consequence	Risk before Control			Recommended Mitigation Measures to be implemented	Risk after Control			Comments
			P	I	R		P	I	R	
						a detailed hydrogeological assessment should be completed.				
9	Flooding	Major works disruption and consequent cost increases	3	5	**15**	Historical records of Avoca River flooding. A flood risk assessment (FRA) should be completed and any recommendations followed.	2	4	**8**	
10	Potential for UXO unknown.	Risk of death or injury Programme delays and cost increases	3	5	**15**	Zetica detailed desk study assessment indicates the site is considered medium risk of UXO contamination	3	5	**15**	UXO contamination survey should be completed prior to site works and staff to receive UXO briefing from UXO expert.
11	Shallow Groundwater	Temporary works stability.	3	4	**12**	No groundwater monitoring information to date. Groundwater monitoring rounds required as part of Ground Investigation to appreciate long term groundwater levels and variances, and hence allow consideration within design.	1	4	**4**	
12	Contaminated Soils	Health risk to construction personnel Increased disposal costs of any materials going off-site	3	3	**9**	Ground Investigation and testing required.	1	3	**3**	
13	Aggressive Soils	Sulphate attack on buried concrete	3	3	**9**	Ground investigation undertaken with appropriate testing to BRE SD1	1	3	**3**	

11. Northern Landfall: Options Appraisal

11.1 General

A number of potential constraints have been highlighted through the preparation of this report which will need to be considered in the detailed design of the cable landfall:

- The bedrock is expected to consist of slate, phyllite and schist with bands of siltstone, granite and orthoquartzite. The granite and orthoquartzite will likely result in hard drilling or excavation.
- The bedrock is recorded on mapping to dip steeply towards the south at between 70° and 88° and as with any schistose rock the foliation plane presents a plane of weakness.
- Approximately 300m and 700m off-shore there are two faults running approximately north to south which again present a possible plane of weakness. It would be recommended that the drill profile exits before this fault line.
- There is a significant level difference between the cliff tops and the foreshore. This is approximately 9m to the top of the cliff line and 14m to the site compound level, as acquired by the UAV and land based topographic survey carried out by Murphys.
- Two groundwater extraction boreholes exist close to the site boundaries to the north and south. Their exact locations are unconfirmed, but the presence of the extraction boreholes indicate a potential for contamination of drinking water resource if there is any escape of drill fluids into the aquifer. The extraction wells are however noted as poor yield, and therefore the risk may be reduced. This will require further consideration as part of design development.
- The Buckroney - Brittas Dunes and Fen area, a Special Area of Conservation, comprising of wild asparagus, meadow flowers and grasses, is located approximately 500m north of site and then extends north for a distance of around 8.50km. Although this does not directly impact the site location, any potential impact from site operations should be considered further.

11.2 Options Appraisal

In consideration of the above a number of potential options have been considered for constructing the northern cable landfall and are summarised in Table 8 below.

Table 8: Options Appraisal (Northern Site)

Option	Advantages	Disadvantages
Open-cut Trench	Accuracy of installation operations. Generally of lower cost than Trenchless Techniques.	Steep cliffs (approximately 9m high) in conjunction with an exposed location susceptible to stormy sea conditions will preclude the use of open cut trenching. This option should be discounted from further consideration.
Micro-tunnelling / pipe jacking	Suitable for geological conditions. Accuracy of installation operations (vertical ±25mm	Typically, cannot be curved when drill length <1km. Typical maximum single drive of 300m to 500m (intermediate thrust jacking stations

Option	Advantages	Disadvantages
	horizontal ±100mm).	may be required).
	Speed of installation operations.	Relatively expensive.
	Minimum impact to environment.	Temporary sheet piles required for Launch and Reception Pits.
	Pre-Cast Concrete sections installed with the advancing tunnel drive providing immediate shoring support	
	Suitable for installation below groundwater level.	
Horizontal Directional Drilling	Suitable ground conditions.	Additional space required for stringing out / laydown if required.
	Minimum impact to environment.	Minor earthworks cut and fill required to create level area at proposed entry compound.
	Reasonable accuracy of installation operations (+/- 1m to 2m horizontally dependant on geological conditions)	
	Speed of installation operations	
	Continuous monitoring and control during the operations	
Direct Pipe	Suitable ground conditions.	Insufficient bending radii to account for topography / need to pass below cliff line.
	Minimum impact to environment.	Temporary sheet piles required for Launch and Reception Pits.
	Accuracy of installation operations (vertical ±25mm horizontal ±100mm).	
	Speed of installation operations.	

Table 8 considers four potential cable landfall methods and through a process of options appraisal Horizontal Directional Drilling ('HDD') is determined as the favoured technique for the cable landfall at the Northern Site.

12. Northern Landfall: HDD Concept Design

12.1 General

Two concept HDD design options have been developed based on the information obtained from Desk Study, Site Walkover Survey and Topographical Survey Outputs. Cable Route 2 was previously identified as the preferred cable route option utilising the northern most site compound area for progression (WIE12731-113-R-1-3-3 [1]), primarily as the HDD borepath was shortest and provided maximum compound area. However, in order to fully assess the merits of each cable route outline design profiles have been progressed.

This is presented as Drawings No. LF100034-16435-100-WIE-ZZ-XX-DR-C-90001 (Cable Route 2), LF100034-16435-100-WIE-ZZ-XX-DR-C-90002 (Cable Route 2), LF100034-16435-100-WIE-ZZ-XX-DR-C-90005 (Cable Route 1) and LF100034-16435-100-WIE-ZZ-XX-DR-C-90006 (Cable Route 1) presented in Appendix E along with Designers Risk Analysis.

The bore profiles in plan were selected to provide the optimum route passing through the subsea cable junction whilst providing the maximum compound area which allows the HDD entry point to be as far east as possible. This allows space for stringing out product pipe behind the compound, aided with the use of rollers, if required. However, through design development, it is considered more likely that the duct would be pre-fabricated and floated off-shore prior to being pulled back through the HDD after reaming operations.

For the proposed cable specification, a data sheet for which is contained in Appendix A, based on 266mm outside cable diameter each bore path will require to be of a minimum 665mm internal diameter. This is based on the current industry standard of minimum 2.5 times cable outside diameter, which is to mitigate the risk of any gravel or sediments pulled into the duct during the cable installation phase damaging the cable. It is however commented that appropriate controls should be in place to prevent this, such as a positive water pressure and outflow of water from the duct during cable pulling couple with a series of roller brushes at the duct entry point.

Due to available duct sections, and assuming HDPE SDR 11, a nominal 800mm diameter duct will be required. The initial HDD pilot hole would therefore be reamed out from circa 311mm ($12^{1/4}$”) diameter to 1118mm (44”) diameter prior to the 800mm duct being pulled through the bore.

Figures 32 to 34 show a typical HDD set-up for an HDD Cable Landfall.

Figure 32: Typical HDD Rig and Control Cabin Set-up



Figure 33: Typical HDD Compound Set-up



Figure 34: Typical Temporary Access Track



12.2 Site Compound Area (Cable Route 2)

The site compound area is proposed to be located within a gently undulating agricultural field to the west of the R750 road and will be accessed directly from the R750. At the site location this is a single-track road estimated to be around 4m in width.

The compound field sits about 14m above beach level.

The field is roughly trapezoidal in shape and approximately 200m wide at the northern end narrowing to approximately 100m wide at the southern end. The field is approximately 250m in length.

A 3.5m to 4.0m wide temporary access track suitable for the equipment to be employed will need to be formed through the field from the access off the public road to the compound. This will require the placing of a suitable depth of imported clean angular stone, such as SRW Type A to Clause 801 (Transport Infrastructure Ireland, Specification for Roads Works Series 800, Road Pavements [14], placed on top of a geotextile separation membrane. Alternatively, temporary metal roadway could be used.

For a typical HDD application, a compound of a minimum 70m x 70m will typically be required with level and stable terrain which will require minor earthworks on site with approximately 2m of cut and fill required. The compound is required to site a variety of containers which contain welfare, offices, storage, mud labs, mud mixing, mud recycling units and workshops. In typical HDD applications a minimum of 100m space behind the entry pit is used to facilitate stringing out the product pipe with the support of stilts and rollers, albeit in this instance the proposal at this stage would be to float the ducts offshore and pull the ducts in from the offshore end after reaming of the boreholes. This will require duct fabrication to be undertaken at a marine yard (Arklow) and floated to the “punch-out” location for pulling back to shore. This operation will be weather dependant.

12.3 Entry Points (Cable Route 2)

A 10°(-18%) entry angle is indicated, based on the completion of previous drills in similar geology, which would be around the maximum entry angle for HDD and is considered sufficiently steep to mitigate the risk of the drill head skipping off rockhead at the till / rockhead interface. However, the optimum entry angle should be confirmed on completion of ground investigation and as part of final design.

On the basis that the compound area is positioned 14m above the beach and that each HDD will have an entry angle of 10° (-18%) and shall pass a maximum of 10.6m below the base of the sea cliff the entry points shall be around 160m from the toe of the cliffs just inside the site compound field (see Drawing No. LF100034-16435-100-WIE-ZZ-XX-DR-C-90001). This leaves approximately 150m for stringing of product piping behind the entry points if required.

The entry points are shown with a 5m separation and then diverge along the length of the drill. This is to mitigate the risk of the two drill paths converging due to any unforeseen steering influence.

12.4 Entry Pits (Cable Route 2)

For each bore, an entry pit should be formed for the containment of drill fluids and may require temporary support. Given that the overburden at site is likely to consist of Glacial Till, with some granular content, there may be issues with leakage of the drill fluid which should be overcome through lining the pit with an impermeable barrier such as visqueen sheeting, so as to form a sump.

12.5 HDD Radius (Cable Route 2)

A minimum radius of R500m has been detailed, based on previous drills in similar geology, but should be considered further once full details of the rock bedding and joint structure are understood from intrusive ground investigation. The proposed cable has a minimum bending radius of 4m and is therefore well within the designed drill profile. A technical data sheet for the proposed cable is presented within Appendix A. Potentially a relaxation of the drill radius may be required if the orientation of softer lithological units are such that they could influence the HDD steering.

12.6 Offshore Exit Points (Cable Route 2)

The off-shore exit points are indicatively shown on Drawing No. LF100034-16435-100-WIE-ZZ-XX-DR-C-90001 at Chainage 364. Bore 1 has an exit point co-ordinate of 727531, 677239 and Bore 2 has an exit point co-ordinate of 727529, 677220. The exit pits have a separation of 20m.

The proposed alignments have also been selected on the basis of the 2No. bore paths passing either side of the subsea cable route junction of Cable Routes 1 & 2 and running along the alignment of subsea Cable Route 2 This allows for the shortest bore path, and optimum on-shore set-up, when compared with Cable Route 1. The exit points have been selected to terminate before the first of the offshore faults whilst having a sufficient water depth for the operation of cable laying barges and support vessels. Based on Lowest Astronomical Tide Level (0.2m ACD) and bathymetrical data supplied by the GSI, water depth is a minimum 6m at the proposed exit point which correlates well with bathymetry data obtained for the start of the proposed subsea cable route supplied by SPL. This should be confirmed as suitable once the full details of the offshore support vessels are known. A 6° (10%) exit angle is proposed currently and should be confirmed in conjunction with developing the HDD & Trenching interface upon completion of the offshore ground investigation once exit point sediment thickness are confirmed.

The seabed at this location is relatively flat however, the final exit location must be refined upon receipt of full ground investigation data.

It is understood that the offshore cables shall be laid in a trench of approximately 2m depth in order to protect them from erosional effects of tidal currents. Whilst the HDD's will punch-out on the seabed the cable ducts will ultimately be cut-down so as to tie in with the trench invert level. This is a standard detail for offshore cable landings, although the specific details will require to be developed as part of detailed design once final cable specification confirmed and the thickness of sediments at the proposed punch-out are confirmed through intrusive ground investigation.

Localised scour protection, consisting or reno-mattresses or suitably placed armourstone, may be required as protection to the cables where they exit the HDD ducts. Detailed consideration of this is beyond the scope of this study.

12.7 HDD Outline Calculations (Cable Route 2)

12.7.1 Hydro-Fracture Calculations

Hydro-fracture (frac-out) occurs if during the drilling process the drilling fluid pressure in the borehole exceeds the resistance of the overburden soils resulting in a breakout at the surface. In this case, there is a potential risk that this could occur within the sea leading to a pollution incident. Drilling mud pressure within the HDD bore should not exceed that which can be supported by the surrounding soils to prevent hydro-fracture.

The geology at the Site is expected to consist of steeply dipping rock with the potential that discontinuities may provide a plane of weakness leading to the occurrence of frac-out. This would likely be a result of fluid migration through the fractures and fissures, and exacerbated by shallow groundwater within the overburden material which may mix with the drilling fluids preventing it setting and creating a seal through the soils.

Typically, increasing cover depth of the bore path to give a larger overburden pressure is the best way to mitigate this issue, but, in this instance a maximum limit of 10m cover has been specified due to thermal limitations of the export cables. Calculations showing the maximum allowable downhole pressures exerted by the drilling annulus have been determined based on achieving maximum 10m cover depth and using assumed ground parameters. Based on results of these preliminary calculations, it is possible that the limit of cover could be reduced to approximately 4m subject to ground investigation results and final duct / bore path diameters. This limit of cover would translate to approximately 9m cover below the cliffs depending on the bore profile, this shows that a bore profile not exceeding the maximum limit of cover whilst being suitable in terms of hydrofracture should be possible.

There are several possible methodologies, but this analysis has been based upon the widely used 'Dutch' method which was developed by Luger & Hergarden (1988) assuming a cavity expansion. The main parameters used in this assessment are set out in Table 9.

Table 9: Hydrofracture Parameters

Parameter	
Gravity (m/s/s)	9.81
Density of Water (kg/m^3)	1000
Density of Drilling Mud (kg/m^3)	1300
Soil Density (kg/m^3)	2200
Cohesion (kN/m^2)	50

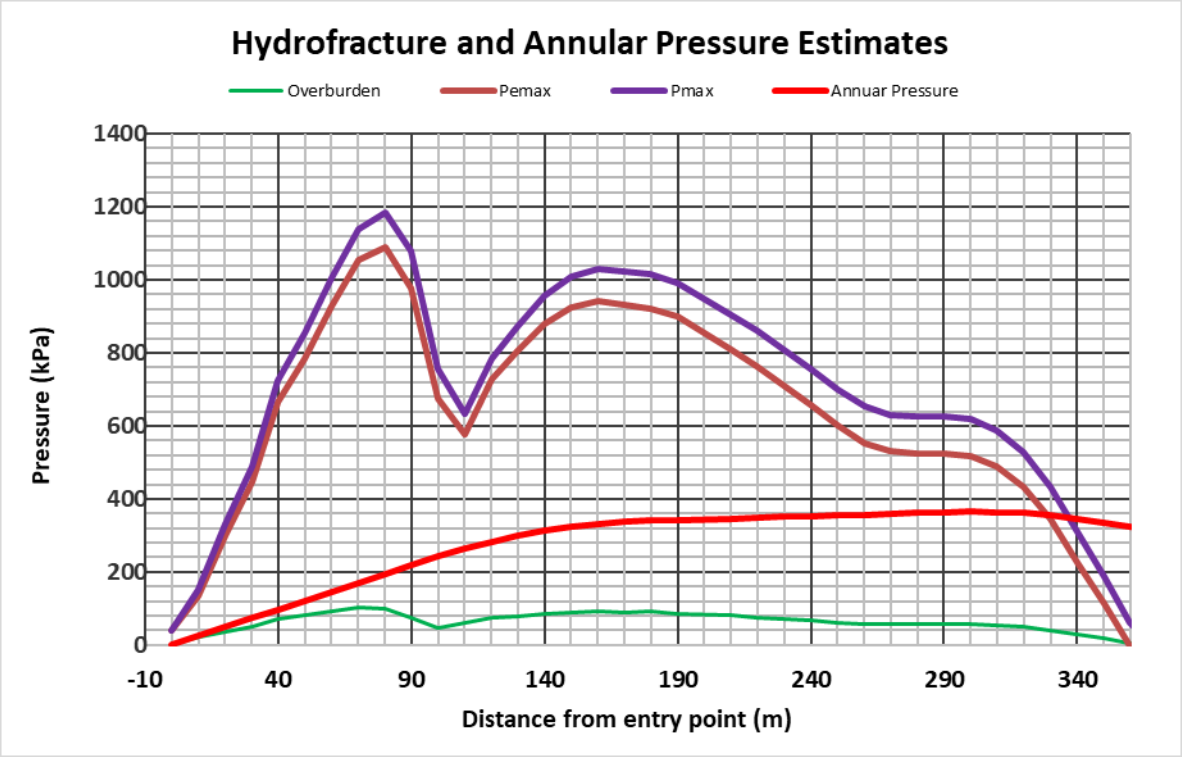
Friction Angle (°)	36
Poission's Ratio	0.35
Elasticity Modulus (kPa)	50000
Drill Bit Diameter (m)	1.118
Drill Pipe OD (m)	0.279
Allowable Plastic Radius Factor	0.50

Due to unknown ground water conditions onshore, the ground water has been assumed as at the ground surface (worst case scenario) meaning that buoyant soil conditions are considered throughout. Offshore the water level has been taken as Lowest Astronomic Tide (LAT). The proportion of soil cover set as the plastic allowance is 0.5 (worst case scenario), thus the actual depths will vary significantly and rapidly as the borehole approaches the surface at either end.

Calculation sheets are presented in Appendix G and are based on a 1.118m reamed borehole.

The variation in pressures along the borehole are shown in Figure 35, where it can be seen the permissible boreholes pressures $P_e$max and Pmax graphs fall rapidly towards the end due to the above-mentioned factor. Another feature to note on this graph is that the permissible pressures are significantly larger than the overburden pressure and this is due to the nature of the assumptions in the 'Dutch' model. The difference between $P_e$max and Pmax arises from consideration of the water table level and the added confinement pressure due to its hydrostatic effect.

Figure 35: HDD Permissible Borehole Pressures



The most significant line on Figure 35 is the Annular Pressure which is the pressure in the borehole due to the drill fluid return flow. This pressure varies as the borehole progresses and is the sum of the static

head and friction (flow) head. For most of the distance the annular pressure is well below $P_e$max but as it approaches the borehole exit (Ch330) it exceeds the allowable pressure and this would lead to a risk of hydro-fracture within the very final stages of the HDD as it nears the exit point in the seabed (termination Ch360). This is unavoidable and will require appropriate site controls to be in place.

Ground parameters require to be confirmed through Intrusive Ground Investigation, and the hydro-fracture calculations updated as required.

12.7.2 Duct Pulling Calculations

On completion of the HDD bore the product pipe will most likely be inserted by pulling after floating offshore to the HDD exit point. Within the industry pulling is preferred as the pipe acts in tension, which eliminates potential issues of buckling associated with the compressive forces created from the pushing method. In this particular instance it is expected that pulling the product pipe from offshore to onshore is most likely the best solution, as such, product pipe pulling calculations have been carried out to understand the likely forces involved with such an installation.

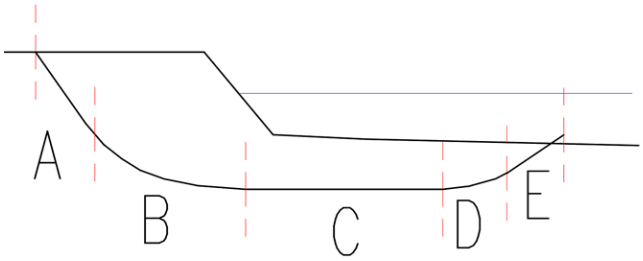
Within this analysis, the frictional forces, hydrodynamic forces and gravitational forces have been considered. Furthermore, the profile of the borehole has been considered as a series of sections to best represent the additional forces associated with areas of curvature within the borehole. As will be apparent, the required force to move the pipe will increase as the pipe progresses through the borehole.

Note that there can be a considerable difference between the static and kinematic coefficients of friction. It is assumed that normally the pipe insertion will be undertaken in one continuous operation thus the kinematic coefficient of friction would apply throughout. However, if the operation is stopped then in order to get the pipe moving again the static coefficient of friction will apply. This could be 2 or 3 times the kinematic coefficient value. Depending on the duration of the interruption, other factors such as the thixotropic properties of bentonite may also increase the force required to move the pipe.

Also, it should be noted that within this analysis the frictional forces associated prior to entering the borehole have been considered as a nominal value of 50kN. This force is assumed and should be assessed at the design stage when the method of installation has been determined.

All calculations have been considered using the bore path determined within drawing LF100034-16435-100-WIE-ZZ-XX-DR-C-90001, and a breakdown of the considered section can be seen in Figure 36 below.

Figure 36: HDD Bore Path Schematic



A summary of the HDD borehole geometry can be seen in Table 10, note that as mentioned previously it is assumed that the pipe is pulled from Section E back towards Section A.

Table 10: HDD Bore Path Geometry

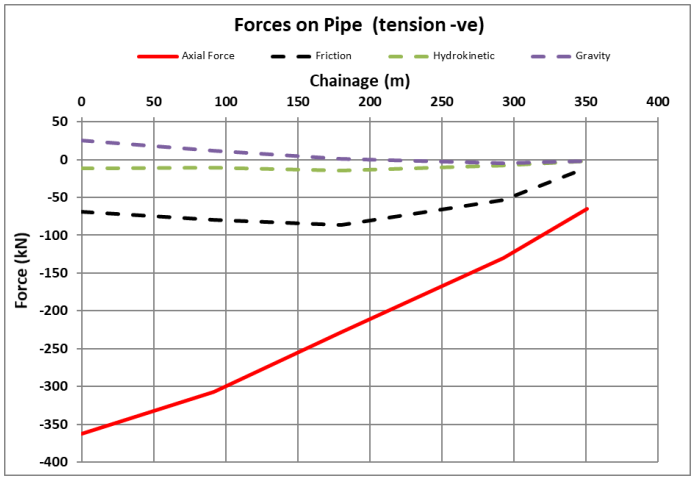
	A	A:B	B:C	C:D	D:E	E
Ch	0.00	92.00	180.00	293.00	351.00	365.00
mOD	14.53	-1.86	-10.43	-11.23	-8.45	-7.09
Radius		500		500		
Slope	-10.32		-0.42		6.2	

Based on information received from SPL the proposed product pipe is to be minimum circa 665mm, meaning that due to available pipe sections a nominal 800mm diameter HDPE pipe is considered. It is assumed that the HDD drill will be circa 311mm then reamed out to a diameter circa 1118mm.

Dependent on project specifics the pipe is sometimes filled with ballast water whilst installing to counteract buoyancy. For the purpose of these calculations it has been assumed that the pipe is filled with ballast water and is unpressurised (typical when pulling) as this is the most feasible approach for the drill profile. When designing the pipe installation this should be reassessed by determining the buoyant forces and considering if ballast water is required.

Using the proposed profile and properties of the product pipe the pulling forces shown in Figure 37 were obtained.

Figure 37: HDD Product Pipe Pulling Forces



The main feature shown in Figure 37 is the Axial Force, which is a combination of the friction, gravity and hydrokinetic components. The friction arises from the action of the pipe against the soil/rock in the borehole but is somewhat lubricated by the bentonite. The gravity component is initially of resistance when pulling as the profile is of a downwards trajectory and the pipe is buoyant but then assists when the profile begins to rise. The hydrokinetic force arises from the displacement of the bentonite as the pipe is pulled through the borehole. As seen within Figure 35, the gravity and hydrokinetic components are minor when compared to friction component and have only been considered as good practice.

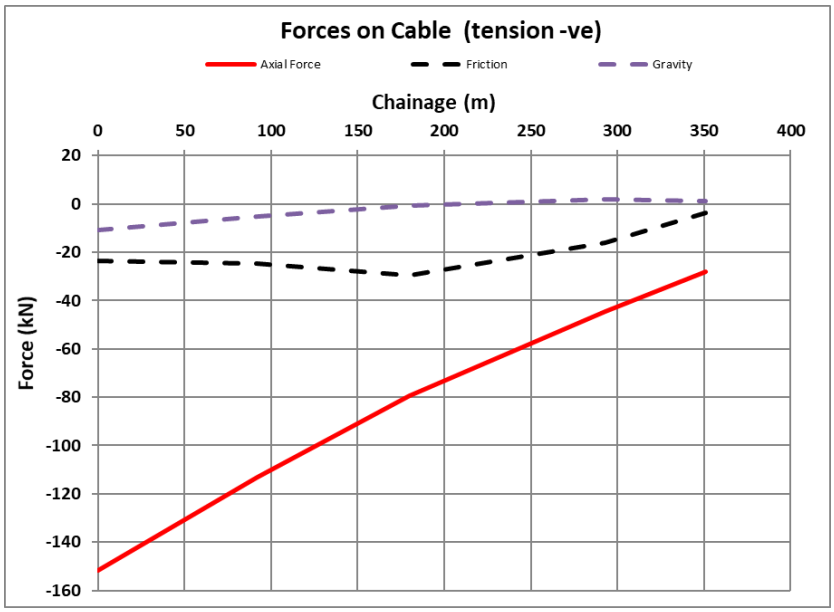
From the analysis a Maximum Required Axial Force of 360kN has been determined, however, as the forces associated with pulling the pipe from the stringing out area to the start of the borehole have been considered as a nominal force, 50kN and that various assumptions have been made regarding pipe and soil properties, then this analysis should be revised as the design process is carried out and the variables become known. Furthermore, it is assumed throughout this analysis that no obstructions are present, such as debris dislodged from the soffit of the borehole, the additional pulling forces required if this is found to be an issue will likely be significant.

From the maximum axial force required a maximum axial stress of approximately 4N/mm^2 can be derived, the nominal yield strength of HDPE is approximately 24N/mm^2 and from review of advisable safe pulling strength for HDD applications a axial stress of 7.5N/mm^2 to 9N/mm^2 is a limiting factor, thus the HDD pulling calculations are acceptable in terms of tensile stresses. However, these calculations should be reviewed after variables become more defined through the design process.

12.7.3 Cable Pulling Calculations

From the data sheet provided by SPL (Appendix A), the cable outside diameter is 266mm. All calculations have been considered using the bore path determined within drawing LF100034-16435-100-WIE-ZZ-XX-DR-C-90001, and a breakdown of the considered section can be seen in Figure 34 above and the HDD borehole geometry presented in Table 10. The results are presented on the cable forces graph Figure 38.

Figure 38: HDD Cable Forces



From the analysis a Maximum Required Axial Force of 150kN has been determined for the cable. From the cable data sheet received an allowable pulling force of 400kN with no bending is stated. Through reviewing the cable pulling forces within the profile bending resulted in an increase of 10% when compared with a flat profile. Therefore, reducing the allowable force by 10% results in an approximate limiting value hence allowable pulling force 360kN. Therefore, the maximum required cable pulling force of 150kN is comfortably below the limiting value of 360kN.

Given the forces associated with pulling the cable from the stringing out area to the start of the borehole have been considered as a nominal force, 25kN, and that an assumption of the friction factor between the pipe and cable has been used, then this analysis should be revised as the design process develops and the variables become known.

12.8 Site Compound Area (Cable Route 1)

The site compound area is proposed to be located within an undulating agricultural field to the west of the R750 road and will be accessed directly from the R750. At the site location this is a single-track road estimated to be around 4m in width.

The compound field sits about 16.5m above beach level.

The field is roughly trapezoidal in shape and approximately 240m long at its longest point and is approximately 180m at its widest point.

A 3.5m to 4.0m wide temporary access track suitable for the equipment to be employed will need to be formed through the field from the access off the public road to the compound. This will require the placing of a suitable depth of imported clean angular stone, such as SRW Type A to Clause 801 (Transport Infrastructure Ireland, Specification for Roads Works Series 800, Road Pavements [14], placed on top of a geotextile separation membrane. Alternatively, temporary metal roadway could be used.

For a typical HDD application, a compound of a minimum 70m x 70m will typically be required with level and stable terrain which will require minor earthworks on site with approximately 2m of cut and fill required. The compound is required to site a variety of containers which contain welfare, offices, storage, mud labs, mud mixing, mud recycling units and workshops. In typical HDD applications a minimum of 100m space behind the entry pit is used to facilitate stringing out the product pipe with the support of stilts and rollers in this case there is 90m, albeit in this instance the proposal at this stage would be to float the ducts offshore and pull the ducts in from the offshore end after reaming of the boreholes. This will require duct fabrication to be undertaken at a marine yard (Arklow) and floated to the “punch-out” location for pulling back to shore. This operation will be weather dependant.

12.9 Entry Points (Cable Route 1)

A 9°(-15%) entry angle is indicated, based on the completion of previous drills in similar geology, which would be around the maximum entry angle for HDD and is considered sufficiently steep to mitigate the risk of the drill head skipping off rockhead at the till / rockhead interface. However, the optimum entry angle should be confirmed on completion of ground investigation and as part of final design.

On the basis that the compound area is positioned 16.5m above the beach and that each HDD will have an entry angle of 9° (-15%) and shall pass a maximum of 13m below the base of the sea cliff the entry points shall be around 160m from the toe of the cliffs just inside the site compound field (see Drawing No. LF100034-16435-100-WIE-ZZ-XX-DR-C-90005). This leaves approximately 150m for stringing of product piping behind the entry points if required.

The entry points are shown with a 5m separation and then diverge along the length of the drill. This is to mitigate the risk of the two drill paths converging due to any unforeseen steering influence.

12.10 Entry Pits (Cable Route 1)

For each bore, an entry pit should be formed for the containment of drill fluids and may require temporary support. Given that the overburden at site is likely to consist of Glacial Till, with some granular content, there may be issues with leakage of the drill fluid which should be overcome through lining the pit with an impermeable barrier such as visqueen sheeting, so as to form a sump.

12.11 HDD Radius (Cable Route 1)

A minimum radius of R500m has been detailed, based on previous drills in similar geology, but should be considered further once full details of the rock bedding and joint structure are understood from intrusive ground investigation. The proposed cable has a minimum bending radius of 4m and is therefore well within the designed drill profile. A technical data sheet for the proposed cable is presented within Appendix A. Potentially a relaxation of the drill radius may be required if the orientation of softer lithological units are such that they could influence the HDD steering.

12.12 Offshore Exit Points (Cable Route 1)

The off-shore exit points are indicatively shown on Drawing No. LF100034-16435-100-WIE-ZZ-XX-DR-C-90005 at Chainage 465. Bore 1 has an exit point co-ordinate of 727526, 677304 and Bore 2 has an exit point co-ordinate of 727532, 677285. The exit pits have a separation of 20m.

The exit points have been selected to terminate before the first of the offshore faults whilst having a sufficient water depth for the operation of cable laying barges and support vessels. Based on Lowest Astronomical Tide Level (0.2m ACD) and bathymetrical data supplied by the GSI, water depth is a minimum 6m at the proposed exit point which correlates well with bathymetry data obtained for the start of the proposed subsea cable route supplied by SPL. This should be confirmed as suitable once the full details of the offshore support vessels are known. A 7° (11%) exit angle is proposed currently and should be confirmed in conjunction with developing the HDD & Trenching interface upon completion of the offshore ground investigation once exit point sediment thickness are confirmed.

The seabed at this location is relatively flat however, the final exit location must be refined upon receipt of full ground investigation data.

It is understood that the offshore cables shall be laid in a trench of approximately 2m depth in order to protect them from erosional effects of tidal currents. Whilst the HDD's will punch-out on the seabed the cable ducts will ultimately be cut-down so as to tie in with the trench invert level. This is a standard detail for offshore cable landings, although the specific details will require to be developed as part of detailed design once final cable specification confirmed and the thickness of sediments at the proposed punch-out are confirmed through intrusive ground investigation.

Localised scour protection, consisting or reno-mattresses or suitably placed armourstone, may be required as protection to the cables where they exit the HDD ducts. Detailed consideration of this is beyond the scope of this study.

12.13 Anchoring of HDD Rigs

During the drilling of a pilot hole, reaming out and installation of product pipe, an HDD rig can exert a considerable pushing and pullback force of generally 30T but potentially up to the order of 300T. The rig must therefore be anchored to the ground and this is usually achieved by either anchoring directly to rock or, where this is not possible, driving a line of sheet piles to provide kentledge support.

Given the information available it may be that the rock is too deep to anchor directly, but the superficial deposits may not be deep enough to provide adequate kentledge from sheet piles. Therefore, anchor blocks of reinforced concrete cast in-situ may be required to secure the rigs during the works. An anchor block typically consists of a mesh reinforced concrete block of approximate plan dimensions 4.50m x 4.00m and thickness of circa 1.50m. Final details are dependent on specific HDD plant details and ground conditions a typical anchor block design is presented on drawing LF100034-16435-WIE-ZZ-XX-DR-C-90300.

This should be assessed further on completion of ground investigation, once the depth and nature of overburden is confirmed.

12.14 Guidance and Monitoring Systems

Given that the bedrock bedding and joints are likely to have a controlling influence on the HDD steering, it would be recommended to utilise a wireline gyroscopic sensor employed during the drilling of the HDDs. This provides 'real time' 3D location tracking with an accuracy of typically +/- 1m to 2m horizontally and should be in conjunction with undertaking downhole pressure monitoring to ensure that pressures remain

within acceptable limits.

12.15 HDD Outline Calculations (Cable Route 1)

12.15.1 Hyrdo-Fracture Calculations

Hydro-fracture (frac-out) occurs if during the drilling process the drilling fluid pressure in the borehole exceeds the resistance of the overburden soils resulting in a breakout at the surface. In this case, there is a potential risk that this could occur within the sea leading to a pollution incident. Drilling mud pressure within the HDD bore should not exceed that which can be supported by the surrounding soils to prevent hydro-fracture.

The geology at the Site is expected to consist of steeply dipping rock with the potential that discontinuities may provide a plane of weakness leading to the occurrence of frac-out. This would likely be a result of fluid migration through the fractures and fissures, and exacerbated by shallow groundwater within the overburden material which may mix with the drilling fluids preventing it setting and creating a seal through the soils.

Typically, increasing cover depth of the bore path to give a larger overburden pressure is the best way to mitigate this issue, but, in this instance a maximum limit of 10m cover has been specified due to thermal limitations of the export cables. Calculations showing the maximum allowable downhole pressures exerted by the drilling annulus have been determined based on achieving maximum 13m cover depth and using assumed ground parameters. Based on results of these preliminary calculations, it is possible that the limit of cover could be reduced subject to ground investigation results and final duct / bore path diameters thus possibly achieving the maximum limit of 10m cover depth. In this instance, this is not achievable whilst providing the minimum cover of 5.5m below the cliffs, therefore, a maximum cover of 13m has been used as shown in the profile on drawing LF100034-16435-WIE-ZZ-XX-DR-C-90005.

There are several possible methodologies, but this analysis has been based upon the widely used ‘Dutch’ method which was developed by Luger & Hergarden (1988) assuming a cavity expansion. The main parameters used in this assessment are set out in Table 11.

Table 11: Hydrofracture Parameters

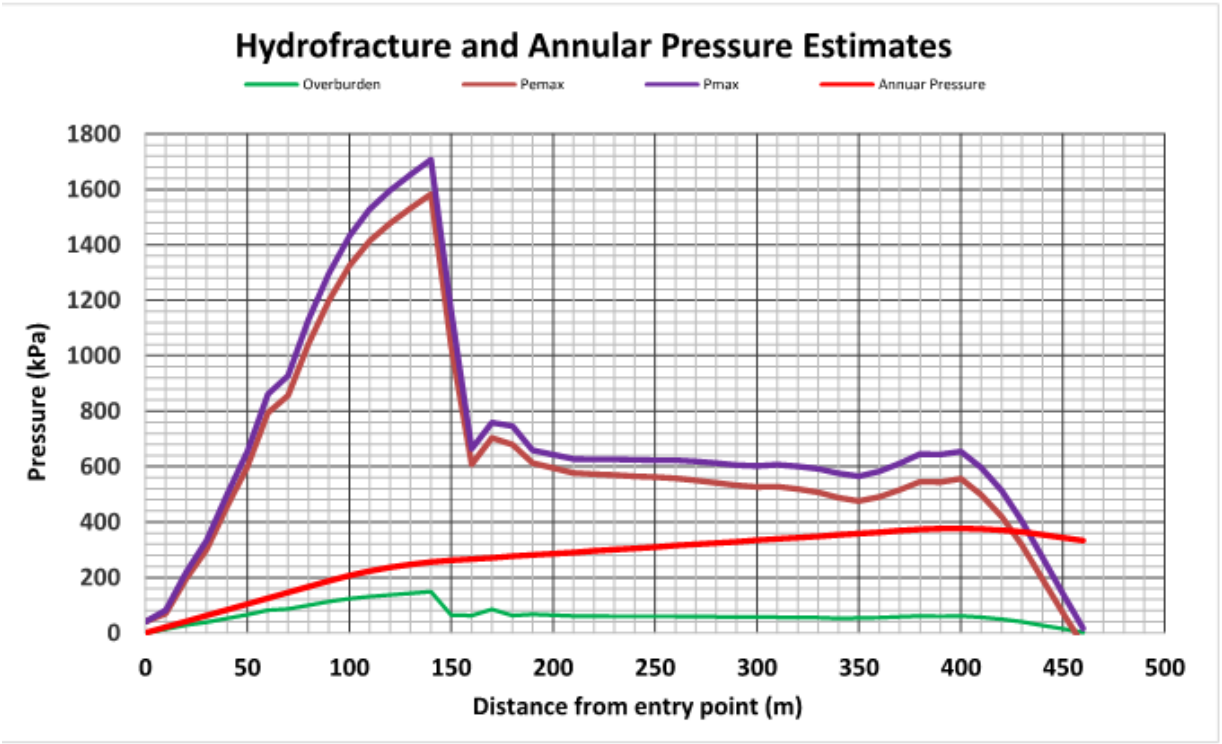
Parameter	
Gravity (m/s/s)	9.81
Density of Water (kg/m^3)	1000
Density of Drilling Mud (kg/m^3)	1300
Soil Density (kg/m^3)	2200
Cohesion (kN/m^2)	50
Friction Angle (°)	36
Poission’s Ratio	0.35
Elasticity Modulus (kPa)	50000
Drill Bit Diameter (m)	1.118
Drill Pipe OD (m)	0.279
Allowable Plastic Radius Factor	0.50

Due to unknown ground water conditions onshore, the ground water has been assumed as at the ground surface (worst case scenario) meaning that buoyant soil conditions are considered throughout. Offshore the water level has been taken as Lowest Astronomic Tide (LAT). The proportion of soil cover set as the plastic allowance is 0.5 (worst case scenario), thus the actual depths will vary significantly and rapidly as the borehole approaches the surface at either end.

Calculation sheets are presented in Appendix G and are based on a 1.118m reamed borehole.

The variation in pressures along the borehole are shown in Figure 39, where it can be seen the permissible boreholes pressures Pemax and Pmax graphs fall rapidly towards the end due to the above-mentioned factor. Another feature to note on this graph is that the permissible pressures are significantly larger than the overburden pressure and this is due to the nature of the assumptions in the 'Dutch' model. The difference between Pemax and Pmax arises from consideration of the water table level and the added confinement pressure due to its hydrostatic effect.

Figure 39: HDD Permissible Borehole Pressures



The most significant line on Figure 39 is the Annular Pressure which is the pressure in the borehole due to the drill fluid return flow. This pressure varies as the borehole progresses and is the sum of the static head and friction (flow) head. For most of the distance the annular pressure is well below Pemax but as it approaches the borehole exit (Ch420) it exceeds the allowable pressure and this would lead to a risk of hydro-fracture within the very final stages of the HDD as it nears the exit point in the seabed (termination Ch460). This is unavoidable and will require appropriate site controls to be in place.

Ground parameters require to be confirmed through Intrusive Ground Investigation, and the hydro-fracture calculations updated as required.

12.15.2 Duct Pulling Calculations

On completion of the HDD bore the product pipe will most likely be inserted by pulling after floating offshore to the HDD exit point. Within the industry pulling is preferred as the pipe acts in tension, which eliminates potential issues of buckling associated with the compressive forces created from the pushing method. In this particular instance it is expected that pulling the product pipe from offshore to onshore is most likely the best solution, as such, product pipe pulling calculations have been carried out to understand the likely forces involved with such an installation.

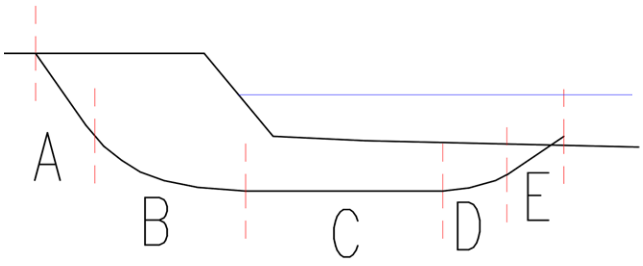
Within this analysis, the frictional forces, hydrodynamic forces and gravitational forces have been considered. Furthermore, the profile of the borehole has been considered as a series of sections to best represent the additional forces associated with areas of curvature within the borehole. As will be apparent, the required force to move the pipe will increase as the pipe progresses through the borehole.

Note that there can be a considerable difference between the static and kinematic coefficients of friction. It is assumed that normally the pipe insertion will be undertaken in one continuous operation thus the kinematic coefficient of friction would apply throughout. However, if the operation is stopped then in order to get the pipe moving again the static coefficient of friction will apply. This could be 2 or 3 times the kinematic coefficient value. Depending on the duration of the interruption, other factors such as the thixotropic properties of bentonite may also increase the force required to move the pipe.

Also, it should be noted that within this analysis the frictional forces associated prior to entering the borehole have been considered as a nominal value of 50kN. This force is assumed and should be assessed at the design stage when the method of installation has been determined.

All calculations have been considered using the bore path determined within drawing LF100034-16435-100-WIE-ZZ-XX-DR-C-90005, and a breakdown of the considered section can be seen in Figure 40 below.

Figure 40: HDD Bore Path Schematic



A summary of the HDD borehole geometry can be seen in Table 12, note that as mentioned previously it is assumed that the pipe is pulled from Section E back towards Section A.

Table 12: HDD Bore Path Geometry

	A	A:B	B:C	C:D	D:E	E
Ch	0.00	86.00	149.00	378.00	439.00	462.00
mOD	14.67	-1.00	-4.30	-10.90	-9.00	-6.91
Radius		500		500		
Slope	-8.76		-1.63		5.29	

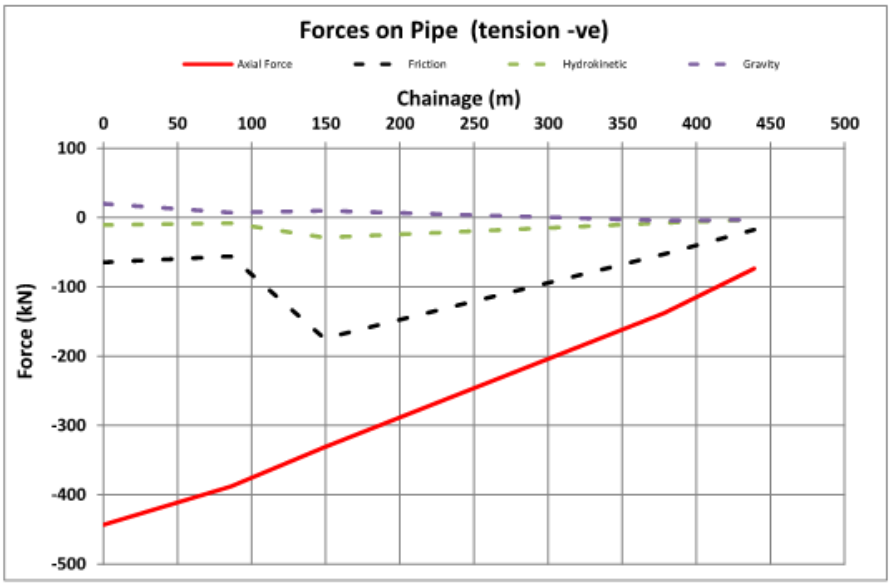
Based on information received from SPL the proposed product pipe is to be minimum circa 665mm, meaning that due to available pipe sections a nominal 800mm diameter HDPE pipe is considered. It is

assumed that the HDD drill will be circa 311mm then reamed out to a diameter circa 1118mm.

Dependent on project specifics the pipe is sometimes filled with ballast water whilst installing to counteract buoyancy. For the purpose of these calculations it has been assumed that the pipe is filled with ballast water and is unpressurised (typical when pulling) as this is the most feasible approach for the drill profile. When designing the pipe installation this should be reassessed by determining the buoyant forces and considering if ballast water is required.

Using the proposed profile and properties of the product pipe the pulling forces shown in Figure 41 were obtained.

Figure 41: HDD Product Pipe Pulling Forces



The main feature shown in Figure 41 is the Axial Force, which is a combination of the friction, gravity and hydrokinetic components. The friction arises from the action of the pipe against the soil/rock in the borehole but is somewhat lubricated by the bentonite. The gravity component is initially of resistance when pulling as the profile is of a downwards trajectory and the pipe is buoyant but then assists when the profile begins to rise. The hydrokinetic force arises from the displacement of the bentonite as the pipe is pulled through the borehole. As seen within Figure 41, the gravity and hydrokinetic components are minor when compared to friction component and have only been considered as good practice.

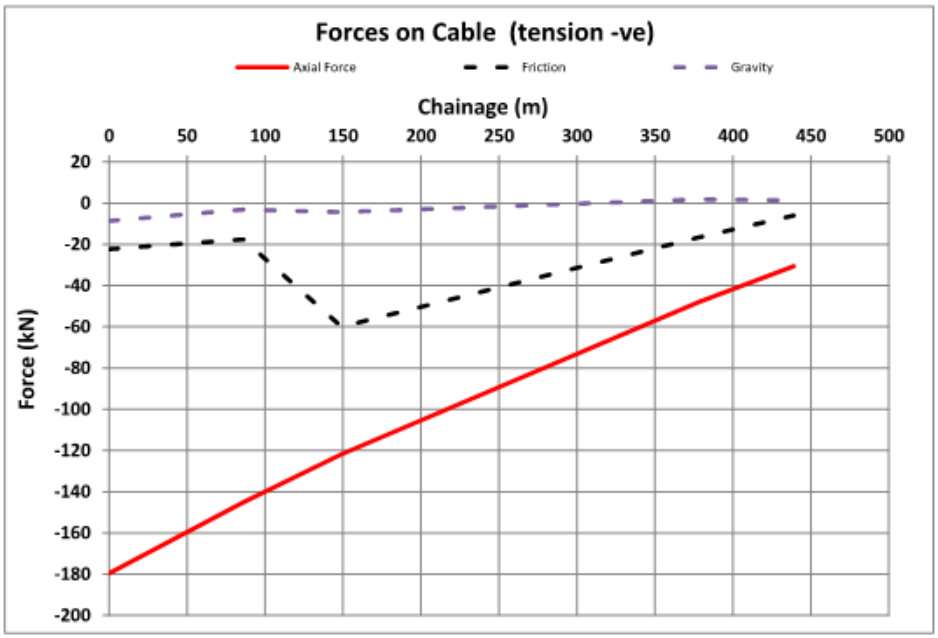
From the analysis a Maximum Required Axial Force of 443kN has been determined, however, as the forces associated with pulling the pipe from the stringing out area to the start of the borehole have been considered as a nominal force, 50kN and that various assumptions have been made regarding pipe and soil properties, then this analysis should be revised as the design process is carried out and the variables become known. Furthermore, it is assumed throughout this analysis that no obstructions are present, such as debris dislodged from the soffit of the borehole, the additional pulling forces required if this is found to be an issue will likely be significant.

From the maximum axial force required a maximum axial stress of approximately 4.9N/mm^2 can be derived, the nominal yield strength of HDPE is approximately 24N/mm^2 and from review of advisable safe pulling strength for HDD applications a axial stress of 7.5N/mm^2 to 9N/mm^2 is a limiting factor, thus the HDD pulling calculations are acceptable in terms of tensile stresses. However, these calculations should be reviewed after variables become more defined through the design process.

12.15.3 Cable Pulling Calculations

From the data sheet provided by SPL (Appendix A), the cable outside diameter is 266mm. All calculations have been considered using the bore path determined within drawing LF100034-16435-100-WIE-ZZ-XX-DR-C-90005, and a breakdown of the considered section can be seen in Figure 40 above and the HDD borehole geometry presented in Table 12. The results are presented on the cable forces graph Figure 42.

Figure 42: HDD Cable Forces



From the analysis a Maximum Required Axial Force of 180kN has been determined for the cable. From the cable data sheet received an allowable pulling force of 400kN with no bending is stated. Through reviewing the cable pulling forces within the profile bending resulted in an increase of 10% when compared with a flat profile. Therefore, reducing the allowable force by 10% results in an approximate limiting value hence allowable pulling force 360kN. Therefore, the maximum required cable pulling force of 180kN is comfortably below the limiting value of 360kN.

Given the forces associated with pulling the cable from the stringing out area to the start of the borehole have been considered as a nominal force, 25kN, and that an assumption of the friction factor between the pipe and cable has been used, then this analysis should be revised as the design process develops and the variables become known.

12.16 Budget Cost & Outline Programme

Working with a specialist drilling contractor, Stockton Drilling Ltd, a budget cost estimate and outline programme for the HDD works has been established.

- For installation of the two bores shown on Drawing LF100034-16435-100-WIE-ZZ-XX-DR-C-90001 (Cable Route 2) the Budget Cost Estimate is in the order of €8.5M to €12M.
- Outline programme including site set up, drilling of pilot hole, reaming and duct installation is in

the order of 200 days.

- It should be noted that if the drills were required to be completed from offshore to onshore, then the Budget Cost Estimate increases to €12M to €14M with outline programme increasing to circa 250 days.
- The costs and programme for Cable Route 1 would be marginally higher and longer..

Budget costs and programme should be re-visited on completion of Detailed Design, and with input from a specialist contractor such as SDL.

13. Southern Landfall: Options Appraisal

13.1 General

A number of potential constraints have been highlighted through the preparation of this report which will need to be considered in the detailed design of the southern cable landfall:

- The unknown nature of the ground conditions both onshore and offshore. From the information available the depth of superficial deposits is likely to be significant (>20m) below the proposed site compound area and launch pits through the nearshore area as indicated by the Waste Water Treatment Works outfall pipe boreholes. However, this is not confirmed by the geophysics data from around the "punch-out" location, where superficial deposits are considerably thinner (approximately 7.50m).
- From the site walkover, no definitive conclusions were made on the ground conditions and since no rock outcropping was identified there is no indication of the depth to bedrock or the dip direction of the rock. Given that the ground conditions are the controlling factor in choosing a method for the drilling, then more information on the nature and thickness of drift deposits is required, in addition to rock type, depth and dip direction. This would be established by a campaign of intrusive ground investigation to be undertaken as part of design development, should the southern landfall be confirmed as the preferred site to progress.
- Approximately 270m and 560m off-shore there are two faults running approximately north to south. These present locations where there may be a sudden variance in the depth to rock, and possible planes of weakness associated with fault brecciation, with a risk of 'frac-out' of drilling fluids or choking and collapse of the bore profile in weak and broken rock. The fault approximately 560m offshore appears to coincide with and area of mobile sediments as shown on Ultrabeam Hydrographic [12] drawing UHC19004-REV00-09 (see Appendix C).
- There are four groundwater extraction boreholes indicated to be within 2km Site, however their specific locations are not provided. Dependant on the design solution to be progressed and using information on ground and groundwater conditions to be confirmed through ground investigation, a detailed hydrogeological assessment may be required in order to ascertain the risks of aquifer contamination as a result of the proposed works.
- The site area has flooded in the past and this could not be discounted during the site works phase therefore, a detailed Flood Risk Assessment should be undertaken prior to construction works to allow measures to be in place in order to minimise disruption to works.
- Due to the historical adjacent site uses the site area is considered to be at medium risk of Unexploded Ordnance (UXO) contamination and mitigation measures must therefore be in place during any phase of construction works.
- Observations made during the walkover survey highlight a number of failures in the existing coastal embankment, comprising localised slippages and wash out. It seems likely that this is as a result of storm damage, and it is noted that the coast at this location fronts the open sea. As a result, there is considered a high potential for sediment mobilisation and scour during storm events, which should be considered further in terms of the risk of erosion leading to exposure of the landfall cables. Detailed consideration of this is beyond the scope of this report.

13.2 Options Appraisal

In consideration of the above a number of potential options have been considered for constructing the southern cable landfall and are summarised in Table 13 below.

Table 13: Options Appraisal (Southern Site)

Option	Advantages	Disadvantages
Micro-tunnelling / pipe jacking	Suitable for geological conditions. Accuracy of installation operations. Speed of installation operations. Minimum impact to environment. Pre-Cast Concrete sections installed with the advancing tunnel drive providing immediate shoring support Suitable for installation below groundwater level.	Typically, cannot be curved when drill length <1km. Typical maximum single drive of 300m to 500m (intermediate thrust jacking stations may be required). Relatively expensive. Temporary sheet piles required for Launch and Reception Pits.
Open-cut Trench	Accuracy of installation operations. Relatively Low Cost when compared to trenchless techniques.	Excavation required through erosion protection revetment requiring significant temporary works. Significant temporary works required on the foreshore. High risk of downtime due to exposed coastal location (storm damage to existing erosion protection revetment). Buried high voltage electrical cable (existing Arklow Phase 1 export cable) runs below the erosion protection revetment. Likely requirements for shallow groundwater control.
Horizontal Directional Drilling	Minimum impact to environment. Accuracy of installation operations Speed of installation operations Continuous monitoring and control during the operations	Unsuitable ground conditions (thick layer of granular deposits). Kentledge likely to be required within launch pits. Additional space required for stringing out / laydown if required. Disposal of potentially contaminated arisings.
Direct Pipe	Suitable ground conditions. Minimum impact to environment. Accuracy of installation operations. Speed of installation operations.	Limited bending radii to avoid existing/ proposed utilities along the route. Temporary sheet piles required for Launch and Reception Pits. Disposal of potentially contaminated arisings.

Table 13 above considers four typical methods for the southern cable landfall, however, due to the ground conditions expected at the site HDD has been discounted as typically where gravels are encountered the borehole requires casing which would not be possible over this length.

Micro-tunnelling has also been discounted as it cannot be guaranteed that intermediate thrust jacking stations would not be required and due to there being limited bending radii on a tunnel of this length the

exit point would be at depth and therefore require a significant retrieval pits to be formed offshore.

Open cut trenching is technically possible, but the risks associated, and temporary works requirements involved in working on the foreshore and excavating through the erosion protection revetment as well as the location of an existing high voltage electrical cable below the erosion protection revetment deem the technique unadvisable.

Direct pipe is considered the preferred option for the southern cable landfall as the technique removes most of the risk associated with weather and working on the foreshore. The ground conditions generally appear suitable, the entry angle and launch pits can be designed so as to avoid the high voltage electrical cable and a minimal bending radius can be achieved to avoid existing and proposed offshore infrastructure as well as maintaining a feasible recovery pit depth.

In the absence of site-specific ground investigation data, and on the basis of assumed ground conditions at site of Made Ground and Alluvial deposits to a significant depth over bedrock (of up to 23m), at this stage the most suitable trenchless technique is considered to be Direct Pipe.

14. Southern Landfall: Direct Pipe Concept Design

14.1 General

A Concept Direct Pipe design has been developed based on the information obtained from Desk Study, Site Walkover Survey and Topographical Survey Outputs. This is presented as Drawings No. LF100034-16435-100-WIE-ZZ-XX-DR-C-90003 and LF100034-16435-100-WIE-ZZ-XX-DR-C-90004 presented in Appendix F along with Designers Risk Analysis.

Direct Pipe is a proprietary method developed by Herrenknecht whereby a Micro-Tunnel Boring Machine (MTBM), which has cutting wheels and high pressure jetting nozzles, is launched from an excavated launch pit on-shore. A steel casing is attached to the MTBM, and the whole assembly then jacked seawards by hydraulic rams located within the launch pit. The arisings generated by the MTBM are then passed back along the casing annulus suspended in drilling mud, and processed through shakers and screeners located onshore for disposal and drilling muds recycled. The casing forms the permanent ducting through which the cabling will be installed at a later date by others.

The bore profile was developed on the basis of an approximate 670m drill length and a 800mm ducting diameter, which would require a MTBM of circa 1300mm diameter with circa 1200mm diameter casing. In plan and section, the profiles provide the optimum route exiting on the subsea cable alignment whilst providing sufficient clearances from existing and proposed infrastructure. The entry pits have been indicated as far east as possible, to allow the maximum meterage of piping to be welded prior to drilling on site. Consideration was given to increasing the size of the bore to enable the two proposed cables to be passed through a single Direct Pipe however, due to the thermal dissipation requirements of the cables this was not considered feasible.

Figures 43 to 46 show a typical Direct Pipe set-up for a Direct Pipe Cable Landfall.

Figure 43: Typical Direct Pipe Launch Pit, with sheet piling support.



Figure 44: Direct Pipe Launch Pit with excavators supporting pre-welded steel casing behind



Figure 45: Direct Pipe Hydraulic Jacking Assembly



Figure 46: Direct Pipe Arisings



14.2 Site Compound Area

The Direct Pipe technique can be installed as continuous pipe or welded together in sections. A minimum of 50m length for the thruster machine and pipe section is typically required.

The Site compound area is a relatively level playing field, with associated running track and park. Direct access to the proposed Site can be taken from Seaview Avenue via playing field access gates (approximately 3.50m wide) to the west and east of the sports centre. It is noted that height restrictions apply due to 2m high height restriction barriers, although these appear to be demountable, and also overhead cables which cross Seaview Avenue at various locations. The height of these and any clearance requirements would need confirmed, although it is acknowledged Seaview Avenue is in use as a public highway and therefore assumed there is sufficient clearance for standard HGV vehicles.

The compound is required to site a variety of units and containers which contain welfare, offices, storage, mud labs, mud mixing, mud recycling units, control unit and workshops. Individual details are specific to contractors.

A high voltage electrical cable is noted running below the erosion protection revetment and must be considered in the detailed design (utility plans are presented in Appendix D). The concept design assumes a maximum depth of 1.2m to the cable, with the Direct Pipes passing a further 2 metres below.

At the site location, a length of 180m and width of 160m are available, meaning there is adequate space for carrying out the Direct Pipe method. As part of detailed design, further planning into the dimensions of pipe sections should be assessed to maximize the space available on-site prior to any site works through discussion with a specialist contractor.

14.3 Entry Pits

A shallow launch pit is required to house the Pipe Thruster machine. Horizontal and vertical push forces are then transferred to the soil through a suitable anchorage, normally comprising sheet piles with

bracing. It is advised that the Direct Pipe is launched at a shallow entry angle of around 3-5°, however, instances of the method being used up to around 11-12° have been achieved using extensive temporary works. It is recommended that an overburden thickness of 2-3 times the outer diameter of the Direct Pipe Machine should be maintained at all times.

In this instance 7.5° entry angle is required, and is sufficiently steep to ensure that the bore path passes a minimum of 2m below any existing infrastructure (onshore high voltage electrical cable assumed to be 1.20m bgl and offshore infrastructure 2m below sea bed). However, the entry angle should be optimised as part of detailed design development, in conjunction with obtaining further information on ground conditions from an intrusive ground investigation.

14.4 Radius

A minimum radius of R5000m has been detailed, based on previous drills in similar geology, but should be considered further once full details of the underlying geology are understood. The proposed cable has a minimum bending radius of 4m and is therefore well within the designed drill profile. A technical data sheet for the proposed cable is presented within Appendix A.

14.5 Offshore Exit Points

The proposed exit points have been selected on the basis of the bore path exiting at the start of subsea Cable Route 3, whilst having a sufficient water depth for the operation of cable laying barges and support vessels. Based on Lowest Astronomical Tide Level (0.2m ACD) and bathymetrical data supplied by Ultrabeam, Hydrographic, water depth is a minimum 7.6m at the proposed exit point. This should be confirmed as suitable once the full details of the offshore support vessels are known. A 4° exit angle is proposed currently and should be confirmed/reviewed in conjunction with developing the Direct Pipe and trenching interface upon completion of the offshore ground investigation once exit point sediment thickness are confirmed.

A small target pit is required to allow recovery of the MTBM, which is likely to require installation of an offshore cofferdam and / or assisted recovery by divers / Remotely Operated Vehicle (ROV) if possible. The target pit is typically a minimum of 2m x 2m to allow recovery of the MTBM.

It is understood that the offshore cable shall be laid in a trench of approximately 2m depth in order to protect it from erosional effects of tidal currents. Therefore, a design detail will have to be carried out for running the cables from the pipeline into this trench. This is a standard detail for offshore cable landings, although the specific details will require to be developed as part of detailed design once the final cable specification is confirmed and the thickness of sediments at the proposed punch-out are confirmed through intrusive ground investigation.

Due to the exit point locations being near the mouth of the Avoca River estuary, plus the likely high energy storm environment, localised scour protection, consisting of reno-mattresses or suitably placed armourstone, may be required as protection to the cable where it exits the Direct Pipe duct as the seabed is expected to be mobile. Detailed consideration of this is beyond the scope of this study.

14.6 Anchoring of Direct Pipe Rigs

Dependent on the thruster machine used then pushing and pullback forces as large as 750t can be exerted. Therefore, adequate anchorage is required to transfer the forces into the soil or bedrock. This is typically achieved through the installation of sheet piles with bracing and propping to form the launch pits. Sheet piles must be designed as part of the temporary works package however, ground investigation data will be required to inform the design.

14.7 Guidance and Monitoring Systems

A high-precision navigation system within the Direct Pipe machine is used to survey its position in the ground. The vertical orientation is given with the aid of a hydraulic water levelling system giving accuracy to within ±3 to 15mm. The horizontal orientation is given by means of a continuous measuring gyro compass giving maximum horizonal deviations of ±5cm.

14.8 Direct Pipe Outline Calculations

During the drilling of the bore path from the Direct Pipe method the product pipe is installed within the process which eliminates the requirement to carry out pulling/pushing calculations for this step, as would be required from an HDD method. However, the process of inserting the cables is still required, thus calculations of the pulling forces involved with this process have been considered.

It is assumed that the cable installation has been carried out from offshore to onshore by a pulling method as this is the best solution for this specific project.

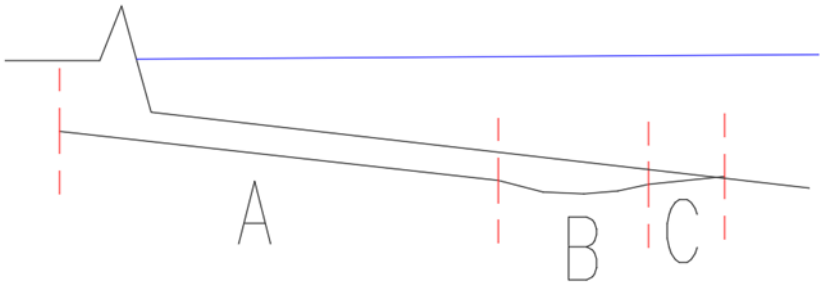
Within this analysis, the frictional forces and gravitational forces have been considered. Furthermore, the profile of the borehole has been considered as a series of sections to best represent the additional forces associated with areas of curvature within the borehole. As will be apparent, the required force to move the cable will increase as the cable progresses through the borehole.

Note that there can be a considerable difference between the static and kinematic coefficients of friction. It is assumed that normally the cable insertion will be undertaken in one continuous operation thus the kinematic coefficient of friction would apply throughout. However, if the operation is stopped then in order to get the cable moving again the static coefficient of friction will apply. This could be 2 or 3 times the kinematic coefficient value.

Also, it should be noted that within this analysis the frictional forces associated prior to entering the borehole have not been calculated and have been assumed as a nominal value, 25kN. These forces should be assessed at the design stage when the method of installation has been determined.

All calculations have been considered using the bore path determined within drawing LF100034-16435-100-WIE-ZZ-XX-DR-C-90003, and a breakdown of the considered section can be seen in Figure 47 below.

Figure 47: Direct Pipe Bore Path Schematic



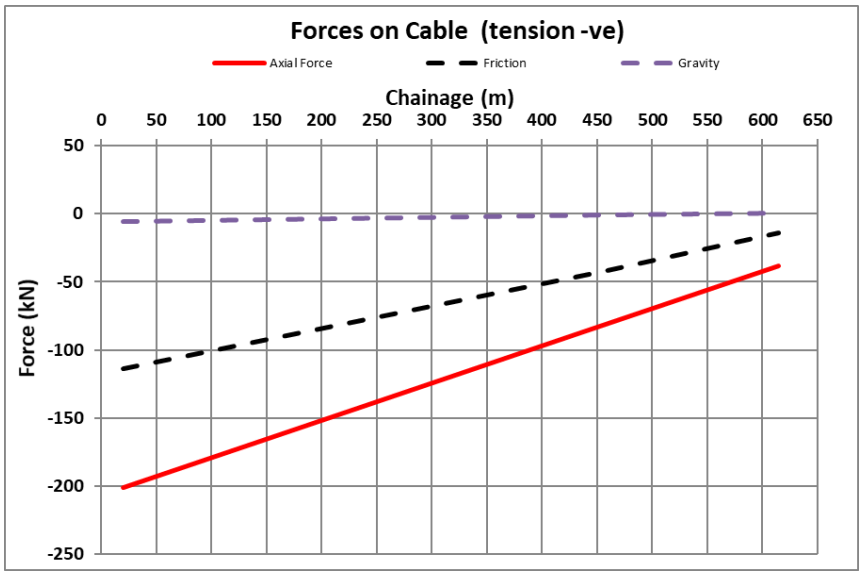
A summary of the Direct Pipe borehole geometry can be seen in Table 14, note that as mentioned previously it is assumed that the cable is pulled from Section C back towards Section A.

Table 14: Direct Pipe Borehole Geometry

	A	A:B	B:C	C
Ch	20.00	455.00	615.00	669.00
mOD	-2.40	-11.44	-12.12	-11.50
Radius		5000		
Slope	-1.19		0.66	

From the data sheet provided by SPL (Appendix A), the cable outside diameter is 266mm. All calculations have been considered using the bore path determined within drawing LF100034-16435-100-WIE-ZZ-XX-DR-C-90003, and a breakdown of the considered section can be seen in Figure 47 above and the Direct Pipe borehole geometry presented in Table 14. The results are presented on the cable forces graph Figure 48.

Figure 48: Direct Pipe Cable Pulling Forces



From the analysis a Maximum Required Axial Force of 202kN has been determined for the cable installation. From the cable data sheet received an allowable pulling force of 400kN with no bending is stated. Through reviewing the cable pulling forces within the profile, bending resulted in an increase of 3% when compared with a flat profile. Therefore, reducing the allowable force by 3% results in an approximate limiting value hence allowable pulling force 388kN. Therefore, the maximum cable pulling force of 202kN is below the limiting value of 388kN.

Given the forces associated with pulling the cable from the stringing out area to the start of the borehole have been considered as a nominal force, 25kN and that an assumption of the friction factor between the pipe and cable has been used, then this analysis should be revised as the design process develops and the variables become known.

14.9 Budget Cost & Outline Programme

Working with a specialist drilling contractor, Stockton Drilling Ltd ('SDL'), a budget cost estimate and outline programme for the Direct Pipe works has been established.

- For installation of the two Direct Pipes shown on Drawing LF100034-16435-100-WIE-ZZ-XX-DR-

C-90003 the Budget Cost Estimate is in the order of €10.5M to €14M.

- Outline programme including site set up and duct installation is in the order of 160 days.

Budget costs and programme should be re-visited on completion of Detailed Design, and with input from a specialist contractor such as SDL.

15. Conclusions and Recommendations

As outlined in Sections 10.2 and 11.2 it is concluded that the most suitable option for the northern landfall is Horizontal Directional Drilling and that the most suitable option for the southern landfall is Direct Pipe.

However, there are further factors which need to be considered as part of the site selection process and these are summarised in Table 15 below.

Table 15: Site Selection: Advantages and Disadvantages

Option	Advantages	Disadvantages
Northern Site (HDD)	Greenfield sites minimal public disruption. Negligible UXO risk. Limited utilities in the vicinity (all above ground) of either site. Shorter cable landing bore path (Cable Route 2 approximately 365m per bore, Cable Route 1 460m). Shorter Offshore connection route (~12km).	Earthworks required to form level compound area. No specific cable landing ground investigation onshore or offshore completed to date. Narrow (single track road access) with overhead cables.
Southern Site (Direct Pipe)	Suitable flat site area. Readily accessible. Close to existing infrastructure	Public space will be impacted for the duration of the works. Likely access road through housing estate, impacting local community. Medium risk of UXO contamination. Access will need to be negotiated following completion of bore path and cable pulling to onshore jointing bay on a permanent basis. Existing below ground services. Offshore consented waste water treatment works outfall may be installed before direct pipe and will need considered in detailed design. No specific cable landing ground investigation has been completed onshore or offshore. Longer cable landing bore path (approximately 670m per bore) Longest offshore cable connection route (~20km).

Option	Advantages	Disadvantages
		Site area within a potential flood zone. Consideration must be given to erosional effects of the Avoca River outflow.

Whilst it is technically feasibility to use either the north or south cable landing sites, Table 13 above clearly shows that the northern site offers more advantages and less disadvantages when compared with the southern site.

This study therefore concludes that, on technical grounds only, the Northern Landfall site using a method of Horizontal Direction Drilling would be the preferred option for the cable landfalls, reference should be made to the Northern Desk study report [1] for comparison of northern landing sites.

15.1 Recommendations

15.1.1 Northern Landfalls

The following recommendations are made in relation to developing detailed design for either of the northern cable landfall:

- A campaign of onshore and nearshore intrusive ground investigation is required;
- For the onshore ground investigation, it is considered that trial pits and cable percussive boreholes with rotary core follow-on would be required. All boreholes should be marginally offset from the proposed bore paths to avoid the creation of potential weak zones that may impact “frac-out”;
- Boreholes should be sunk to at least 5m below the proposed bore path depth;
- A suite of suitable laboratory testing should be completed, including rock strength testing and soils classification testing, with all results to be presented in a Ground Investigation Factual Report;
- For the nearshore ground investigation, it is considered likely that the extents of the geophysics completed to date have been limited by water depths and therefore further nearshore geophysics is not considered appropriate. It is recommended that the offshore ground investigation comprises cable percussive boreholes with rotary core follow-on, interspersed with CPTu data from a jack-up (or similar) barge in order to ascertain the ground conditions from the proposed exit point back to the beach/ base of cliffs;
- Although accessible to farm traffic, due to the narrow nature of the access road (R750) it would be prudent to undertake a route study which includes a swept path analysis, traffic surveys, a review of any culvert/ bridge crossings and overhead utilities; and
- A supplemental bathymetric survey should be considered subject to the findings of the intrusive ground investigation, using suitable vessels with a shallow draught, to cover the data gap in the existing survey.

15.1.2 Southern Landfall

The following recommendations are made in relation to developing detailed design of the southern cable landfall:

- A campaign of onshore and nearshore intrusive ground investigation is required;
- Prior to any site works a UXO contamination survey should be completed to clear all excavation positions. This should be undertaken by an experienced Explosives Engineer;
- UXO awareness briefing should be carried out for site workers by a suitably qualified UXO expert;
- For the onshore ground investigation, trial pits and cable percussive boreholes with rotary follow-on boreholes to prove rockhead and gather soil samples. Groundwater and ground gas monitoring standpipes should be installed and monitored included as part of the ground investigation;
- A suite of suitable laboratory testing should be completed, including soils classification testing, rock strength, contamination testing and soil aggressivity testing (BRE SD1) all results to be presented in a Ground Investigation Factual Report;
- For the nearshore ground investigation, further nearshore geophysics should be completed utilising a shallow draft vessel.
- It is recommended that the offshore ground investigation comprises cable percussive boreholes with rotary core follow-on (if shallow rock is determined), interspersed with CPTu data from a jack-up (or similar) barge in order to ascertain the ground conditions from the proposed onshore/ offshore transition bay back to the coastal erosion revetment;
- Flood Risk Assessment (FRA) should be completed given the area is within a historic flood plain from the adjacent Avoca River;
- A Ground Penetrating Radar Survey is recommended to identify all utilities below any areas of excavation are and should include the revetment in order to identify the Arklow Phase 1 cable route.

16. References

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APPENDICES

A. Cable Data Sheet

1.1 Design data for TKRA 245 kV 3x1x2000 mm² KQ + FO

Conductor	Diameter of conductor Key stone shaped copper conductor filled with a water-blocking semiconducting compound	51.9 mm
Conductor screen	Extruded layer of semiconducting crosslinked polyethylene	
Insulation	Nominal thickness Diameter over insulation Extruded layer of insulating crosslinked polyethylene (XLPE)	22.0 mm 99.4 mm
Insulation screen	Extruded layer of semiconducting crosslinked polyethylene	
Longitudinal water-block	Semiconducting water-swellable tape	
Lead sheath	Nominal thickness The sheathing material is lead alloy	2.1 mm
Inner sheath	Nominal thickness Extruded sheath of semiconducting polyethylene	2.2 mm
Laying up	The cores are laid up. Extruded PE fillers and possibly one fiber optic cable are located in the interstices between the cores.	
Armour bedding	Nylon tapes	
Armour	Shape of armour wires Diameter of armour wires Number of armour wires, approx. One layer of round galvanized steel wires	Round 5.6 mm ⌀ 138
Outer serving	Two layers of polypropylene yarn and bitumen	
Diameter	Diameter of cable, approx.	266 mm
Weight	Total weight of cable, approx.: - in air - submerged	 139 kg/m 92 kg/m

1.2 Mechanical data for TKRA 245 kV 3x1x2000 mm² KQ + FO

Bending radius	Minimum permissible bending radius during laying	4.0 m
Pulling tension	Maximum permissible pulling tension (no bending)	400 kN

1.3 Electrical data for TKRA 245 kV 3x1x2000 mm² KQ + FO in HDD

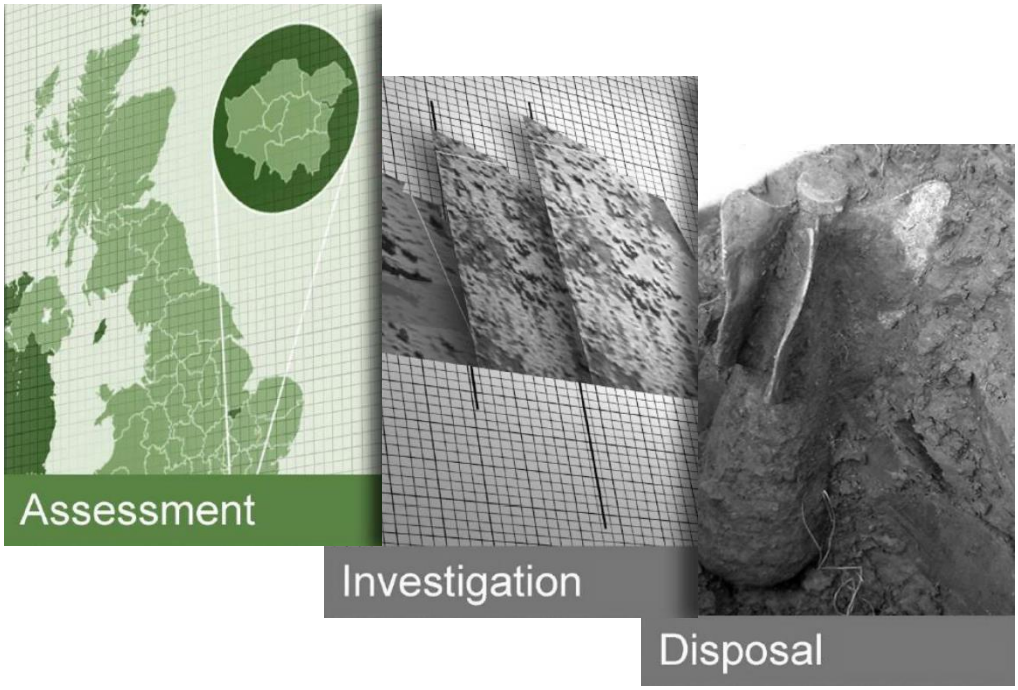
Current rating	Current rating in Bentonite filled HDD	950 A
Conductor temperature	Max. permissible conductor temperature	90 °C
Ambient conditions	Max. ambient temperature for the cable in seabed at burial depth Max. burial depth in seabed Thermal resistivity of seabed Thermal resistivity of Bentonite Inner diameter of HDD Outer diameter of HDD Lead sheaths and armour are bonded and earthed at both ends	10 °C 10.0 m 1.0 K.m/W 0.65 K.m/W 705 mm 660 mm
Frequency	Frequency	50 Hz
Load factor	Load factor	100 %
Short circuit current	Permissible thermal short circuit current: - in the conductor for 1.0 sec - in the lead sheaths for 1.0 sec	 286 kA 3x18 kA
Rated voltage	Rated RMS system voltage (U) Rated RMS voltage between conductor and screen (U_o)	220 kV 127 kV
Highest voltage	Highest continuous RMS system voltage (U_m)	245 kV
Basic insulation level	Lightning impulse withstand voltage (1.2/50 µsec.)	1050 kV
Electrical stress	Maximum electrical stress in insulation at rated voltage U_o	7.8 kV/mm
Conductor resistance	Max. d.c. resistance at 20 °C a.c. resistance at 90 °C	0.0090 Ω/km 0.0181 Ω/km
Cable impedance	Cable impedance at 940 A	0.03 + j0.11 Ω/km
Zero impedance	Zero sequence impedance at 940 A	0.16 + j0.09 Ω/km
Capacitance	Capacitance between conductor and screen	0.24 µF/km
Charging current	Charging current at 220 kV	9.5 A/km
Loss angle	Maximum value at ambient temperature and rated voltage	0.001
Losses	Losses at 220 kV and 940 A in HDD: - conductor losses - dielectric losses - sheath losses - armour loss Total losses per cable	 3x16.0 W/m 3x1.2 W/m 3x8.1 W/m 8.4 W/m *) 84.3 W/m

*) Assumed reduced armouring losses

B. Unexploded Ordnance Reports

- LF100034-Zetica_UXO_Pre-Desk_Study_Assessment_Northern
- LF100034-P9313-19-Zetica_UXO_Desk_Study_Arklow_County_Wicklow

zeticaUXO



Arklow, County Wicklow - UXO Desk Study & Risk Assessment

Drafted by	**Alex Seddon & Robert Lea**
Checked by	**Stefan Lang**
Authorised by	**Mike Sainsbury**

Document Title	**UXO Desk Study & Risk Assessment**
Document Ref.	**P9313-19-R1**
Revision	**A**
Project Location	**Arklow, County Wicklow**
Client	**Waterman Group**
Date	**31st January 2020**

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UXO DESK STUDY & RISK ASSESSMENT

EXECUTIVE SUMMARY

Key findings: Potential explosive contamination hazard on the Site.

Key actions: An explosive contamination survey is recommended to determine the extent of the explosive hazard (if any) and its impact on intended Site use.

Explosive Contamination

Between 1895 and 1920 the Site was encompassed by Kynoch's Arklow explosives works. This produced explosives for military and commercial use, including nitroglycerine (NG), nitrocellulose (NC), cordite, and a variety of low-yield proprietary explosives for industrial use.

A canal and part of the factory's tramway network ran across the Site. The line was used to transport explosive compounds and finished explosives between the two main sections of the factory. The canal on the Site was infilled prior to the factory's closure.

Tramways and canals were common locations of spillage at explosives factories, particularly at loading points, bends and junctions. It was also common for residues to be emptied from barges into canals. It also cannot be discounted that the canal was infilled with explosive contaminated materials from the factory.

Given this, it is considered prudent to assign these parts of the Site a moderate hazard level due to the potential for explosive contamination in the soils at depth.

There is also evidence that the post-World War Two (WWII) land reclamation of the Site may have resulted in materials from the former explosives factory being incorporated within the Made Ground. This has the potential to be contaminated with explosives in discrete locations.

It is considered that there is a moderate hazard in the post-WWII Made Ground on the Site due to potential explosive contamination.

Such contamination can provide a potential explosive detonation (or deflagration) hazard in high concentrations, and a toxic hazard in lower concentrations.

No significant sources of explosive contamination hazard have been identified on the marine part of the Site, which is assigned a low hazard level.

UXO Hazard

No records have been found indicating that the Site was bombed and no other significant sources of UXO hazard have been identified on the Site.

Given this, it is considered that the Site has a low UXO hazard level.

The figures below, reproduced as Figures 9 and 10 in the main report, provide explosive contamination and UXO hazard zone plans of the Site.

Figure	Explosive contamination hazard zone plan of the Site



Source: Zetica *Not to Scale*

Legend					
	Very Low		Low		Moderate
	High		Very High		Site boundary

Figure	UXO hazard zone plan of the Site



Source: Zetica *Not to Scale*

Legend					
	Very Low		Low		Moderate
	High		Very High		Site boundary

The main findings of the report are summarised below.

- Records indicate that in 1895 Kynoch's Arklow explosives works was established on an area encompassing the Site. A canal and tramway supplying the works ran across the Site.
- During World War One (WWI) The Kynoch factory supplied large quantities of explosives for the war effort. This included NG, NC and cordite. The factory closed in 1920.
- No records have been found indicating that any military activity or bombing occurred on the Site during WWII.
- No records of military activity on the Site post-WWII have been found.
- There is evidence that the post-WWII reclamation of marshland on the Site may have resulted in explosive contaminated materials being incorporated in the Made Ground.

Data Confidence Level

The findings of this report were based on good corroborative evidence of the military activity and bombing on the Site.

Proposed Works

Proposed works are to be confirmed. At this stage, it is understood that they may comprise intrusive ground investigations and Horizontal Directional Drilling (HDD) associated with the installation of an offshore cable.

Risk Assessment

The Table below, reproduced as Table 2 in the main report, provides a risk assessment for potential works on the Site.

Further details on the methodology for the risk assessment are provided in Section 8.2 of the main report.

Table Risk assessment for the Site

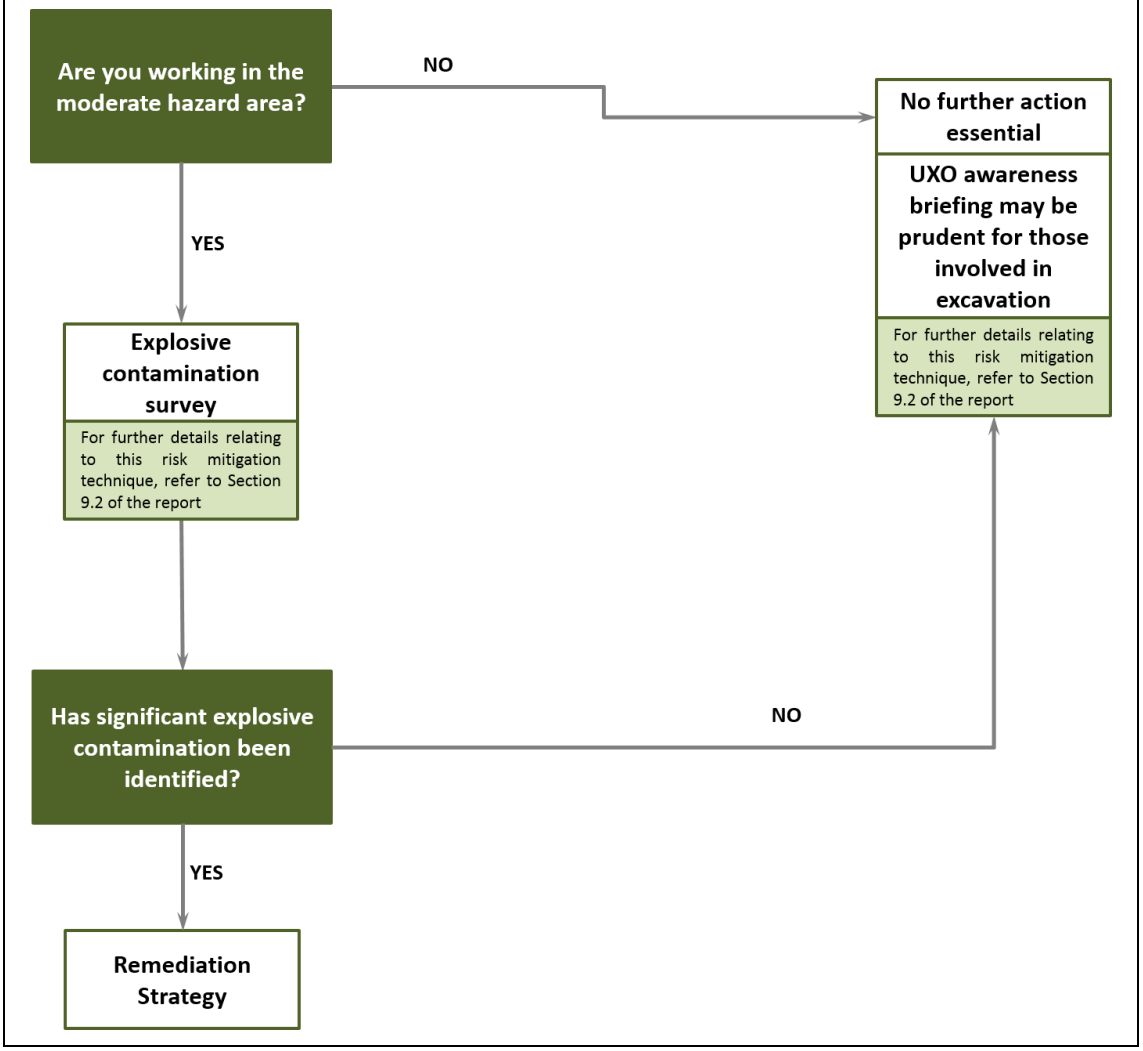
Hazard Zone	Potential Hazard	Anticipated Works	PE	PD	P = PE x PD	Likelihood	Severity	Risk Rating	UXO Risk
Moderate	Explosive Contamination	Excavations	3	1	3	2	4	8	Moderate
		Boreholes	3	1	3	2	3	6	Moderate
		HDD	3	1	3	2	3	6	Moderate
	UXB	Excavations	1	1	1	1	5	5	Low
		Boreholes	1	1	1	1	4	4	Low
		HDD	1	1	1	1	4	4	Low
	Other UXO	Excavations	1	1	1	1	4	4	Low
		Boreholes	1	1	1	1	3	3	Low
		HDD	1	1	1	1	3	3	Low
Low	Explosive Contamination	Excavations	1	1	1	1	4	4	Low
		Boreholes	1	1	1	1	3	3	Low
		HDD	1	1	1	1	3	3	Low
	UXB	Excavations	1	1	1	1	5	5	Low
		Boreholes	1	1	1	1	4	4	Low
		HDD	1	1	1	1	4	4	Low
	Other UXO	Excavations	1	1	1	1	4	4	Low
		Boreholes	1	1	1	1	3	3	Low
		HDD	1	1	1	1	3	3	Low

PE (Probability of Encounter), PD (Probability of Detonation), P (Overall Probability)

Risk Mitigation Plan

The Figure below, reproduced as Figure 11 in the main report, provides a risk mitigation plan to ensure that the risk for the proposed works is reduced to As Low As Reasonably Practicable (ALARP).

Figure Recommended risk mitigation plan for the Site



Further details on the recommended risk mitigation techniques are given in Section 9.2 of this report.

The Table below, reproduced as Table 3 in the main report, summarises the risk for proposed works on the Site and recommended techniques to mitigate the risk.

Table	Summary of risk and mitigation recommendations

Proposed Works	Risk	Recommended Mitigation
Excavations		**Proceed with works** – if additional comfort is required to address the residual UXO hazard, a formal UXO awareness briefing can be provided.
Drilling		**Proceed with works**
All Works		**Explosive Contamination Survey** – to determine the extent of explosive contamination (if any) and its impact on intended site use. This should be undertaken by an experienced Explosives Engineer.

In summary, it is recommended that an explosive contamination survey is carried out prior to any works in the moderate hazard area.

What Do I Do Next?

If you wish to proceed with risk mitigation, Zetica would be happy to assist. Just contact us via phone (01993 886682) or email (uxo@zetica.com) and we can provide a proposal with options and prices.

If you have requirements to identify other buried hazards (such as mapping utilities or obstructions) we can provide these surveys.

If proposed works on the Site change, or additional works are planned, contact Zetica for a re-assessment of the UXO risk and the risk mitigation requirements.

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Figure 4 Historical map of 1912 showing the explosives factory at Arklow

Figure 5 Plan showing damage caused by NC mixing hut explosion, 16th September 1917

Figure 6 Compiled bomb impact map for the vicinity of the Site

Figure 7 Plan of 12-pdr firing templates at Arklow, 20th July 1915

Figure 8 Extract of Admiralty chart for the vicinity of the Site

Figure 9 Explosive contamination hazard zone plan of the Site

Figure 10 UXO hazard zone plan of the Site

Figure 11 Recommended risk mitigation plan for the Site

Plate 1 Recent aerial photograph of the Site

Plate 2 Photograph of the nitroglycerine hill at Arklow, circa 1900

Plate 3 Aerial photograph of the Site, May 1957

Plate 4 Recent aerial photograph of the Site

Table 1 Estimated average maximum bomb penetration depths

Table 2 Risk assessment for the Site

Table 3 Summary of risk and mitigation recommendations

ABBREVIATIONS

AA	Anti-Aircraft
ALARP	As Low As Reasonably Practicable
ARP	Air Raid Precaution
AXO	Abandoned Explosive Ordnance
BD	Bomb Disposal
BDO	Bomb Disposal Officer
BDU	Bomb Disposal Unit
CMD	Conventional Munitions Disposal
DAB	Delayed Action Bomb
DCLG	Department of Communities and Local Government
EO	Explosive Ordnance
EOC	Explosive Ordnance Clearance
EOR	Explosive Ordnance Reconnaissance
ERW	Explosive Remnants of War
ESA	Explosive Substances and Articles
FFE	Free From Explosives
HAA	Heavy Anti-Aircraft
HE	High Explosive
HSE	Health and Safety Executive
IB	Incendiary Bomb
IED	Improvised Explosive Device
IEDD	Improvised Explosive Device Disposal
JSEODOC	Joint Services EOD Operations Centre
LAA	Light Anti-Aircraft
MoD	Ministry of Defence
NC	Nitrocellulose
NG	Nitroglycerine
OB	Oil Bomb
PM	Parachute Mine
PUCA	Pick Up and Carry Away
RAF	Royal Air Force
RFC	Royal Flying Corps
TEP	Time Expired Pyrotechnics
UXAA	Unexploded Anti-Aircraft
UXB	Unexploded Bomb
UXIB	Unexploded Incendiary Bomb
UXO	Unexploded Ordnance
WWI	World War One
WWII	World War Two

UXO DESK STUDY & RISK ASSESSMENT

Please read: Zetica has colour coded each paragraph. Paragraphs with black text on a white background are paragraphs that provide site-specific information or information specifically researched as part of this project.

Boxed paragraphs in a dark green text with a green background are paragraphs providing general information and, where appropriate, links to online resources giving further detail. These are all available at www.zeticauxo.com. If you cannot gain access to these resources, Zetica can forward them on request.

1 INTRODUCTION

1.1 Project Outline

Zetica Ltd was commissioned by Waterman Group to carry out an Unexploded Ordnance (UXO) Desk Study and Risk Assessment for an area of approximately 4.4 hectares (ha) at Ferrybank in Arklow, County Wicklow ('the Site').

The aim of this report is to gain a fair and representative view of the UXO hazard for the Site and its immediate surrounding area in accordance with the Construction Industry Research and Information Association (CIRIA) C681 'Unexploded Ordnance (UXO), a Guide for the Construction Industry' and C754 'Assessment and Management of Unexploded Ordnance (UXO) Risk in the Marine Environment'.

Where appropriate, this hazard assessment includes:

- Likelihood of ordnance being present.
- Type of ordnance (size, filling, fuze mechanisms).
- Quantity of ordnance.
- Potential for live ordnance.
- Probable location.
- Ordnance condition.

It should be noted that some military activity providing a source of UXO hazard may not be recorded and therefore there cannot be any guarantee that all UXO hazards affecting the Site have been identified in this report.

1.2 Sources of Information

Zetica Ltd researched the military history of the Site and its surrounding area using a range of information sources. The main sources of information are detailed in the following sections and referenced at the end of this report.

1.2.1 Zetica Ltd Defence Related Site Records

Zetica Ltd's in-house records were consulted, including reference books and archived materials from past work in the region. Relevant documents have been cited within the bibliography of this report.

1.2.2 Zetica Ltd Bombing Density Records and Maps

Reference has been made to the Zetica Ltd bomb risk maps located on Zetica's website (http://zeticauxo.com/downloads-and-resources/risk-maps/)

1.2.3 Ministry of Defence and Government Records

Government departments and units within the Ministry of Defence (MoD) were approached for information of past and present military activity in the area.

1.2.4 Other Historical Records, Maps and Drawings

Numerous reference documents including historical maps, aerial photographs and drawings have been consulted from sources such as the British National Archives, the US National Archives & Records Administration (NARA), the Imperial War Museum (IWM) and the British Newspaper Archive.

Ordnance Survey Ireland (OSI) was consulted for historical mapping, and the Geological Survey of Ireland was consulted for geological data.

1.2.5 Local Authority Records

Information has been obtained from Wicklow County Council.

1.2.6 Local Record Offices and Libraries

The Library of Birmingham and Wicklow County Archives were consulted.

1.2.7 Local Historical and Other Groups

Local history groups and archaeological societies were consulted.

1.3 Data Confidence Level

In general, there is a high level of confidence in the researched information sources used for this report. Exceptions to this are specifically detailed in the text of the report.

2 THE SITE

2.1 Site Location

The Site is centred on Ordnance Survey National Grid Reference (OSNGR) SG 207304. It is located in Ferrybank, north of the River Avoca and approximately 0.9km east-northeast of Arklow town centre.

The majority of the Site comprises a running track associated with Arklow Sports and Leisure Centre. The eastern boundary of the Site occupies an area of coastal sea defences.

The Site is bounded to the north by Arklow Sports and Leisure Centre and Seaview Avenue, to the east by the Irish Sea, to the south by Mill Road, and to the west by North Quay and a car park.

Figure 1 is a Site location map and Plate 1 is a recent aerial photograph of the Site.

Figure 1	Site location map



Source: OpenStreetMap *Not to Scale*

Legend	Site boundary

Plate 1	Recent aerial photograph of the Site



Source: Google Earth *Not to Scale*

Legend	Site boundary

3 MILITARY ACTIVITY

The following sections outline the recorded military activity in the vicinity of the Site. The potential UXO hazard from WWI and WWII bombing is detailed in Section 4.

Each sub-section provides hyperlinks to further information on potential sources of UXO hazard. These are also available at www.zeticauxo.com. If you cannot gain access to these resources, Zetica can forward them on request.

3.1 Explosives Factories, Munitions Depots and Disposal Areas

For further information on explosives factories, munitions depots and disposal areas, and the potential UXO hazards associated with them, see Appendices 2.1 to 2.3. Alternatively, follow the links below:

- Explosives Factories
- Munitions Depots
- Munitions Disposal Areas

Records indicate that from 1895 to 1920 the Site was encompassed by Kynoch's Arklow explosives works. An operational history of the works is given below.

3.1.1 Operational history of Kynoch's Arklow works

In 1895 G Kynoch and Co Ltd purchased approximately 170 acres of land at Arklow, encompassing the Site, to build a cordite factory for the British government.

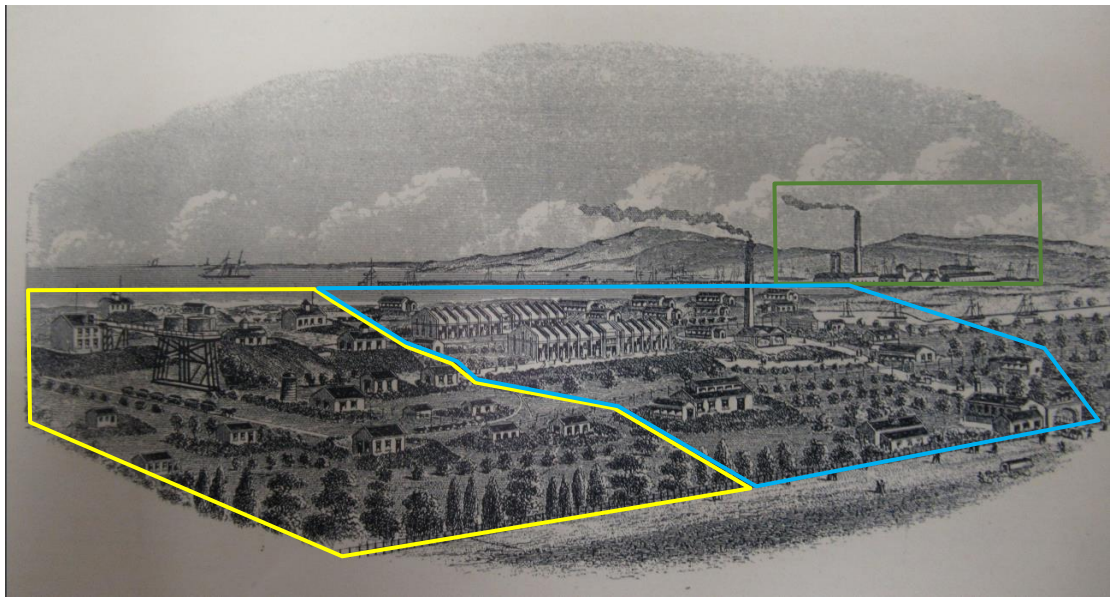
This also included the disused Arklow Chemical Works, which was incorporated into the factory.

By late 1900 the works was producing nitrocellulose (NC – also known as Guncotton), nitroglycerine (NG), cordite, dynamite, gelignite, gelatine dynamite, and Kynite (see Appendix 4 for further details on these explosives).

Figure 2 is a sketch of the works dating from circa 1900. It shows the explosives manufacturing section, with areas of the factory responsible for producing NG and cordite visible in the foreground.

Note that in the NG section there is an area of buildings located on raised sand mounds. This is referred to as an "NG Hill", where gravity is used to move the NG between manufacturing stations.

Figure 2	Sketch of Kynoch's Arklow works, circa 1900



Source: Library of Birmingham

Legend	NG hill	Cordite section	Chemical works

Plate 2 is a photograph of the NG Hill dating from circa 1900.

Plate 2	Photograph of the nitroglycerine hill at Arklow, circa 1900



Source: The Kynoch Journal

The Boer War resulted in a large demand for cordite from the British Government, which was the factory's largest client. Government demand continued until 1907 when a batch of cordite from Arklow was rejected for allegedly being of inferior quality.

The British government ceased buying cordite from Kynoch and until WWI the factory sustained itself by producing explosives for sporting firearms and industrial use.

The factory was divided into 2No. main sections. The Arklow Chemical Works, approximately 0.2km south of the Site, produced the raw chemicals required for explosives manufacturing, including sulphuric acid and nitric acid, as well as nitrates of lead and acetone.

Figure 3 is an extract from the historical map of 1912, showing the chemical works section.

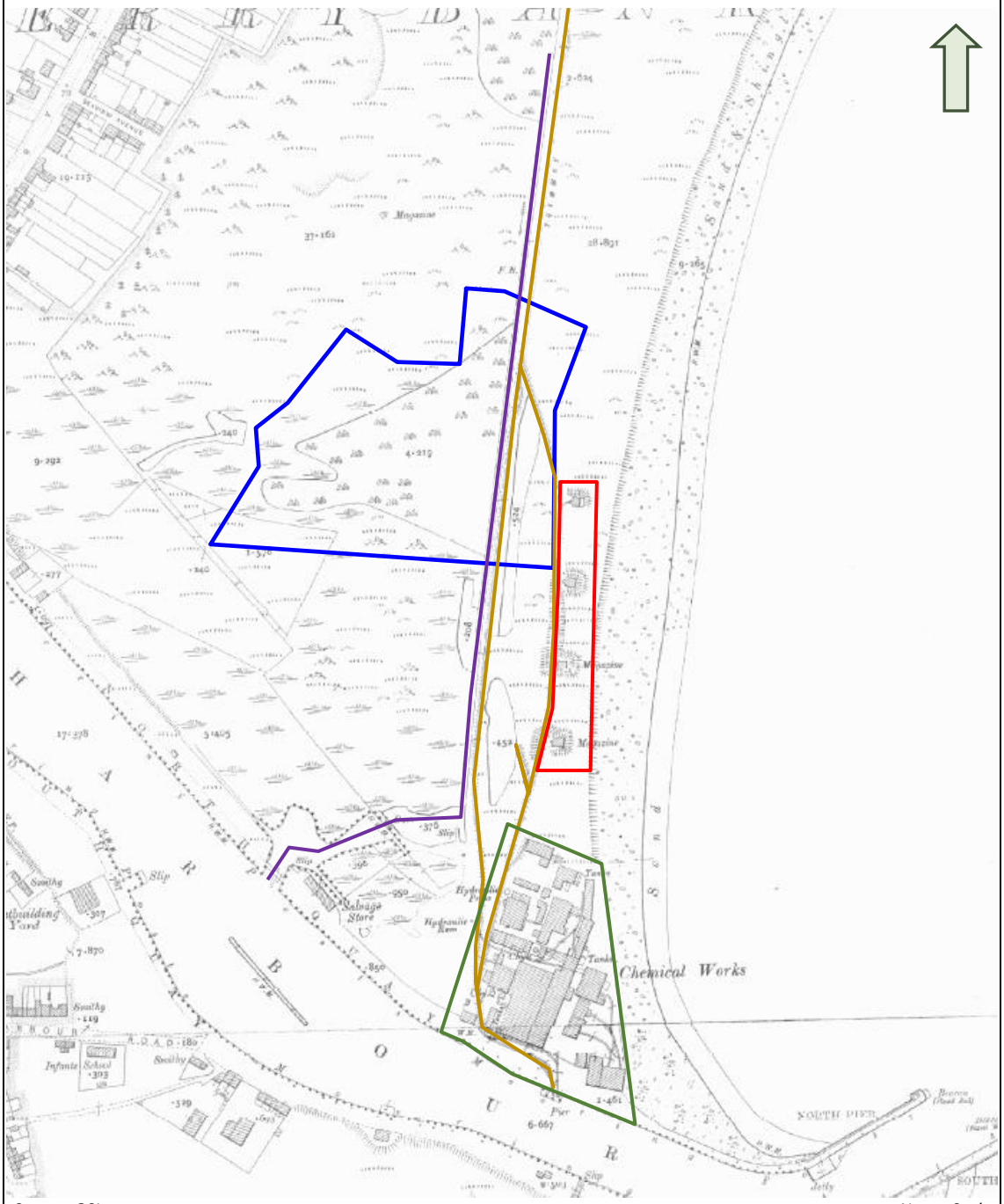
When the factory was opened, a tramway and canal were established to connect the chemical works to the explosives manufacturing section. Both the tramway and canal crossed the Site.

Note that by 1912 the canal terminated approximately 0.1km north of the Site, with the remainder having been filled in.

Storage magazines were located adjacent to the Site. It is likely that these were used for storing finished explosives prior to them being taken to the docks for shipment overseas.

The majority of the Site comprised unoccupied marshland.

Figure 3	Historical map of 1912 showing Arklow Chemical Works



Source: OSI *Not to Scale*

Legend	Site boundary	Chemical works	Magazines
	Tramway	Canal	

The explosives manufacturing section was located between approximately 0.6km and 1.7km northeast of the Site.

This is where the chemicals were refined and processed into finished explosives, including NG, NC, cordite and various types of blasting explosives used for commercial mining operations.

Figure 4 is an extract from the historical map of 1912, showing the explosives manufacturing section.

The direction of production was counter-clockwise. Trams would enter the works through the primary magazines approximately 0.6km northeast of the Site. Here they would deposit raw chemicals and other materials needed to manufacture the explosives, such as un-nitrated cellulose.

From here they would be moved to the NC mixing section, approximately 1.4km northeast of the Site, or the NG section, approximately 1.2km northeast of the Site.

The NG section is where nitrogen compounds produced at the chemical works were processed, and became purified NG. Purified NG was the primary basis for the explosives manufactured by Kynoch.

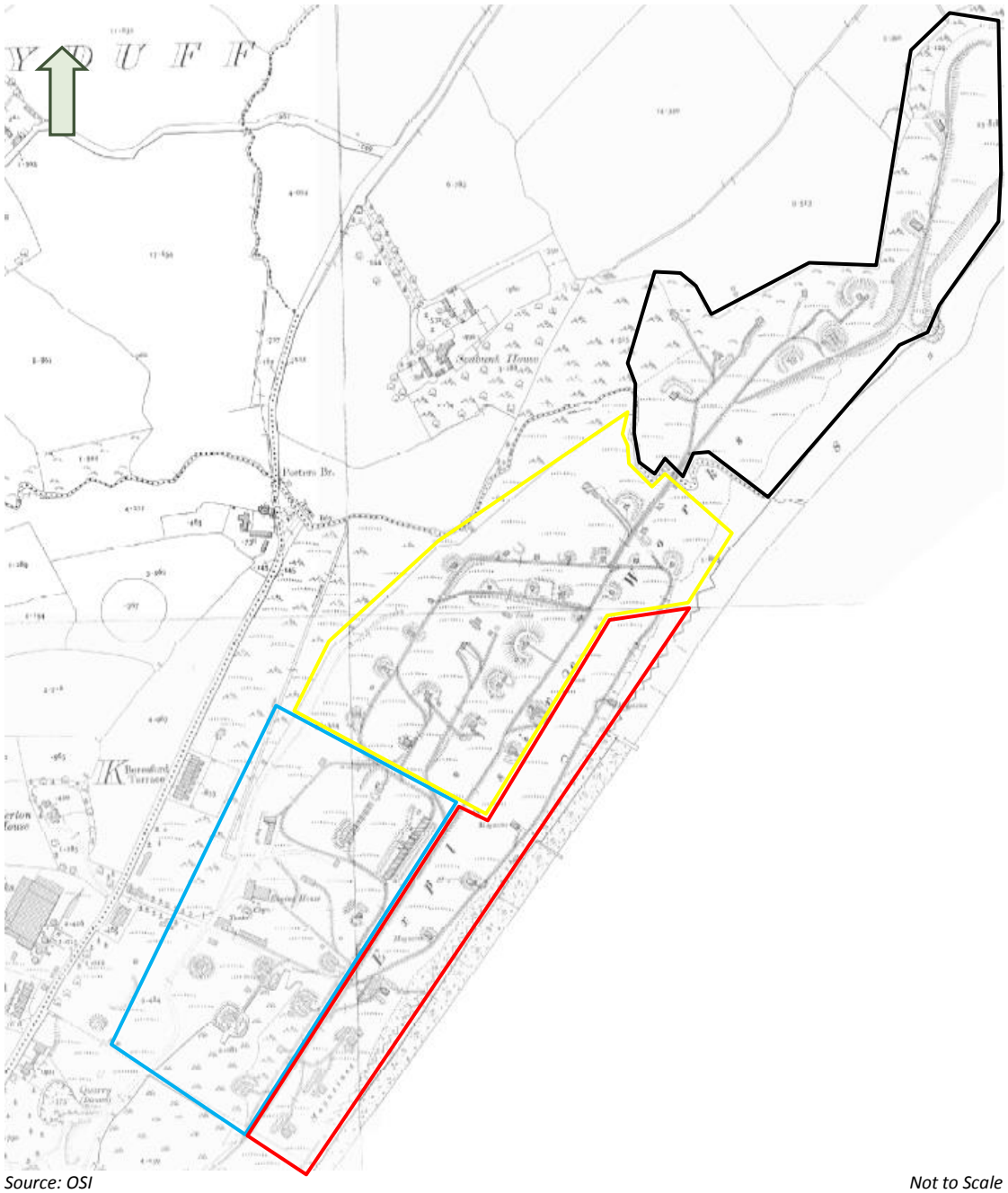
The NC mixing section was where cellulose was combined with NG and then dried. This is a deliberately isolated area of the factory, due to the high risk of explosion in the mixing process.

Blasting explosives for industrial use were also produced in this section. Cartridges were manufactured and packed with blasting explosives, including Arkite, Kynite, Anchorite, Monarkite, Erin Gelignite, and dynamite. These were all primarily NG-based, and could be synthesised simply from chemicals produced at the Arklow Chemical Works.

The cordite section was where NC was combined with NG in presses to create finished cordite.

The cordite was then moved from the presses to drying houses and, once dry, was packed ready for shipment.

Figure 4	Historical map of 1912 showing the explosives factory at Arklow



Source: OSI *Not to Scale*

Legend	NG Hill & NG processing buildings	Magazines
	NC mixing & charge packing	Cordite processing & packing

At the outbreak of WWI Kynoch's Arklow works resumed producing cordite for the military. The factory expanded during the war, with the number of employees increasing from around 600No. to 5,000No.

At this point the works consisted of approximately 400No. buildings, as well as accommodation for workers.

The factory was defended by 100No. troops from the Leinster, Royal Garrison and Royal Horse Artillery. Records indicate that troops occupied huts near to the present-day location of Seaview Avenue, within approximately 0.1km north of the Site.

Between 1914 and 1916 the factory exported at least 158 tons of NC, 190 tons of cordite and 1,542 tons of unspecified explosives, together with 2,464 tons of nitrate cake, 2,022 tons of nitrate soda and 1,296 tons of burnt ore. It is known that these figures are incomplete and early in WWI the factory may have been producing over 100 tons of cordite per week.

In early 1918 it was announced that the factory was to close as part of rationalisation measures.

By July 1919 production of cordite had ceased. In November 1919 the factory was sold and most of the buildings were demolished.

Records indicate that some remaining explosives, including large amounts of gelignite and dynamite, continued to be stored at the former factory premises until they could be sold, and troops remained stationed there during 1920.

There was no significant redevelopment of the former factory premises until after WWII.

Plate 3 is an aerial photograph of the Site dating from May 1957. The Site largely remained unoccupied marshland, with the outline of the former tramway visible across its eastern part.

The former magazines adjacent to the Site had since been by destroyed by coastal erosion.

Plate 3	Aerial photograph of the Site, May 1957



Source: National Library of Ireland *Not to Scale*

Legend	Site boundary	Former tramway

Plate 4 is a recent aerial photograph of the Site, demonstrating its redevelopment since 1958.

The marshland has been reclaimed and built up with fill and areas of bunding. It is unclear what the origin of the fill used to build up the Site is.

On the eastern part of the Site there is a landfill associated with the redevelopment of the Arklow Gypsum Works, which occupied the former Arklow Chemical Works.

The Site was redeveloped around the same time as parts of the former explosives factory.

The possibility that rubble from the factory was used as fill material to reclaim the marshland on the Site cannot be discounted. This may be contaminated with explosives and/or chemicals (see section 3.1.2).

Plate 4	Recent aerial photograph of the Site



Source: Google Earth *Not to Scale*

Legend	Site boundary	Bund	Landfill

3.1.2 Potential Explosive Contamination Hazard

Potential pathways for explosives onto the Site are addressed in the section below.

The main pathways onto the Site are the former factory tramway and canal, in addition to materials used in the reclamation of the marshland on the Site post-WWII.

Such contamination can provide a potential explosive detonation (or deflagration) hazard in high concentrations, and a toxic hazard in lower concentrations.

Railway networks

A tramway connecting the explosives manufacturing section and chemical manufacturing section of Kynoch's Arklow works ran across the Site for the duration of the factory's existence.

The tramway was used to transport chemicals required for the production of cordite and blasting explosives from Arklow Harbour and chemical works to the explosive factory. It was also used to transport finished products from the explosives manufacturing section to the harbour.

Records indicate that carts mounted on bogies were used for this, and were pushed along the tramway by hand or pulled by horses, donkeys or mules.

Spillages would have been common during the transportation and unloading process, particularly during WWII when production was significantly increased. Spillages were particularly common at loading points, bends, and junctions, with explosives becoming mixed into the surrounding soil.

A junction was located on the northern part of the Site, with a tram spur leading to nearby storage magazines (see Figure 3). This is an area where spillages would be more likely to occur.

The former tramway is considered to provide a possible source of explosive contamination hazard to the Site.

Explosives present could include anything manufactured at the factory during its existence. Given the post-WWII development of the Site, any such contamination is likely to be beneath the existing Made Ground.

Water features

A canal connecting the explosives manufacturing section and chemical manufacturing section of Kynoch's Arklow works ran across the Site between 1895 and 1912.

This canal was used in the same way as the tramway described above, for the transport of raw materials and finished products between the two sections of the factory.

Explosives spillages frequently occurred and were allowed to accumulate on canal bottoms. Barges used to transport explosives were also sometimes upturned to make cleaning easier, providing another pathway for explosive residue to reach the canal bottom.

Historical mapping indicates that by 1912 the canal no longer connected the two sections of the factory. It may still have been used for dumping unwanted material, or transporting material as far as the nearby magazines (see Figure 3).

The section of the canal crossing the Site was infilled by 1912 and it is possible that the material used was taken from the factory premises. This may have been contaminated with explosives.

The former canal is considered to provide a possible source of explosive contamination hazard to the Site.

Given the post-WWII development of the Site, any such contamination is likely to be at depth.

Made Ground

The Site is underlain by Made Ground, as part of the infill for marshland reclaimed during its development. The source of the fill material is not known.

Given that the Site was redeveloped at the same time as parts of the former explosives factory, the potential that materials and demolition risings from contaminated buildings were used as fill cannot be discounted.

It is considered that there is the potential for explosives contamination at discrete locations within the post-WWII Made Ground on the Site.

Magazines

1No. explosives magazine was located adjacent to the eastern boundary of the Site and 3No. further magazines were located within 0.2km south-southeast of the site. The tramway was connected to these magazines for offloading explosive materials (see Figure 3).

The magazines consisted of tunnels encased in mounds of earth to reduce the damage from any accidental explosion. Materials stored in the magazines are most likely to have comprised finished explosives, such as NC and cordite, in addition to some quantities of raw manufacturing materials.

Due to coastal erosion the locations of the former explosives magazines near the Site are now underwater.

Explosive magazines are not considered to provide a source of explosive contamination hazard to the Site.

Explosions

A number of explosions are recorded at the factory during its operation. These are described below.

4th October 1895

An explosion occurred in one of the cordite drying houses, approximately 0.6km northeast of the Site. It was being temporarily used for drying NC.

No records have been found to indicate that the explosion caused major damage to any other buildings.

1910

A tram carrying Arkite pulp exploded during transit in the NC mixing and charge packing section of the factory, approximately 1.2km northeast of the Site.

The resulting blast caused a sympathetic detonation to a cotton stove, which damaged several nearby buildings.

1911

A tram carrying boxes of Erin Gelignite and Arkite jelly exploded during transit in the central part of the explosives manufacturing section, approximately 1km northeast of the Site.

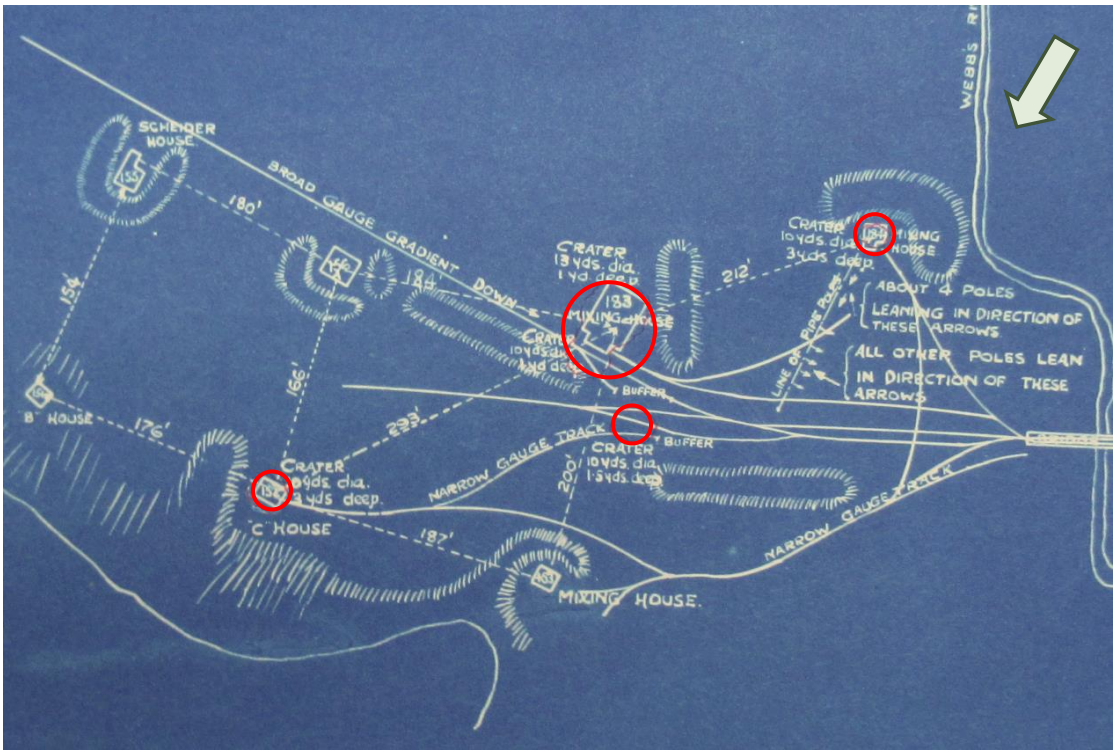
The resulting explosion damaged 15No. buildings.

21st September 1917

An NC mixing hut exploded approximately 1.3km northeast of the Site. 3No. trams containing approximately 1,600 pounds of NC were located next to the hut at the time which carried the explosion beyond the blast protection. 2No. further huts were destroyed and 1No. was seriously damaged.

Figure 5 is a plan dating from the 26th September 1917, showing where craters are located at the former mixing huts and on the tramway where the trams detonated.

Figure 5	Plan showing damage caused by NC mixing hut explosion, 16th September 1917



Source: National Archives

Legend	Craters ○

No records have been found to indicate that any explosions occurred on the Site, or that debris from the explosion areas was scattered on the Site.

Explosions at the Kynoch Works are considered unlikely to provide a source of explosive contamination hazard to the Site.

Explosives processing facilities

Localised contamination can be found in the former buildings associated with explosives manufacture and storage, and in the surrounding soil.

Airborne explosives dusts can accumulate in the cracks, fabric and recesses of buildings and can be found under floors and behind walls.

No explosives processing facilities have been identified on the Site. The nearest explosives manufacturing activity occurred approximately 0.6km northeast of the Site.

Explosives processing facilities are not considered to provide a direct source of explosive contamination hazard to the Site.

The potential for explosive contaminated building materials being used as fill material during the redevelopment of the Site cannot be discounted.

Chemical plants and bulk storage

The chemicals used in the explosive manufacturing process can be a source of contamination when leaked into the soil and waterways.

No chemical manufacturing facilities have been identified on the Site. Chemicals were produced at the Arklow Chemical Works and imported at Arklow Harbour, approximately 0.2km south of the Site.

Sulphuric acid, nitric acid, acetone, nitrate of lead and chrome yellow are known to have been produced here. Sulphuric and nitric acids are known to have been transported across the Site as required in the explosives factory.

Records indicate that chemical contamination from heavy metals, hydrocarbons and asbestos have been found at the former chemical works and these contaminants have migrated into the groundwater.

The chemical plants and bulk storage are not considered to provide a significant source of contamination hazard to the Site.

Burning grounds

Most explosives factories had designated burning grounds to dispose of unwanted or outdated products. This can provide significant concentrations of explosive residue and is a likely area of contamination.

No burning grounds have been identified on the Site.

Samples of explosives were test fired for quality control purposes in a series of artificial craters north of the explosives section, approximately 2.3km north-northeast of the Site.

Remote areas of the factory, such as the NC mixing section, approximately 1.4km northeast of the Site, would also have been a likely location for a burning ground.

Burning grounds are not considered to provide a source of explosive contamination hazard to the Site.

Disposal areas

Explosives sites may contain areas where wastes were tipped. A wide range of contaminants can be present including explosives. Some sites have been found to contain large quantities of waste materials accumulated over many years.

A possible disposal area has been identified within approximately 0.1km south of the Site. This was connected to the factory's tramway network and may have been used to dispose of waste from the chemical works including NC.

Disposal areas are not considered to provide a source of explosive contamination hazard to the Site.

Laboratories and inspection areas

Although the quantities of explosives within laboratories were usually small, explosives contamination can, in particular, be expected within effluent drains and any local disposal areas.

In some laboratories, explosives samples have been known to have been stored in containers which are not normally associated with explosives.

A wide range of chemicals was frequently used in laboratories. In the past these chemicals were not always well controlled.

The laboratory and its associated magazine were located near the entrance to the explosives factory, approximately 0.7km north-northeast of the Site.

Laboratories and inspection areas are not considered to provide a source of explosive contamination hazard to the Site.

Potential UXO Hazard

There is no evidence that any blasting charges or other types of ordnance were manufactured, stored or disposed of on the Site.

Records indicate that troops were stationed and accommodated at the Kynoch factory during WWI and stored Small Arms Ammunition (SAA) for their use. As such the potential for encountering SAA and other munitions cannot be totally discounted.

SAA is not considered to provide a significant UXO hazard (see Appendix 1).

Kynoch's Arklow works is not considered to provide a source of UXO hazard to the Site.

3.2 Defences

For further information on military defences, and the potential UXO hazards associated with them, follow the links below:

- Anti-Aircraft Guns
- Anti-Invasion Defences
- Barrage Balloons
- Bombing Decoys
- Home Guard
- Mined Locations
- Mortar & Gun Emplacements
- Pillboxes

No military defences have been identified on the Site. The nearest are described below.

3.2.1 Anti-Aircraft Guns

No records have been found to indicate that any Anti-Aircraft (AA) gun batteries within 10km of the Site.

3.2.2 Coastal Gun Batteries

Records have been found to indicate that 2No. coastal batteries were located in the vicinity of the Site. Further details are provided in Section 5.1.

3.3 Military Airfields

For further information on military airfields, and the potential UXO hazards associated with them, follow the links below:

- Military Airfields

No records of any military airfields on or in close proximity to the Site have been found.

3.4 Aircraft Crashes

For further information on military aircraft crashes, and the potential UXO hazards associated with them, follow the links below:

- Aircraft Crashes

No records of any aircraft crashes on or in close proximity to the Site have been found.

3.5 Firing Ranges and Military Training Areas

For further information on firing ranges and military training areas, and the potential UXO hazards associated with them, follow the links below:

- Artillery Ranges
- Bombing Ranges
- Military Training Areas
- Small Arms Ranges

No records of any firing ranges or military training areas on or in close proximity to the Site have been found.

3.6 Other Military Establishments

No other military establishments have been identified on or in close proximity to the Site.

Records indicate that during WWI temporary barracks were set up on the site of The Ticknock Brick and Tile Works, approximately 0.6km north of the Site.

The barracks were used during WWI and the Irish War of Independence to accommodate British troops and to hold Republican prisoners.

These barracks are not considered to provide a source of UXO hazard to the Site.

4 BOMBING

4.1 WWI Bombing

For further information on WWI bombing in the UK, and the potential UXO hazard associated with it, use the following link.

- WWI Bombing

Ireland was out of range of German aircraft and airships during WWI and was not bombed.

WWI bombing is not considered to provide a source of UXO hazard to the Site.

4.2 WWII Bombing

For further information on WWII bombing in the UK, and the potential UXO hazard associated with it, see Appendix 2.4. Alternatively, use the following link.

- WWII Bombing

No records have been found to indicate the Site was bombed during WWII. Further details on bombing in the vicinity of the Site are given in the following sections.

4.2.1 Bombing in The Republic of Ireland

Due to its neutrality in WWII the Republic of Ireland was never officially targeted for bombing by the Luftwaffe. Ireland was bombed on several occasions due to navigational errors by Luftwaffe crews targeting mainland Britain and Northern Ireland.

The first bombing of neutral Ireland by German aircraft occurred on the 26th August 1940, when bombs destroyed a creamery at Campile, County Wexford.

On the first 3No. days of January 1941, German bombs were dropped at a number of locations along the east coast of Ireland, including counties Carlow, Kildare, Louth, Meath, Wexford and Wicklow.

On the nights of the 2nd and 3rd January 1941, German bombs were dropped for the first time on Dublin in the Donore area, around the South Circular Road and in Terenure district.

On the 31st May 1941, 4No. HE bombs were dropped by German aircraft on the North Strand area of Dublin, causing damage to over 300No. properties.

The last recorded bombing incident on Ireland in WWII was at Dundalk on the 24th July 1941.

4.2.2 Strategic Targets

There were no official strategic targets in the vicinity of the Site.

4.2.3 Bombing Incidents

Details of the nearest recorded bombing incidents to the Site are given in the following section.

2nd June 1941

1No. bomb (type unspecified) fell on marshland beside the Avoca River in Arklow, between approximately 0.4km and 1.4km west of the Site.

2No. HE bombs fell in a wheat field approximately 220 yards west of Parnell Terrace, approximately 1.2km southwest of the Site. 1No. was recorded as an Unexploded Bomb (UXB).

It should be noted that during WWII, many UXB were mapped and subsequently removed as and when conditions and demands on Bomb Disposal teams allowed. Their removal was not always accurately recorded and sometimes records were later destroyed. In practice, most UXB were probably removed and only a much smaller number were actually registered as officially abandoned bombs.

Figure 6 is a map showing the approximate location of recorded bomb impacts in the vicinity of the Site.

Figure 6	Compiled bomb impact map for the vicinity of the Site



Source: © Crown Copyright 2020. Reproduced by permission of Ordnance Survey *Not to Scale*

Legend	Site boundary	HE bomb	UXB

No records have been found indicating that the Site was bombed and no bomb damage has been identified on the Site on historical aerial photography.

WWII bombing is not considered to provide a source of UXO hazard to the Site.

4.2.4 Geology and Bomb Penetration Depths

It is important to consider the geological materials present at the time that a bomb was dropped in order to establish its maximum penetration depth.

At the time of writing, no Site-specific ground investigation data was available.

Geological Survey Ireland (GSI), as well as borehole and excavation records in the surrounding area, have been consulted to get an indicative overview of the Site geology.

The Site geology is understood to consist of post-WWII fill material and older Made Ground over Alluvium and River Terrace Deposits, as well as Glacial Gravels and Tills, overlying slates of the Kilmacrea Formation.

Table 1 provides an estimate of average maximum bomb penetration depths assuming ground conditions during WWII of 2m of Made Ground, over 2m of soft to firm clay and 2m of medium dense to dense sand and gravel, overlying more than 10m of very weak to moderately strong rock.

Table 1	Estimated average maximum bomb penetration depths	
Estimated average bomb penetration depths for anticipated geology		
Bomb Weight	50kg	3.0m
	250kg	5.0m
	500kg	7.0m

Note that where stronger bedrock is nearer the surface, bomb penetration will be less than the theoretical maximum.

These calculations can be refined on receipt of Site-specific information.

The estimated bomb penetration depths given in Table 1 are from the WWII ground level and are based on the following assumptions:

a) High level release of the bomb resulting in an impact velocity of 260m/s (>5,000m altitude).

b) A strike angle of 10 to 15 degrees to the vertical.

c) That the bomb is stable, both in flight and on penetration.

d) That no retarding units are fitted to the bomb.

e) That the soil type is homogenous.

A high altitude release of a bomb will result in ground entry at between 10° and 15° to the vertical with the bomb travelling on this trajectory until momentum is nearly lost. The bomb will then turn abruptly to the horizontal before coming to rest. The distance between the centre of the entry hole and the centre of the bomb at rest is known as the 'offset'. A marked lateral movement from the original line of entry is common.

Low-level attacks may have an impact angle of 45° or more, which will frequently lead to a much greater amount of offset movement during soil penetration.

The average offset is one third of the penetration depth, i.e. an offset of 2m may be expected for a 50kg bomb in dry silts and clays. If hard standings or Made Ground were present during WWII, bomb penetration depths would have been significantly reduced but offset distances may have been up to four times greater.

5 UXO IN THE MARINE ENVIRONMENT

Both wartime and peace time military and naval activities provide numerous sources of UXO within the marine environment. The principal sources of UXO hazards are from ordnance disposal at sea, WWII aerial laid mines and bombing, mines laid as beach defences, crashed aircraft and wrecks containing ordnance.

Clearance certification for UXO within a marine environment may be valid only for a limited period as storms, floods, tides and general current movement can cause UXO to migrate into an area that may have been cleared of UXO only hours before. This also makes it very difficult to accurately predict where UXO may be found.

UXO is most likely to be concentrated on and immediately around the principal sources of the UXO hazard. These are typically ordnance disposal sites, WWII mines, bombed areas, offshore ranges and wrecks containing ordnance.

5.1 Coastal Gun Batteries and Ranges

Records have been found to indicate that by July 1915 the Irish Command had established 2No. Quick Firing (QF) 12-pounder (-pdr) guns at Arklow as a defence against German submarine attacks.

The nearest of these was located near the brick and tile works, approximately 0.6km north-northwest of the Site. The firing templates of these guns are shown in Figure 7, an extract from a defence plan dated 20th July 1915.

Figure 7	Plan of 12-pdr firing templates at Arklow, 20th July 1915



Source: National Archives *Not to Scale*

Legend	Site boundary	Firing templates

The possibility that the WWI 12-pdr guns stationed at Arklow may have contributed UXO to the marine environment in the vicinity of the Site, albeit unlikely, cannot be totally discounted.

No records have been found to indicate that any other offshore ranges or coastal gun batteries were located in the vicinity of the Site.

Coastal gun batteries and offshore ranges are not considered to provide a source of UXO hazard to the Site.

5.2 Wrecks Containing UXO

No records have been found to indicate that wrecks which may contain UXO are located in the vicinity of the Site.

5.3 Mines and Minefields

No records have been found to indicate that mines or minefields were laid in the vicinity of the Site.

There are records of mines being laid during both WWI and WWII in the waterways off Arklow.

The possibility of a marine mine washing up on the shore, albeit very unlikely, forms part of the low background risk for any similar coastal site.

5.4 Disposal Areas in the Marine Environment

No munitions disposal areas have been identified in the marine environment in the vicinity of the Site.

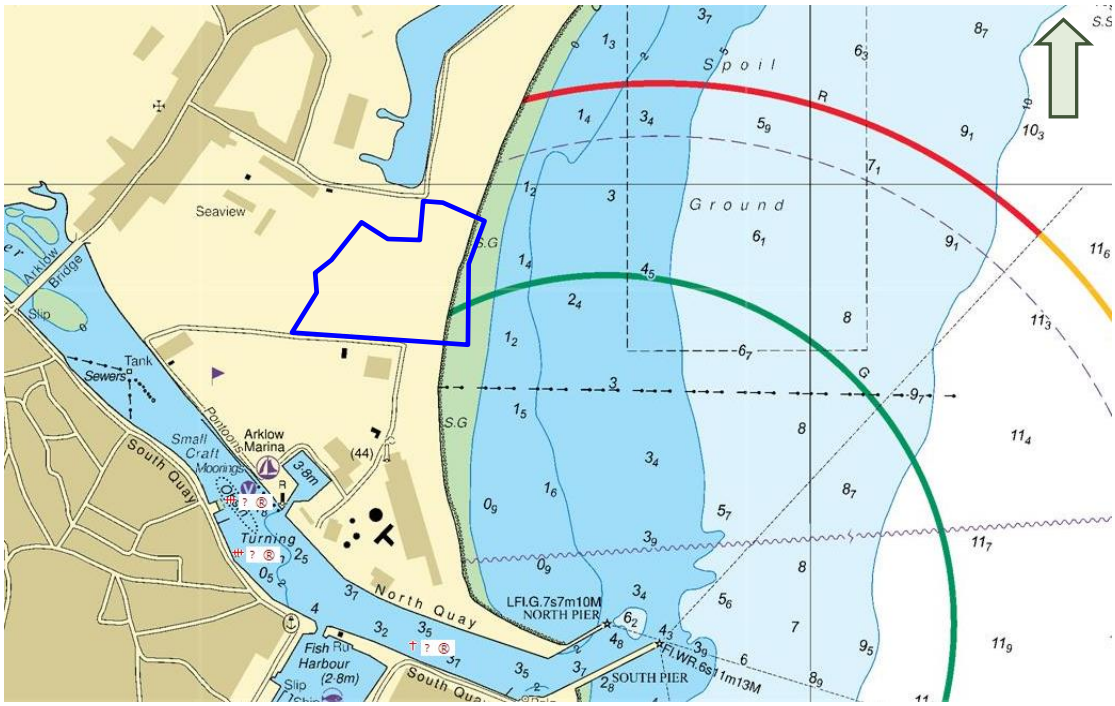
Explosions at Kynoch's Arklow works may have resulted in explosives materials being scattered offshore.

Post-WWI, coastal erosion has removed several of the explosive magazines in close proximity to the Site, with the possible liberation of explosive residues or substances into the marine environment.

Maintenance dredging of the Arklow Harbour and Avoca Estuary, within approximately 0.2km west of the Site, has provided contaminated spoil which has required disposal by dig, dump and cover methods offshore.

The nearest offshore spoil ground is approximately 0.2km east of the Site, as shown in Figure 8.

Figure 8	Extract of Admiralty chart for the vicinity of the Site



Source: UKHO *Not to Scale*

Legend	Site boundary

The above activities may provide a source for explosives residue contamination in the marine environment near the Site.

It is considered that wave action would mitigate any risk of explosive contamination remaining on the marine part of the Site.

5.5 UXO Migration in the Marine Environment

The factors controlling UXO and explosives residue migration in the marine environment surrounding the Site are discussed below.

Tidal Currents

The mean tidal range in the vicinity of the Site is approximately 2m, with a maximum of approximately 3.8m. Within Arklow Harbour and the Avoca Estuary, the range is generally <1m.

Nearshore tidal streams vary between maximum flows of approximately 0.5ms^{-1} and 1.0ms^{-1}, parallel to the coast. Offshore currents may exceed 1.5ms^{-1} and are generally in a north –south orientation.

Around the Arklow Bank the flood tides tend to be northwest across the banks and the ebb tides are towards the southeast. This causes the water to ride up and break on the west of the banks on the flood and on the east of the banks on the ebb.

The main channel through the harbour and estuary in close proximity to the Site is maintained by dredging (see Section 5.4).

Wave Action

Low to moderate energy wave action dominates the nearshore and intertidal sediment transport in the vicinity of the Site. Wave data demonstrates that the wave environment in the vicinity of the Site is predominantly wind driven, with maximum wave heights generally 1.5m to 4.5m. The dominant offshore wave direction is south-southwest.

Even at high tide, the Arklow Bank reduces the height of the higher waves passing over it and protects the shoreline in the vicinity of the Site. To the south of the Site, the Arklow Harbour breakwaters afford protection from the waves.

Coastal Defences

The development of Kynoch's Arklow works in 1912 required an increased level of shore protection which used three-tiered timber piles in front of the natural dune system.

Erosion has occurred of the beach which was originally in front of the factory. This was partly due to the removal of the existing wooden defences and extraction of beach sands for construction purposes during WWII, and partly due to the presence of the Arklow Harbour breakwaters.

The coastal defences were replaced in the 1970s with a gabion and rubble revetment.

Following storm damage in 1989, the existing armour stone revetment was constructed to protect the coast between Arklow Harbour and Arklow North Beach.

Sediment Pathways

Offshore, the sediment dynamics of the Arklow Bank are mainly governed by the tide, with the waves acting as a mechanism to place the sediment in suspension, which is then transported by the tidal currents.

The Arklow Bank is a dynamic sandbank, with erosion and deposition processes matching the depletion and accretion on a seasonal basis in response to tide and wave action. There is little sediment movement towards the shoreline.

Locally, the Arklow Bank Wind Turbine Farm has affected erosion and deposition across the bank, necessitating some access channel dredging, but this has had little effect onshore.

Onshore, beach surveys between 1985 and 2016 indicate a loss of material at the seabed in front of the existing revetment in the vicinity of the Site, with profiles lowered between 0.5m and 2m over a 30 year period. This suggests that the sediment transport processes on or along the shore are limited, with erosion dominating the nearshore environment up to approximately 400m offshore, where deposition in deeper water occurs.

Rarely, during severe storms, offshore sediment may be transported towards or along the shoreline, but in general there is a net loss of material into the offshore environment.

UXO Migration onto the Site

The combined influences of wave action and tidal currents create a dynamic environment which may allow the migration of UXO.

Given the tidal streams, wave action and pattern of sediment movement in the vicinity of the Site, as detailed above, it is considered that heavy UXO in the marine environment are unlikely to be transported on to the Site.

Most common for large UXO, which are too heavy for the waves and currents to move, is for them to be exposed by scour and then be left proud of the sediments.

In such cases, the UXO are unlikely to move from source unless fishing or dredging activities disturb the exposed UXO.

Buoyant and semi-buoyant UXO (as may be the case with some marine mines or degrading ordnance), smaller, lighter items of UXO (such as SAA and small or medium calibre shells) and UXO with neutral buoyancy or rounded shapes could move by saltation or roll as bed load particles during high energy storm conditions. Such conditions may provide a pathway for UXO migration onto the Site.

It should be noted that the long term historical beach erosion and maintenance dredging in the vicinity of the Site is likely to reduce the prospect of UXO or explosive residues accumulating.

6 EXPLOSIVE ORDNANCE CLEARANCE ACTIVITIES

Official UK bombing statistics have been compiled from both British and German sources. There were differences in the way the figures were originally reported and collated which has led to discrepancies in the summary data.

Based on data from 1939 to 1945, War Office statistics indicate that 200,195No. HE bombs exploded within Great Britain. Additionally, 25,195No. HE bombs (representing 11%) were recorded as UXBs. However, records from the Royal Engineers who were responsible for bomb disposal at the time indicate that as of 27th February 1946 upwards of 45,000No. UXBs were disposed of.

On average 8.5% of UXBs later self-exploded. In some cases the bombs had delayed action fuzes or were never intended to explode, their purpose being to cause inconvenience and fear. Given the discrepancy in records and the fact that UXBs are still being found unexpectedly, it is clear that the original figures are understated and provide only an approximation of the number of potential UXBs in the UK.

War Office statistics also show that between October 1940 and May 1941 most of the UXBs (93%) were either 50kg or 250kg. It should be noted that details of the recovery and the size of the UXB were not always accurately reported.

The larger WWII UXBs are often difficult to recover due to both penetration depths and the presence of two or more fuzes, combined with more sensitive fillings of explosive mixtures including Amatol and Trialen.

6.1 Abandoned Bombs

For further information on abandoned bombs, and the potential UXO hazard associated with them, follow the link below:

- Abandoned Bombs

No records have been found indicating that any officially abandoned bombs are located on the Site.

6.2 EOC Tasks

Records held by Zetica Ltd show that the following post-WWII EOC task has taken place in the vicinity of the Site.

20th July 2000

1No. unexploded shell was brought ashore at Arklow Harbour, approximately 0.4km south of the Site, by a dredging trawler. It was removed by a bomb disposal unit.

7 HAZARD ASSESSMENT

7.1 Hazard Level

The definitions for the levels of UXO hazard are provided below.

Definitions of UXO Hazard Level for a Site	
Hazard Level	**Definition**
Very Low	There is positive evidence that UXO is not present, e.g. through physical constraints or removal.
Low	There is no positive evidence that UXO is present, but its occurrence cannot be totally discounted.
Moderate	There is positive evidence that ordnance was present or that other uncharted ordnance may be present as UXO.
High	There is positive evidence that UXO is present.
Very High	As high, but requires immediate or special attention due to the potential hazard.

Explosive Contamination

Between 1895 and 1920 the Site was encompassed by Kynoch's Arklow explosives works. This produced explosives for military and commercial use, including NG, NC, cordite, and a variety of low-yield proprietary explosives for industrial use.

A canal and part of the factory's tramway network ran across the Site. The line was used to transport explosive compounds and finished explosives between the two main sections of the factory. The canal on the Site was infilled prior to the factory's closure.

Tramways and canals were common locations of spillage at explosives factories, particularly at loading points, bends and junctions. It was also common for residues to be emptied from barges into canals. It also cannot be discounted that the canal was infilled with explosive contaminated materials from the factory.

Given this, it is considered prudent to assign these parts of the Site a moderate hazard level due to the potential for explosive contamination in the soils at depth.

There is also evidence that the post-WWII land reclamation of the Site may have resulted in materials from the former explosives factory being incorporated within the Made Ground. This has the potential to be contaminated with explosives in discrete locations.

It is considered that there is a moderate hazard in the post-WWII Made Ground on the Site due to potential explosive contamination.

Such contamination can provide a potential explosive detonation (or deflagration) hazard in high concentrations, and a toxic hazard in lower concentrations.

No significant sources of explosive contamination hazard have been identified on the marine part of the Site, which is assigned a low hazard level.

UXO Hazard

No records have been found indicating that the Site was bombed and no other significant sources of UXO hazard have been identified on the Site.

Given this, it is considered that the Site has a low UXO hazard level.

Figures 9 and 10 provide explosive contamination and UXO hazard zone plans of the Site.

Figure 9	Explosive contamination hazard zone plan of the Site



Source: Zetica *Not to Scale*

Legend					
	Very Low		Low		Moderate	
	High		Very High		Site boundary	

Figure 10	UXO hazard zone plan of the Site



Source: Zetica *Not to Scale*

Legend					
	Very Low		Low		Moderate
	High		Very High		Site boundary

8 RISK ASSESSMENT

8.1 Proposed Works

Proposed works are to be confirmed. At this stage, it is understood that they may comprise intrusive ground investigations and Horizontal Directional Drilling (HDD) associated with the installation of an offshore cable.

8.2 Risk Assessment Methodology

A risk assessment has been undertaken for the proposed works, taking into consideration the identified UXO hazard.

Firstly, the probability of encounter (PE) has been considered and rated for the different construction techniques, as detailed below.

Probability of Encounter (PE)	Rating
Frequent, highly likely, almost certain.	5
Probable, more likely to happen than not.	4
Occasional, increased chance or probability.	3
Remote, unlikely to happen but could.	2
Improbable, highly unlikely.	1
Impossible	0

Secondly, the probability of detonation (PD) has been considered and rated for the different construction techniques, as detailed below.

Probability of Detonation (PD)	Rating
Frequent, highly likely, almost certain.	5
Probable, more likely to happen than not.	4
Occasional, increased chance or probability.	3
Remote, unlikely to happen but could.	2
Improbable, highly unlikely.	1
Impossible	0

Next, the probability of encountering and detonating explosives (PE x PD) have been used to generate an overall likelihood rating (P).

P = PE x PD	LIKELIHOOD of Encounter and Detonation	Rating
21 to 25	Frequent, highly likely, almost certain.	5
16 to 20	Probable, more likely to happen than not.	4
6 to 15	Occasional, increased chance or probability.	3
2 to 5	Remote, unlikely to happen but could.	2
1	Improbable, highly unlikely.	1
0	Impossible	0
P ranges from 25, a certainty of explosives being encountered and detonated on the Site by engineering activity, to 0, a certainty that explosives does not occur on the Site and will not be detonated by engineering activity.		

The likelihood of encountering and detonating explosives during site works is multiplied by the severity of such an event occurring (P x S), in order to provide a risk level using the following matrix.

Severity (S)	Rating
Multiple fatalities	5
Major injury, long term health issues, single fatality.	4
Minor injury, short term health issues, no fatalities.	3
First aid case but no lost time or ill health.	2
Minor injuries, no first aid.	1
No injuries.	0

Risk Matrix							
	SEVERITY (S)						
LIKELIHOOD (P)		5	4	3	2	1	0
	5	25	20	15	10	5	0
	4	20	16	12	8	4	0
	3	15	12	9	6	3	0
	2	10	8	6	4	2	0
	1	5	4	3	2	1	0
	0	0	0	0	0	0	0

8.3 Risk Level

The risk assessment for potential works on the Site is given in Table 2.

Table 2 Risk assessment for the Site

Hazard Zone	Potential Hazard	Anticipated Works	PE	PD	P = PE x PD	Likelihood	Severity	Risk Rating	UXO Risk
Moderate	Explosive Contamination	Excavations	3	1	3	2	4	8	Moderate
		Boreholes	3	1	3	2	3	6	Moderate
		Directional Drilling	3	1	3	2	3	6	Moderate
	UXB	Excavations	1	1	1	1	5	5	Low
		Boreholes	1	1	1	1	4	4	Low
		Directional Drilling	1	1	1	1	4	4	Low
	Other UXO	Excavations	1	1	1	1	4	4	Low
		Boreholes	1	1	1	1	3	3	Low
		Directional Drilling	1	1	1	1	3	3	Low
Low	Explosive Contamination	Excavations	1	1	1	1	4	4	Low
		Boreholes	1	1	1	1	3	3	Low
		Directional Drilling	1	1	1	1	3	3	Low
	UXB	Excavations	1	1	1	1	5	5	Low
		Boreholes	1	1	1	1	4	4	Low
		Directional Drilling	1	1	1	1	4	4	Low
	Other UXO	Excavations	1	1	1	1	4	4	Low
		Boreholes	1	1	1	1	3	3	Low
		Directional Drilling	1	1	1	1	3	3	Low

PE (Probability of Encounter), PD (Probability of Detonation), P (Overall Probability)

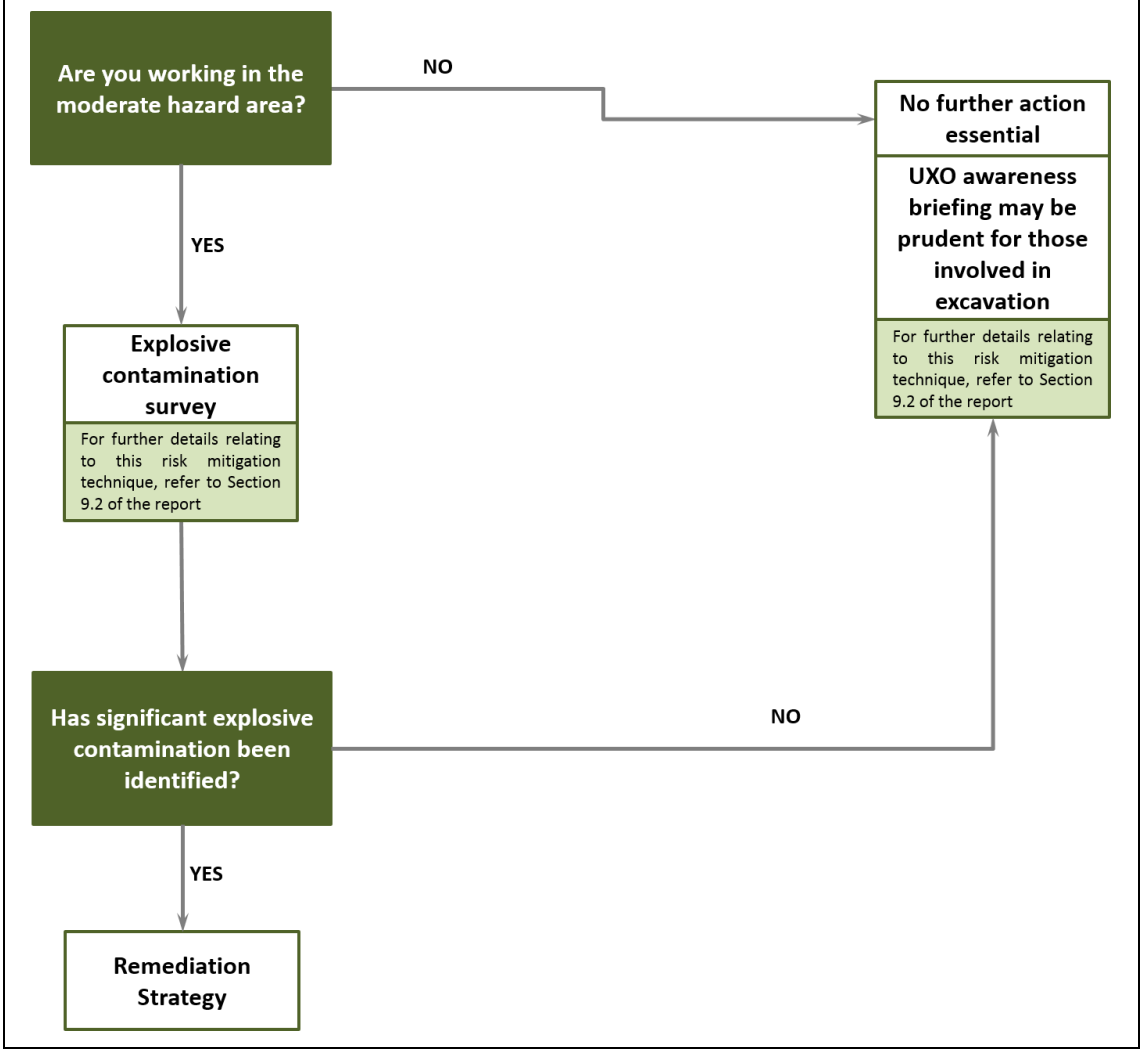
9 RISK MITIGATION PLAN

Key findings: Potential explosive contamination hazard on the Site.

Key actions: An explosive contamination survey is recommended to determine the extent of the explosive hazard (if any) and its impact on intended Site use.

Figure 11 outlines the recommended steps to reduce the risk to ALARP.

Figure 11 Recommended risk mitigation plan for the Site



9.1 Risk Summary

Table 3 summarises the most appropriate risk mitigation recommendations for the proposed works on the Site.

In summary, it is recommended that an explosive contamination survey is carried out prior to any works in the moderate hazard area.

Table 3	Summary of risk and mitigation recommendations	
Proposed Works	**Risk**	**Recommended Mitigation**
Excavations		**Proceed with works** – if additional comfort is required to address the residual UXO hazard, a formal UXO awareness briefing can be provided.
Drilling		**Proceed with works**
All Works		**Explosive Contamination Survey** – to determine the extent of explosive contamination (if any) and its impact on intended site use. This should be undertaken by an experienced Explosives Engineer.

In summary, it is recommended that an explosive contamination survey is carried out prior to any works in the moderate hazard area.

9.2 Risk Mitigation Techniques

The section below provides further details of the recommended techniques for mitigating the risk on the Site.

9.2.1 Explosive Contamination Survey

If works are taking place in the moderate hazard area, it is recommended that an explosive contamination survey is undertaken. The aim is to determine the extent of contamination (if any) and its impact on intended Site use.

The survey will involve taking soil samples on the site. These will be concentrated in areas of proposed works and locations where contamination is most likely to be found (e.g. along the course of the former canal and the tramway junction on the Site).

The survey should be undertaken by an Explosives Engineer, experienced in identifying explosive compounds and their derivatives, who can inform on the most suitable soil sampling locations.

The soil samples will be sent for laboratory analysis which will involve initial visual examination to identify any potential discrete fragments of explosive, colorimetric screening testing, and more detailed analysis for the explosive suite.

Based on this desk study's findings anticipated explosives include nitrocellulose (NC) and nitroglycerine (NG), which will be accounted for during testing. The testing suite will also include all other commonly used explosives found in the UK, to account for any potential unrecorded site activities:

- Nitrocellulose (NC)
- Cyclotetramethylenetetranitramine (HMX)
- Cyclo 1,3,5,trimethylene 2,4,6 trinitramine (RDX)
- Ethylene Glycol Dinitrate (EGDN)
- Tetryl
- 2,4,6 trinitrotoluene (TNT)
- 2,4 and 2,6 Dinitrotoluene (DNT)
- Pentaerythritol tetranitrate (PETN)
- Hexanitrostilbene (HNS)
- Picrite
- 2,4,6, trinitrophenol (picric acid)
- Nitroglycerine (NG)

9.2.2 UXO Awareness Briefing

Typically ~1hour in duration, these briefings will be expected to provide site workers with:-

- Background to the potential UXO hazards that could be encountered.
- Awareness of how the UXO hazard could present a risk.
- Knowledge of what to do in the event that a suspect item is encountered.

The briefing is to be provided along with back-up materials such as UXO awareness posters, emergency contact numbers and other background information to assist site workers in becoming familiar with what potential UXO can look like.

The materials can also be used by key staff to pass on the relevant points of the induction to others who visit or work on the Site.

By providing the UXO awareness briefing, it ensures that in the unlikely event that UXO is encountered:-

- All site staff take appropriate action.
- A support mechanism and points of contact are established.
- The likelihood of harm to people or property is reduced.
- Significant delays to site work are prevented.

9.3 What Do I Do Next?

If you wish to proceed with risk mitigation, Zetica would be happy to assist. Just contact us via phone (01993 886682) or email (uxo@zetica.com) and we can provide a proposal with options and prices.

If you have requirements to identify other buried hazards (such as mapping utilities or obstructions) we can provide these surveys.

If proposed works on the Site change, or additional works are planned, contact Zetica for a re-assessment of the UXO risk and the risk mitigation requirements.

APPENDICES

Appendix 1 Anticipated Ordnance Types

The probability of encountering UXO on the Site is considered to be low. As with any similar site in the UK, there is always a background risk of finding ordnance and potential types to be encountered are detailed below. For a more comprehensive set of ordnance data sheets, see http://zeticauxo.com/downloads-and-resources/ordnance-data-sheets/.

Information Data Sheet

Category Small Arms Ammunition
Type Various



Description: Small Arms Ammunition (SAA) is one of the more recognisable categories of ordnance which is primarily designed for anti-personnel use. SAA include items such as bullets, generally up to a calibre (diameter) of 20mm.

Generally small arms ordnance has a relatively low risk as UXO, although the larger calibre categories may have the same detonation risk as larger high explosive ordnance.

SAA is often associated with discarded ammunition boxes around firing practice ranges and training areas and is often found scattered across former military airfields as a result of aircraft crashes and localised disposal.

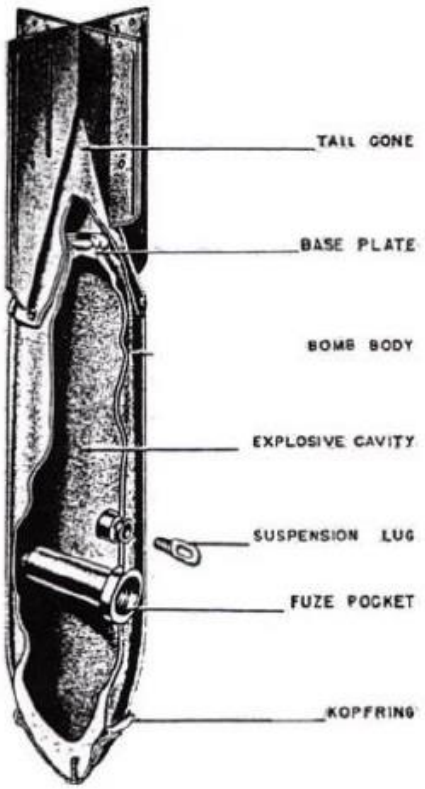




Information Data Sheet

Category Bomb (Luftwaffe)
Type Sprengbombe-Cylindrisch (SC) 50kg

Variants	8
Body Dimensions	762 x 200mm (30" x 7.9")
Weight	55kg (122lbs)
Charge Weight	25kg (54lbs)
Fuze	Single electric impact fuze. Some have short time delay
Composition	Sheet steel
Description	Thick nose welded to a steel body. Nose may be attached to Kopfring (a triangular section steel ring) or spike. Suspension bolt in eye/body and sheet metal tail attached to body with rivets/screws. Originally painted green-grey with a yellow stripe on the tail. Cast TNT, Amatol or Trialen filling.
Function	Designed to maximise shock waves through air, water and earth and for general demolition. Used against easily damageable targets, including roads, aircraft hangars, rolling stock and small buildings. Spike bombs/ 'Stabo' (SC 50 with spikes attached to nose) were used against rail lines and country roads, with Kopfring used against naval targets.



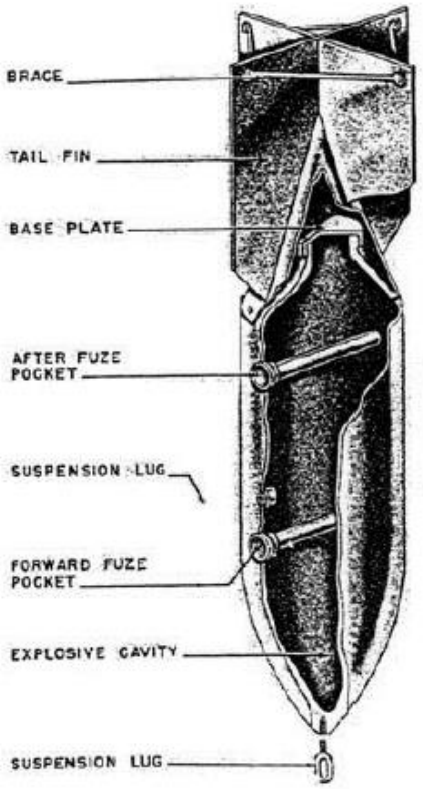




Information Data Sheet

Category Bomb
Type Sprengbombe-Cylindrisch (SC) 250kg

Variants	8
Body Dimensions	1194mm x 368mm (47" x 14.5")
Weight	249-264 kg (548-582lbs)
Charge Weight	130-145 kg (287-320lbs)
Fuze	Electric impact fuze/electric clockwork time fuse & electric anti-disturbance fuze
Composition	Sheet steel with stays
Description	Thick nose welded to steel body. Nose may be attached to Kopfring (triangular section steel ring) or spike. Sheet metal tail attached to body with rivets/ screws. Suspension eye bolt in the nose/body. Originally painted green-grey with a yellow stripe on the tail. TNT; amatol; TNT and aluminium powder, naphthalene, ammonium nitrate and wax/ wood meal filling.
Function	Designed to maximise shock waves through air, water and earth and general demolition. Used against railway installations, large buildings, ammunition depots and below-ground installations (to 8m). Spike bombs/ 'Stabo' (SC 50 with spikes attached to nose) used against rail lines and country roads.



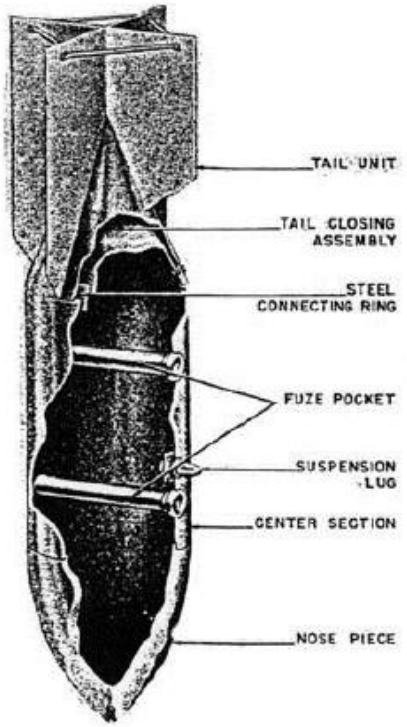




Information Data Sheet

Category Bomb
Type Sprengbombe-Cylindrisch (SC) 500kg

Variants	-
Body Dimensions	1414–1486mm x 470mm (55.7-58.5" x 18.5")
Weight	500kg (1,100lbs)
Charge Weight	220kg (484lbs)
Fuze	Electric impact fuze/electric clockwork time fuse & electric anti-disturbance fuze.
Composition	Sheet steel with stays or drum
Description	Thick nose welded to steel body. Nose may be attached to Kopfring (triangular section steel ring). Tail either steel sheet or drum-shaped. Suspension band. Originally painted green-grey/ buff (some later versions sky blue) with yellow stripe on tail. Filled with amatol, TNT or trialen.
Function	Designed to maximise shock waves through air, water and earth and for general demolition. Used against railway property, large buildings, shipping and below-ground installations.



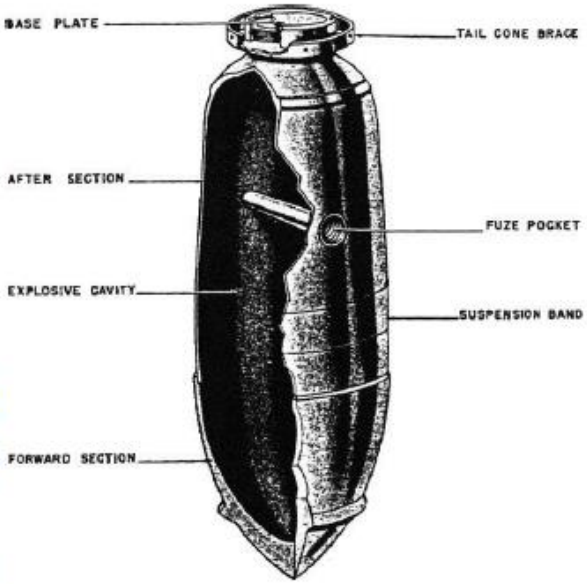


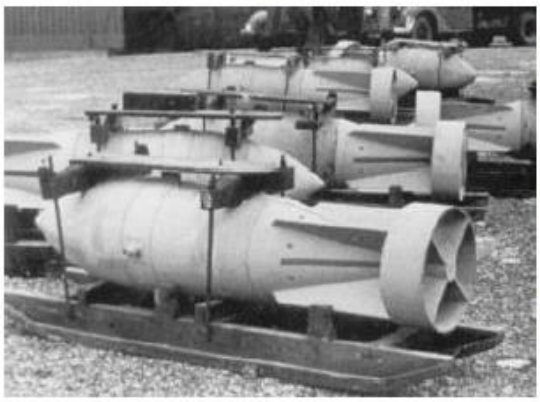


Information Data Sheet

Category Bomb
Type Sprengbombe-Cylindrisch (SC) 1,000kg (HERMANN)

Variants	3
Body Dimensions	1742-1905mm x 648–660mm (68.6-75" x 25.5-26")
Weight	1,000-1,088kg (2,204-2,398lbs)
Charge Weight	529-619kg (1,166-1,364lbs)
Fuze	Electric impact fuze/ electric clockwork time fuze & electric anti-disturbance fuze
Composition	Magnesium alloy with drum
Description	Thick nose welded to steel body. Nose attached to Kopfring (triangular section steel ring). Drum-shaped tail made of magnesium alloy. Suspension band. Originally painted sky-blue. Filled with amatol, TNT/aluminium/wood meal or trialen.
Function	Designed to maximise shock waves through air, water and earth and for general demolition.







Information Data Sheet

Category Mine (British)
Type MK XVII Mine

Variants 1

Body Dimensions 1,020mm x 1,220mm

Weight 105-225kg (320-500lbs)

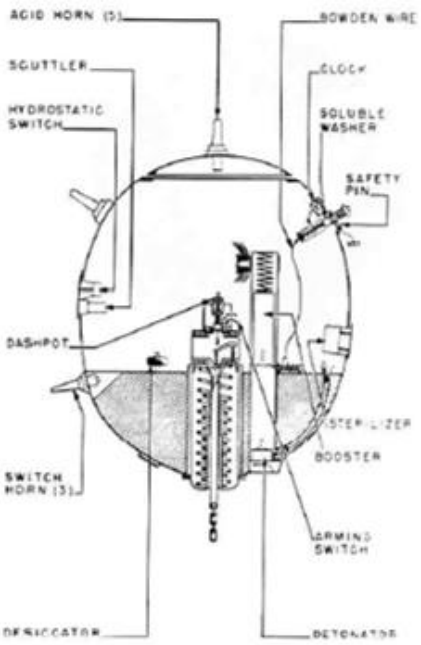
Fuze Contact

Composition Steel

Description Spherical in shape and typically painted black with a coloured band around the lower section. Could be equipped with up to 11 switch horns, protruding from the body at all angles. Top and bottom have fixtures for a detonator and mooring chain respectively.

Function The MK XVII was the most commonly used British naval mine, and could be moored in waters up to 915m depth.

It was a moored contact mine which was frequently used in defensive minefields within UK territorial waters.





Appendix 2 Sources of Hazard

The sections below provide background information on the most likely sources of explosive contamination and UXO hazard affecting the Site. For a more comprehensive set of UXO information sheets, see http://zeticauxo.com/downloads-and-resources/uxo-information-sheets/.

Appendix 2.1 Explosives Factories

For centuries, there has been a requirement for explosives and ordnance manufacture in the UK. Gunpowder mills were established as early as the 16th century and developed over time to manufacture a range of other munitions and explosive products.

The Royal Gunpowder Factory at Waltham Abbey was established in the 1780s and by the beginning of the 19th century the government began to take control of most of the country's ordnance works to standardise production. Production of commercial explosives products also began in the 19th century. This included the manufacture of nitroglycerine, nitrocellulose, TNT and tetryl.

In WWI, when the demand for ordnance manufacture increased dramatically, National Explosives Factories and National Filling Factories were established across the UK. Provisions were also made for the manufacture of chemical munitions, such as phosgene and mustard gas.

Safety procedures were still fairly primitive during WWI and many explosives factories were located in heavily-urbanised areas. This made them vulnerable to enemy bombing and also increased the chances of fatal explosions and the dispersal of explosives residues.



In WWII, 44No. Royal Ordnance Factories (ROFs) were constructed in more remote areas to prevent a repeat of the factory disasters of WWI and to protect them against attack by raiding German aircraft. The ROFs manufactured a wide range of weapons and explosives, including developmental explosives such as RDX and HMX which had been invented in the 1930s.

In addition, a number of commercial facilities were converted to become government 'agency factories' during WWII. Chemical manufacturers, such as ICI, produced explosives products at several of their factories during WWII. Approximately 2,000No. such premises were licensed to store or manufacture small amounts of explosives by 1945.

Standard procedures of explosive/ordnance disposal through burial or burning means that explosive contamination and UXO hazards will be present in some areas of these establishments.

The potential hazard remaining at a former explosives factory depends on the type of historic production and the amount of subsequent remediation that has taken place at the site.

Ground investigations are always advisable at former explosives factories to determine whether any significant concentrations of residue remain that may contaminate the ground. Typically, such contamination is not an explosives hazard but it may provide a toxic hazard to humans.

A UXB hazard may also exist in the vicinity of former explosives factories, which were targeted by enemy aircraft during WWI and WWII.



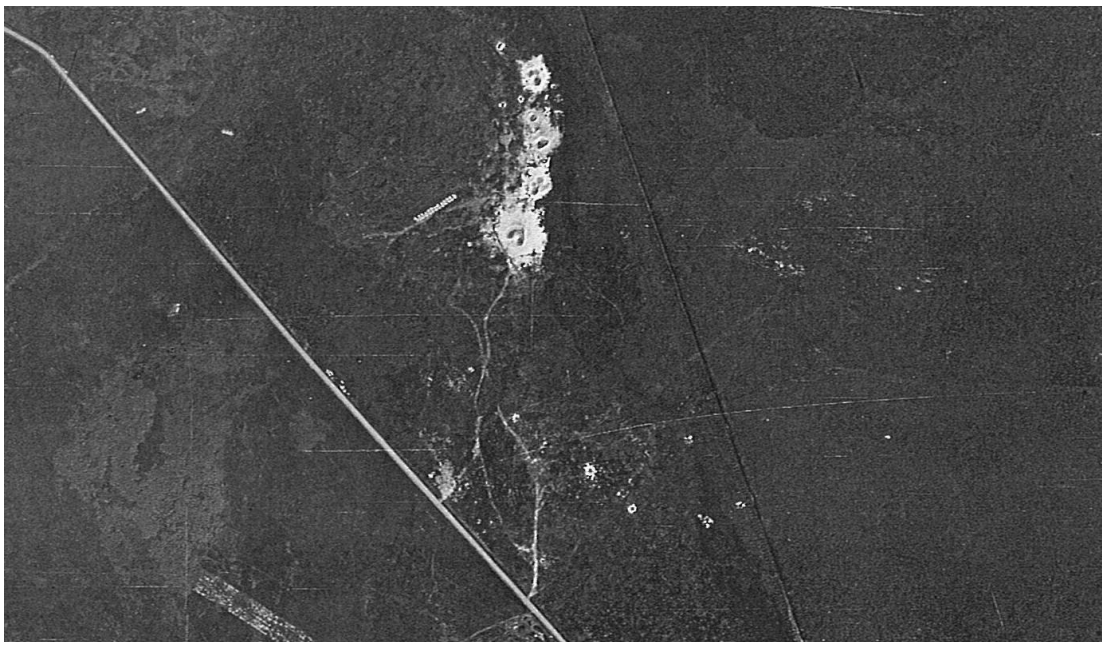
Appendix 2.2 Munitions Disposal Areas

Munitions disposal can take place almost anywhere and often goes unrecorded, particularly during wartime. Areas of open land were requisitioned to dispose of ordnance and burial pits were dug near defensive sites and airfields when munitions were no longer required.

Military land, marshland, beaches or sand dunes were frequently used for this purpose.

All explosives and munitions manufacturing sites have associated disposal areas for defective or unwanted munitions. This often takes the form of a burning pit/ground in a remote part of the site.

During wartime, munitions disposal became a more formalised process, particularly as mass production of munitions led to many defects. The number of unexploded bombs dropped by German aircraft also had to be dealt with in a timely fashion. As such, official bomb cemeteries were established in towns and cities subjected to frequent bombing raids. Parkland in London, Bristol and Coventry, for instance, was formerly set aside for the disposal of UXBs.



Munitions disposal operations provide several potential hazards. Disposal by burial means that live ordnance may remained buried in the ground with the same potential impact it was supposed to have during its initial use.

Areas where munitions were disposed of by burning or controlled explosion may give rise to explosives residue and shrapnel. Waste tips containing explosives residue may also be present in these locations, particularly through accumulation if the site has a long operational history.

Burning grounds are routinely used for the destruction of explosive wastes, explosive devices and explosive contaminated materials and equipment. Various hydrocarbon fuels may have been stored or used on burning grounds.

Residual explosive contamination (including explosive fragments) is generally present in soils around burning grounds. In addition, a range of other contamination including heavy metals and fuel is often present. Ash from burning operations may still contain explosive residues of up to 5%.

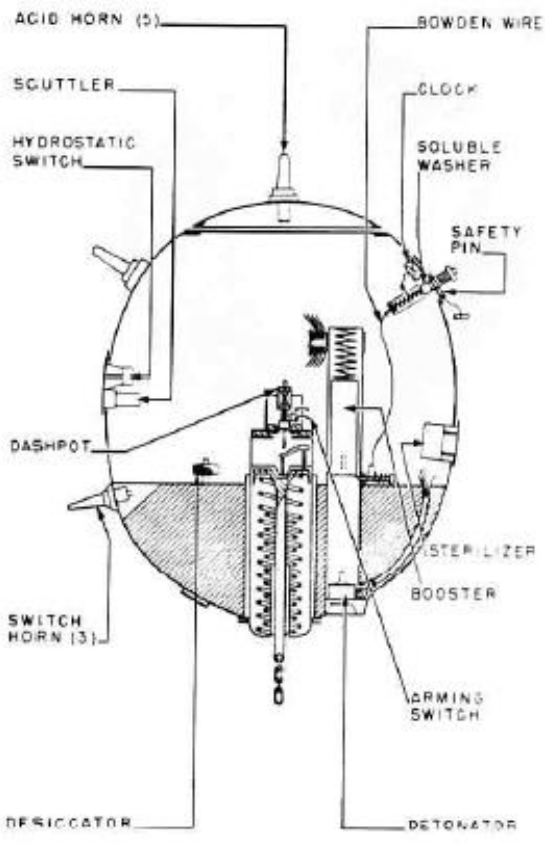
Appendix 2.3 Minefields & Mined Locations

During WWI, approximately 128,000No. mines were laid in the sea around the coast of the UK. At the beginning of WWII, the Admiralty ordered the laying of further extensive minefields around the coast of England. This included both defensive mines on beaches in order to prevent enemy landings, as well as approximately 100,000No. marine mines laid at sea to destroy enemy ships.

Known marine minefields were cleared at the end of WWII using the original layout plans, although less than 30% of the total number of sea mines were cleared as many were moved from their original positions by tidal currents and wave action. As a result there is a possibility that some remain in the marine environment and a mine can be washed up on a beach or found drifting in the water around any part of the UK's coastline.

Buoyant mines, designed to float or sit just below the surface, were the most commonly deployed marine mines. They were typically moored, or tethered to the seabed with an anchor or wire. Generally spherical in shape, the mines were comprised of 2No. hemispheres connected with a cylindrical mid-section.

Marine mines typically carried 100 to 500lbs (50 to 250kg) of explosive. They were detonated by contact (being struck) or by influence (a vessel interfering with the mine's electromagnetic field).





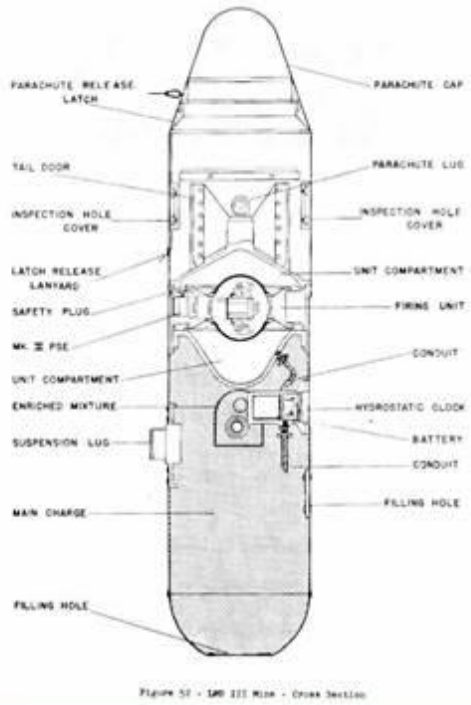


German ground mines (Luftmine) were air-deployed naval mines which were also modified for deployment from submarines and surface craft. Although primarily designed to lie on the seabed, many were also moored or buoyant. Designed as an anti-shipping weapon, the WWII Luftmine was also often used on land based targets.

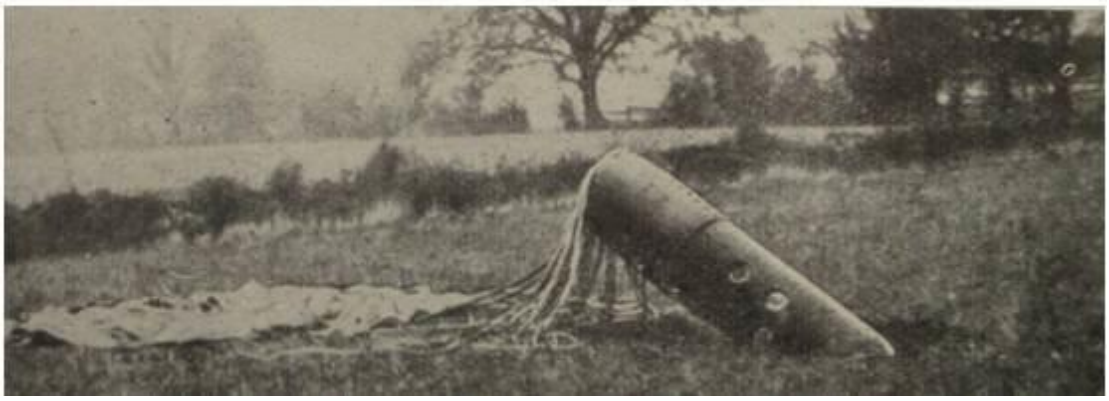
Luftmines typically comprised a cylindrical body with a hemispherical nose and tapered tail, with charges weighing between 675lbs and 1,500lbs (305 to 680kg).

Some German marine mines were composed of aluminium or manganese steel depending on the variant, whereas British mines were typically made of steel.

The initiating mechanisms in these mines have often deteriorated but the explosive charges will not have significantly altered unless the mine has split and the explosives have migrated and dispersed in the marine environment.







Appendix 2.4 WWII Bombing

Bombing raids began in the summer of 1940 and continued until the end of WWII. Bombing densities generally increased towards major cities or strategic targets such as docks, harbours, industrial premises, power stations and airfields. In addition to London, industrial cities and ports, including Birmingham, Coventry, Southampton, Liverpool, Hull and Glasgow, were heavily targeted, as well as seaside towns such as Eastbourne and cathedral cities such as Canterbury.

The German bombing campaign saw the extensive use of both High Explosive (HE) bombs and Incendiary Bombs (IBs). The most common HE bombs were the 50kg and 250kg bombs, although 500kg were also used to a lesser extent. More rarely 1,000kg, 1,400kg and 1,800kg bombs were dropped.

The HE bombs tended to contain about half of their weight in explosives and were fitted with one or sometimes two fuzes. Not all HE bombs were intended to explode on impact. Some contained timing mechanisms where detonation could occur more than 70 hours after impact.

Incendiary devices ranged from small 1kg thermite filled, magnesium bodied Incendiary Bombs (IBs) to a 250kg 'Oil Bomb' (OB) and a 500kg 'C300' IB. In some cases the IBs were fitted with a bursting charge. This exploded after the bomb had been alight for a few minutes causing burning debris to be scattered over a greater area. The C300 bombs were similar in appearance to 500kg HE bombs, although their design was sufficiently different to warrant a specially trained unit of the Royal Engineers to deal with their disposal.



Anti-Personnel (AP) bombs and Parachute Mines (PMs) were also deployed. 2No. types of anti-personnel bombs were in common use, the 2kg and the 12kg bomb. The 2kg bomb could inflict injury across an area up to 150m away from the impact. PMs (which were up to 4m in length) could be detonated either magnetically or by noise/vibration.

Anti-shipping parachute mines were commonly dropped over navigable rivers, dockland areas and coastlines. The Royal Navy was responsible for ensuring that the bombs were made safe. Removal and disposal was still the responsibility of the Bomb Disposal Unit of the Royal Engineers.

In 1944, the Germans introduced new weapons; the V1, a 'flying bomb' and guided missile, and the V2, a ballistic missile rocket that travelled at such speed that no one could see or hear its approach. London was the main target for these attacks.

WWII bomb targeting was inaccurate, especially in the first year of the war. A typical bomb load of 50kg HE bombs mixed with IBs which was aimed at a specific location might not just miss the intended target but fall some considerable distance away.



It is understood that the local Civil Defence authorities in urban areas had a comprehensive system for reporting bomb incidents and dealing with any Unexploded Bombs (UXB) or other UXO. In more rural areas, fewer bombing raids occurred. It is known that Air Raid Precaution (ARP) records under-represent the number and frequency of bombs falling in rural and coastal areas. Bombs were either released over targets or as part of 'tip and run' raids where bomber crews would drop their bombs to avoid anti-aircraft fire or Allied fighter aircraft on the route to and from other strategic targets. Bombs dropped as a result of poor targeting or 'tip and run' raids on rural and coastal areas often went unrecorded or entered as 'fell in open country' or 'fell in the sea'. The Luftwaffe are thought to have dropped approximately 75,000 tons of bombs on Britain throughout the Second World War and an estimated 11% of all bombs dropped during the war failed to detonate.

The potential for a UXB hazard to exist on a site depends on a variety of factors. Were there strategic targets in the surrounding area? Was the site bombed? Could a UXB impact have been missed? Even in rural areas, the potential for UXB cannot be totally discounted and therefore it is essential that detailed local bombing records are obtained when assessing the UXB hazard on any site.

Appendix 3 Recent UXO Finds

UXO finds in the UK are a regular occurrence, although they almost never result in an accidental detonation.

It is still important to note that explosives rarely lose effectiveness with age. In some instances, mechanisms such as fuzes and gaines can become more sensitive and more prone to detonation, regardless of whether the device has been submersed in water or embedded in silt, clay or similar materials.

The effects of an accidental UXO detonation are usually extremely fast, often catastrophic and invariably traumatic to any personnel involved. Such occurrences are largely restricted to current theatres of war and overseas minefields, with occasional events in mainland Europe.

The sections below provide a brief summary of recent significant UXO finds in the UK. To keep up to date with the latest UXO finds, visit http://zeticauxo.com/news/.

On the 15th May 2017, 1No. suspected 250kg German UXB was found on a building site in Aston, Birmingham. Due to the corrosion of the fuzes, the UXB was destroyed in situ on the 17th May 2017.

On the 4th September 2017, 1No. 50kg UXB was found in a ragstone quarry at Kings Hill near West Malling in Kent. It was destroyed in situ in a controlled explosion by an EOD team.

On the 11th February 2018, 1No. 500kg UXB was found in King George V Dock in London, resulting in the temporary closure of the adjacent London City Airport. The UXB was freed from a silt bed and towed along the River Thames to Shoeburyness where it was destroyed in a controlled explosion.

On the 26th February 2018, an EOD team destroyed numerous items of ordnance including shells and 20mm ammunition which had been exposed by storms on Selsey beach. A similar operation was required after more UXO finds on the beach in April 2018.

On the 31st March 2018, 2No. 870lb British PMs were found in waters off Guernsey. They were destroyed in controlled explosions.

On the 20th May 2018, a 1,000kg German sea mine washed ashore at Elmer beach near Bognor Regis, West Sussex. A 1 mile exclusion zone was enforced before an EOD team towed the device out to sea for a controlled explosion.

On the 24th May 2018, numerous ordnance-related items were found on a proposed residential development in Burntwood, Staffordshire.

On the 10th July 2018, a suspected 1,000kg German UXB was found by scuba divers near Teignmouth Pier in Devon. The UXB was towed out into open sea by a RN EOD team for a controlled explosion.

On the 30th August 2018, a 2,000lb German PM was trawled up by a fishing vessel off Mersea in Essex. The PM was moved to an area of open sea where it was destroyed in a controlled explosion by a RN EOD team.

On the 29th November 2018 a large naval projectile was found at Wembury Point, Plymouth. It was destroyed in a controlled explosion.

During January and February 2019 a military EOD was called out to deal with several items of UXO washed up at Medmerry Beach in Selsey. The site of a former gunnery range, it followed on from several similar incidents in 2018.

On the 21st January 2019 a suspected 1,000lb torpedo was brought into Brixham Harbour by a fishing trawler. It was towed back out to sea and destroyed by a Naval EOD team.

On the 6th February 2019 3No. WWII projectiles were found on Chalkwell Beach near Southend-on-Sea, Essex. They were destroyed in a controlled explosion.

On the 19th February 2019 6No. projectiles were found on the beach at Lilstock, Somerset.

On the 14th March 2019 an unexploded pipe mine was found at the former RAF Manston airfield near Ramsgate, Kent. It was destroyed in a controlled explosion.

On the 21st March 2019 2No. unexploded shells were found on a building site in Brighton. They were removed by an EOD team.

On the 25th March 2019 an unexploded shell was found in Stechford, Birmingham. It was removed to a field and destroyed in a controlled explosion.

On the 22nd May 2019 70No. Self-Igniting Phosphorus (SIP) grenades were found during development works at Tongland Dam in Dumfries & Galloway, Scotland. They were destroyed in a controlled explosion.

On the 23rd May 2019 a 250kg German UXB was found by workers on a building site at Kingston University in London (see plate below). The UXB could not be safely removed and was consequently destroyed in situ by an EOD team.



On the 27th May 2019 24No. SIP grenades were found in a field near Sibton in Suffolk. An EOD team constructed a 2ft deep trench into which the grenades were placed before being destroyed in a controlled explosion.

On the 7th June 2019 a 50kg German fragmentation UXB was found at a building site in Kings Hill at the former RAF West Malling airfield. It was destroyed in a controlled explosion by an EOD team the following day. On the 26th September 2019 another 50kg German UXB was found at Kings Hill and was destroyed in a controlled explosion the next day.

On the 20th September 2019 a suspected 250kg German UXB was found on a construction site in Bordon, Hampshire. It was destroyed in a controlled explosion by an EOD team.

In September 2019 a German PM was found by divers off Southend-on-Sea, Essex. It was towed out to open water off Shoeburyness by a Royal Navy EOD team and destroyed in a controlled explosion.

Appendix 4 Glossary and Definitions

Abandoned Explosive Ordnance (AXO)	Abandoned Explosive Ordnance is explosive ordnance that has not been used during an armed conflict, that has been left behind or disposed of by a party to an armed conflict, and which is no longer under control of that party. Abandoned explosive ordnance may or may not have been primed, fuzed, armed or otherwise prepared for use.
Acetone	A colourless, flammable substance used in the production of early High Explosives.
Arkite	A coal-mine explosive made by Kynoch Ltd. It was comprised of nitroglycerine, nitrocellulose, potassium nitrate, wood meal and ammonium oxalate
Close Combat Munitions	Items of ordnance thrown, propelled or placed during land warfare, to include grenades, mortars, projectiles, rockets and land mines.
Cordite	Cordite is a smokeless propellant made from nitrocellulose and nitroglycerine, gelatinised by means of acetone. It was used in a wide variety of munitions.
Demil	Derived from the term 'Demilitarisation', it refers to the break down and the recycling or disposal of ordnance components.
Detonation	The high-speed chemical breakdown of an energetic material producing heat, pressure, flame and a shock wave.
Device	This term is used for any component, sub-assembly or completed ordnance, which may or may not have an explosive risk. It can apply to detonators, primers, gaines, fuzes, shells or bombs.
Dynamite	Dynamite is a name that has been given to various nitroglycerine explosives. Dynamite No. 1 consists of nitroglycerine and Kieselguhr. In other dynamites, the nitroglycerine is absorbed in a material like wood meal, and a nitrate is added to oxidise the latter on explosion. In gelatine dynamite the nitroglycerine is gelatinised with collodion cotton.
Erin Gelignite	A form of gelignite containing a containing a small percentage of dinitro-toluene to prevent the nitroglycerine freezing.
Explosive	The term explosive refers to compounds forming energetic materials that under certain conditions chemically react, rapidly producing gas, heat and pressure. Obviously, these are extremely dangerous and should only be handled by qualified professionals.

Explosive Ordnance (EO)	Explosive Ordnance is all munitions containing explosives, nuclear fission or fusion materials and biological and chemical agents. This includes bombs and warheads, guided and ballistic missiles, artillery, mortar, rocket, small arms ammunition, mines, torpedoes, depth charges, pyrotechnics, cluster bombs & dispensers, cartridge & propellant actuated devices, electro-explosive devices, clandestine & improvised explosive devices, and all similar or related items or components explosive in nature.
Explosive Ordnance Clearance (EOC)	Explosive Ordnance Clearance is a term used to describe the operation of ordnance detection, investigation, identification and removal, with EOD being a separate operation.
Explosive Ordnance Disposal (EOD)	Explosive Ordnance Disposal is the detection, identification, on-site evaluation, rendering safe, recovery and final disposal of unexploded explosive ordnance.
Explosive Ordnance Reconnaissance (EOR)	Explosive Ordnance Reconnaissance is the detection, identification and on-site evaluation of unexploded explosive ordnance before Explosive Ordnance Disposal.
Explosive Remnants of War (ERW)	Explosive Remnants of War are Unexploded Ordnance (UXO) and Abandoned Explosive Ordnance (AXO), excluding landmines.
Explosive Substances and Articles (ESA)	Explosive substances are solid or liquid substances (or a mixture of substances), which are either: • capable by chemical reaction in itself of producing gas at such a temperature and pressure and at such a speed as to cause damage to the surroundings. • designed to produce an effect by heat, light, sound, gas or smoke, or a combination of these as a result of a non-detonative, self-sustaining, exothermic reaction. Explosive article is an article containing one or more explosive substances.
Fuze	A fuze is the part of an explosive device that initiates the main explosive charge to function. In common usage, the word fuze is used indiscriminately, but when being specific (and in particular in a military context), fuze is used to mean a more complicated device, such as a device within military ordnance.
Gaine	Small explosive charge that is sometimes placed between the detonator and the main charge to ensure ignition.
Geophysical survey	A geophysical survey is essentially a range of methods that can be used to detect objects or identify ground conditions without the need for intrusive methods (such as excavation or drilling). This is particularly suited to ordnance as disturbance of ordnance items is to be avoided where ever possible.

Gelignite	Gelignite was a blasting explosive comprised of nitroglycerine, nitrocellulose, wood meal, potassium nitrate, calcium carbonate and water.
Gold line	This is the estimated limit of blast damage from an explosive storage magazine. It usually means that development within this zone is restricted.
High Explosive	Secondary explosives (commonly known as High Explosives (HE)) make up the main charge or filling of an ordnance device. They are usually less sensitive than primary explosives. Examples of secondary explosives are: Nitro glycerine (NG), Trinitrotoluene (TNT), AMATOL (Ammonia nitrate + TNT), Gunpowder (GP), and Cyclotrimethylenetrinitramine (RDX).
Kynite	Kynite was a coal-mine explosive comprised of nitroglycerine, barium nitrate, wood meal, starch and calcium carbonate.
Lead Nitrate	Produced by dissolving lead in nitric acid, lead nitrate has historically been used for producing matches and low-yield explosives.
Monarkite	Monarkite was a coal mining explosive made by Kynoch Ltd. It was comprised of ammonium nitrate, sodium nitrate, nitroglycerine, nitrocellulose, starch, mineral jelly and sodium chloride.
Munition	Munition is the complete device charged with explosives, propellants, pyrotechnics, initiating composition, or nuclear, biological or chemical material for use in military operations, including demolitions. This includes those munitions that have been suitably modified for use in training, ceremonial or non-operational purposes. These fall into three distinct categories:- • inert - contain no explosives whatsoever. • live - contain explosives and have not been fired. • blind - have fired but failed to function as intended.
Nitrocellulose	Nitrocellulose, also referred to as guncotton, is the common designation for nitric acid esters of cellulose (cellulose nitrates). Due to its explosive properties, it was used as a blasting explosive and in the manufacture of composite explosives and propellants.
Nitroglycerine	An explosive made by nitrating glycerine. It was commonly used as a component of composite explosives and propellants.
Primary Explosive	Primary explosives are usually extremely sensitive to friction, heat, and pressure. These are used to initiate less sensitive explosives. Examples of primary explosives are: Lead Azide, Lead Styphnate, and Mercury Fulminate. Primary explosive are commonly found in detonators.

Propellants	Propellants provide ordnance with the ability to travel in a controlled manner and deliver the ordnance to a predetermined target. Propellants burn rapidly producing gas, pressure and flame. Although usually in solid form they can be produced in liquid form. Examples of propellants are: Ballistite often found in a flake form and Cordite used in small arms ammunition.
Proprietary Explosives	Explosives manufactured according to company Kynoch specifications and sold under a trade name to maintain commercial exclusivity.
Pyrotechnic	A pyrotechnic is an explosive article or substance designed to produce an effect by heat, light, sound, gas or smoke, or a combination of any of these, as a result of non-detonative, self-sustaining, exothermic chemical reactions.
Small Arms Ammunition (SAA)	SAA includes projectiles around 12mm or less in calibre and no longer than approximately 100mm. They are fired from a variety of weapons, including rifles, pistols, shotguns and machine guns.
Unexploded Anti-Aircraft (UXAA) Shell	UXAA shells are army ordnance commonly containing HE, though they can also contain pyrotechnic compounds that produce smoke. Most commonly, these were 3.7” and 4.5” HE shells, although they ranged from 2” to 5.25” calibre.
Unexploded Bomb (UXB)	UXB is a common term for unexploded air-dropped munitions.
Unexploded Ordnance (UXO)	UXO is explosive ordnance that has been either primed, fuzed, armed or prepared for use and has been subsequently fired, dropped, launched, projected or placed in such a manner as to present a hazard to operations, persons or objects and remains unexploded either by malfunction or design.

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Pre-Desk Study Assessment

Site:	Northern Site, Arklow, County Wicklow
Client:	Waterman Group
Contact:	Greg Anton
Date:	10th December 2019
Pre-WWI Military Activity on or Affecting the Site	None identified.
WWI Military Activity on or Affecting the Site	None identified.
WWI Strategic Targets (within 5km of Site)	The following strategic targets were located in the vicinity of the Site: • Arklow Harbour. • Transport infrastructure and public utilities.
WWI Bombing	None identified on the Site.
Interwar Military Activity on or Affecting the Site	None identified.
WWII Military Activity on or Affecting the Site	None identified.
WWII Strategic Targets (within 5km of Site)	The following strategic targets were located in the vicinity of the Site: • Arklow Harbour. • Transport infrastructure and public utilities.
WWII Bombing Decoys (within 5km of Site)	None.
WWII Bombing	Despite declaring neutrality, the Republic of Ireland was bombed on several occasions by the Luftwaffe between August 1940 and July 1941. The first bombs were dropped on County Wexford and the heaviest bombing occurred during January and May 1941 in Dublin. No readily available records have been found to indicate that the Site was bombed.
Post-WWII Military Activity on or Affecting the Site	None identified.
Recommendation	A detailed desk study, whilst always prudent, is not considered essential in this instance.

This summary is based on a cursory review of readily available records. Caution is advised if you plan to action work based on this summary.

It should be noted that where a potentially significant source of UXO hazard has been identified on the Site, the requirement for a detailed desk study and risk assessment has been confirmed and no further research will be undertaken at this stage. It is possible that further in-depth research as part of a detailed UXO desk study and risk assessment may identify other potential sources of UXO hazard on the Site.

C. Ultrabeam Hydrographic Report (Arklow Bank Wind Park- Export Cable Routes, Volume 2, July 2019)

ALPHAMARINE
VESSEL SUPPORT & MARINE SERVICES

Arklow Bank Wind Park



EXPORT CABLE ROUTES

VOLUME 2: RESULTS REPORT

UHC19004 – JUNE - JULY 2019

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STANDARD LIST OF COMMON ABBREVIATIONS

ADCP	Acoustic Doppler Current Profiler
AIS	Automatic Identification System
BSB	Below Seabed
CAD	Computer Aided Design
CD	Chart Datum
CM	Central Meridian
CTD	Conductivity Temperature Depth
(d)GPS	(differential) Global Positioning System
ED50	European Datum 1950
EGNOS	Euro Geostationary Navigation Overlay Service
EPIRB	Emergency Position Indicating Radio Beacon
ESA	European Space Agency
GAMS	GPS Azimuth Measurement Subsystem
GPS	Global Positioning System
GSM	Global System for Mobile communications
HAT	Highest Astronomical Tide
HF	High Frequency
Hz	Hertz
IHO	International Hydrographic Organisation
IMO	International Maritime Organisation
INS	Inertial Navigation System
kHz	Kilohertz
km	Kilometre
KP	Kilometre Post
LAT	Lowest Astronomical Tide

STANDARD LIST OF COMMON ABBREVIATIONS

LRK	Long Range Kinematic
MCA	Maritime & Coastguard Agency
MF	Medium Frequency
MHWI	Mean High Water Interval
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MHz	Megahertz
MLWI	Mean Low Water Interval
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MNR	Mean Neap Range
MSL	Mean Sea Level
MSR	Mean Spring Range
OD(N)	Ordnance Datum (Newlyn)
OSGB	Ordnance Survey of Great Britain
PCS	Processing Control System
PPE	Personal Protective Equipment
PPM	Parts Per Million
PPP	Precise Point Positioning
PPS	Pulse Per Second
QC	Quality Control
QPS	Quality Positioning Systems
RMS	Route Mean Square
RTCM	Radio Technical Commission for Maritime services
RTG	Real Time GIPSY (GPS Inferred Positioning System)

STANDARD LIST OF COMMON ABBREVIATIONS

RTK	Real Time Kinematic
SBAS	Satellite Based Augmentation System
SD	Standard Deviation
SoW	Scope of Works
SVP	Sound Velocity Probe
SVS	Sound Velocity Sensor
SWL	Safe Working Load
TPU	Transceiver Processing Unit
TVG	Time Variable Gain
UHF	Ultra-High Frequency
UPS	Uninterrupted Power Supply
USBL	Ultra-Short Base Line
UTM	Universal Transverse Mercator
UXO	Unexploded Ordnance
VHF	Very High Frequency
VORF	Vertical Offshore Framework
WAAS	Wide Area Augmentation System
WGS84	World Geodetic System 1984

1. EXECUTIVE SUMMARY

1.1. Cable Route 1

Water depths along the RPL vary between 2.91m LAT at KP0 to 34.74m LAT in a bathymetric channel at KP11.826. The largest gradient along Cable Route 1 (CR1) occurs at KP3.516 where the route crosses a bank of mobile sediment reaching a peak gradient of 16.3°. The high gradients encountered, from approximately KP9 to KP10 and from KP11 to the end of CR1, are the product of steep mobile sediments.

In total 870 contacts have been identified on SSS; 709 have been interpreted as boulders, 159 have been interpreted as debris and 2 have been interpreted as potential UXO. In total 122 magnetic targets have been interpreted. Sixteen magnetic targets have been associated with SSS targets. Additionally, fishing equipment has been identified on the seabed within the cable route corridor.

Four classification for surface geology have been interpreted along the cable route; SAND, COARSE SEDIMENT, SAND ribbons over COARSE SEDIMENT and GLACIAL TILL. Areas of mobile features and boulder fields have also been identified and interpreted.

Five subsurface units have been interpreted along the cable route. In general, recent mobile SAND intermittently overlies a unit of reworked glacial TILL composed of COARSE SEDIMENT. The presence and thickness of SAND varies along the route but generally the thickness increases towards Arklow Bank. One exposure of Glacial TILL that intersects the proposed RPL has been interpreted in the nearshore section between KP1.255 and KP2.589. Top of Palaeozoic rock has been interpreted dipping east-south eastward between 1.1m below seabed (BSB) at KP1.688 down to 34.0m BSB along the RPL but has been interpreted as shoal a 0.6m within the survey corridor. Between KP11.5 and the end of the route a palaeochannel has been incised into the reworked glacial till sediments and has been subsequently filled with channel fill sediments.

1.2. Cable Route 2

The bathymetry along the RPL varies between 2.97m LAT at KP0 to 33.92m LAT in a bathymetric depression at KP10.993. The largest gradient along Cable Route 2 (CR2) occurs at KP11.593 where the route crosses a bank of mobile sediment reaching a peak gradient of 32.5°. The high gradients encountered, from approximately KP7 and KP10 and from KP11 to the end of CR2, are the product of steep mobile sediments.

In total 1075 contacts have been identified on SSS; 873 have been interpreted as boulders, 188 have been interpreted as debris, 7 have been interpreted as cables, 6 are associated with wrecks and 1 target has been interpreted as potential UXO. In total 151 magnetic targets have been interpreted. Sixteen magnetic targets have been associated with SSS targets. One wreck lies 16m east of the proposed route, whilst all other wrecks identified on CR2 are greater than 100m from the route. The existing export cable has been identified in the magnetic and SSS data and is observed to cross the proposed route, CR2, at KP7.308.

Four classifications for surface geology have been interpreted along the cable route; SAND, COARSE SEDIMENT, SAND ribbons over COARSE SEDIMENT and GLACIAL TILL. Areas of mobile features and boulder fields have also been identified and interpreted.

Four subsurface units have been interpreted along the cable route. In general, recent mobile SAND intermittently overlies a unit of reworked glacial till composed of COARSE SEDIMENT. The presence and thickness of SAND varies along the route but generally the thickness increases towards Arklow Bank. Between KP7.5 and KP8.5 the SAND has accumulated significantly to form Seven Fathom Bank. One exposure of Glacial TILL that intersects the proposed RPL has been interpreted in the nearshore section between KP1.277 and KP2.200. Top of Palaeozoic rock has been interpreted dipping south eastward between 0.9m below seabed (BSB) at KP1.201 down to 36.7m BSB along the RPL but has been interpreted as shoal as 0.6m within the survey corridor.

1.3. Cable Route 3

The bathymetry along the RPL varies between 7.46m LAT at KP0 to 37.75m LAT in a bathymetric depression at KP17.583. The largest gradient along Cable Route 3 (CR3) occurs at KP17.637 where the route crosses large sand waves within mobile sediment reaching a peak gradient of 31.4°. The high gradients encountered, from approximately KP8 and KP15 and from KP17 to the end of CR3, are the product of steep mobile sediments.

In total 1524 contacts have been identified on SSS; 1372 have been interpreted as boulders, 150 have been interpreted as debris and 2 have been interpreted as cables. In total 196 magnetic targets have been interpreted. Eleven magnetic targets have

been associated with SSS targets. The existing export cable has been identified in the magnetic data and is observed to cross the proposed route, CR3, at KP3.984.

Three classification for surface geology have been interpreted along the cable route; SAND, COARSE SEDIMENT and SAND ribbons over COARSE SEDIMENT. Areas of mobile features and boulder fields have also been identified and interpreted.

Four subsurface units have been interpreted along the cable route. In general, recent mobile SAND intermittently overlies a unit of reworked glacial till composed of COARSE SEDIMENT. The presence and thickness of SAND varies along the route but generally the thickness increases towards Arklow Bank. Between KP9.4 and KP10.9 the SAND has accumulated significantly to form Seven Fathom Bank. Top of Palaeozoic rock has been interpreted dipping south eastward between 5.9m below seabed (BSB) at KP1.201 down to 36.5m BSB along the RPL but has been interpreted as shoal as 5.2m within the survey corridor.

2. INTRODUCTION

2.1. Project Overview

Ultrabeam were commissioned by Alpha Marine Ltd to carry out geophysical surveys on the proposed Arklow Bank Wind Park off the east coast of Ireland. The survey was to incorporate the lease area comprising of Arklow Bank and surrounding waters, as well as an export cable routes to shore. SSE Airtricity plan to develop the area in water depths deeper than 8m LAT, avoiding the shallowest part of the bank. Figure 1 shows the extent of the lease area in black along with each cable route; Cable Route 1 (CR1) in red, Cable Route 2 (CR2) in purple and Cable Route 3 (CR3) in green.

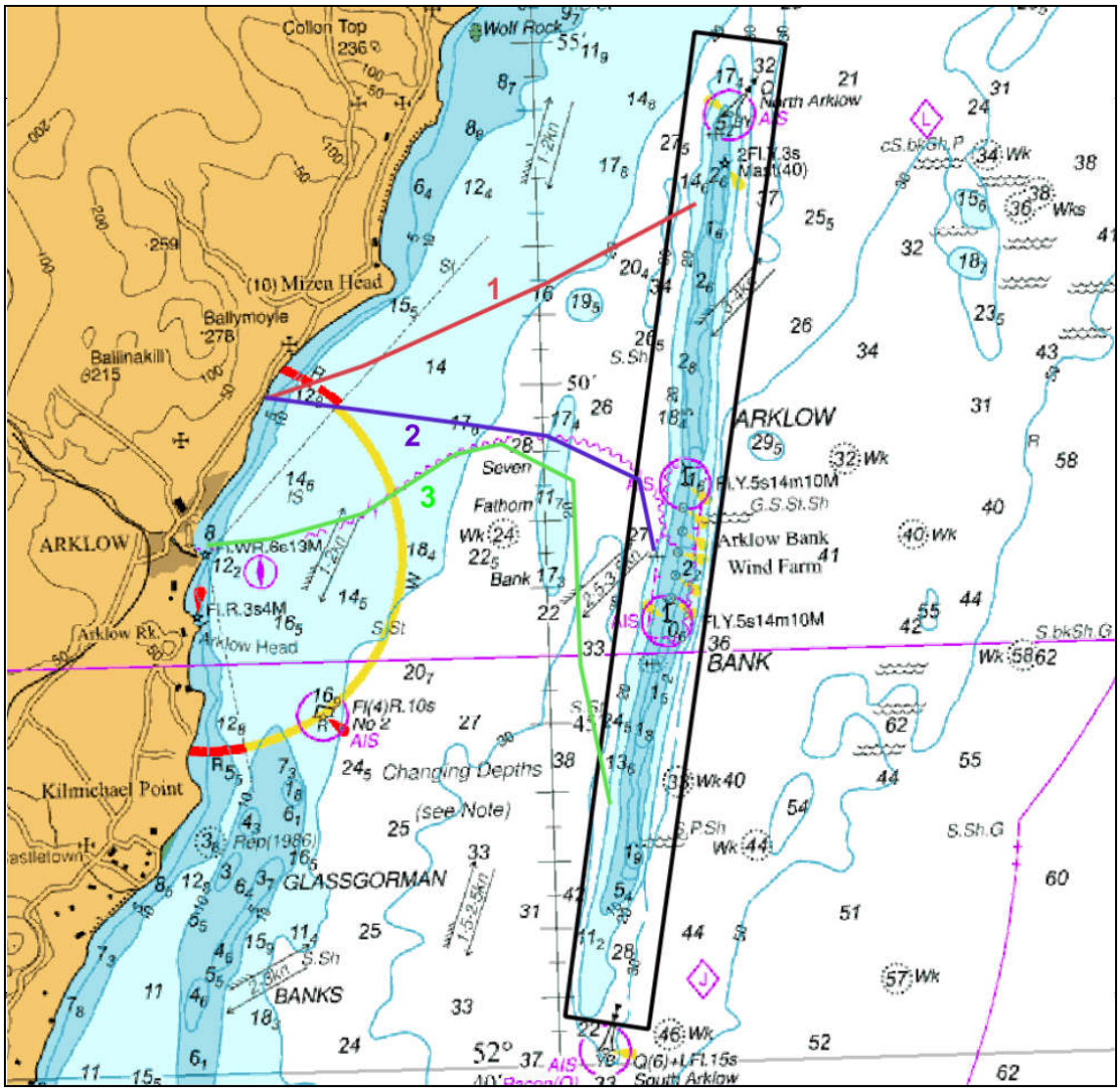


Figure 1: Site overview of the full development area of Arklow Bank Wind Park

The aim of the 2019 geophysical surveys is to gather bathymetric and geophysical data to facilitate the development of a ground model, to support the WTG foundation concept design and provide information on the preferred cable route.

The cable route surveys were undertaken between 16th of June 2019 and 7th of July 2019; with minimal delays incurred due to bad weather or fixed fishing gear, which was especially prevalent on inshore sections of CR1 and CR2.

The processing and results report, describes all processing undertaken and details the geological conditions of the seabed and shallow soils made on the three proposed export cable routes.

2.2. Operational Summary

Data acquisition for the cable route surveys was undertaken onboard the vessel 'AMS Panther'. The AMS Panther was equipped with two Norbit multibeam echo sounders integrated with Applanix POS MV Wavemasters II, Edgetech 4200 sidescan sonar, Applied Acoustics Boomer sub-bottom profiler and a Geometrics G882 magnetometer.

Multibeam, sidescan sonar, sub-bottom profiler and magnetometer systems were acquired simultaneously on all lines with the magnetometer 'piggy-backed' off the sidescan sonar. Each route measured 500m across and lines were spaced at 50m. Due to the presence of fishing gear in the shallowest sections of CR1 and CR2, additional shore parallel lines were acquired for approximately the first 250m of the routes.

2.3. Project Personnel

The following personnel were involved during the processing and interpretation phase of the project:

Andy McLeay	-	Project Manager
Gabriel Walton	-	Project Manager / Senior Data Processor
Tom Potter	-	Lead Geophysicist
Matt Hooke	-	Geophysicist
Max Stacey	-	Geophysicist
John Bunt	-	Geophysicist
Andy Baker	-	Geophysicist
Kayur Patel	-	Geophysicist
Sam Wyllie	-	Geophysicist
Alun Metcalf	-	Geophysicist

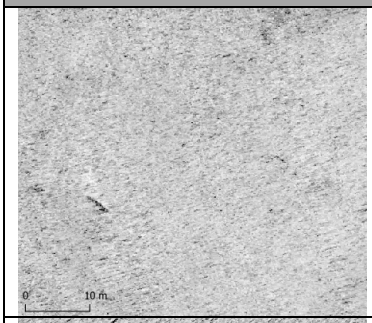
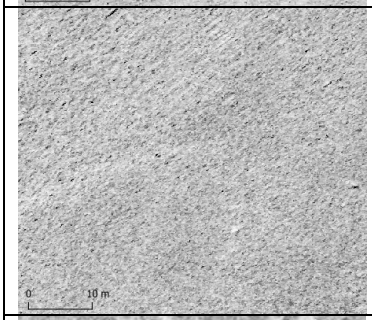
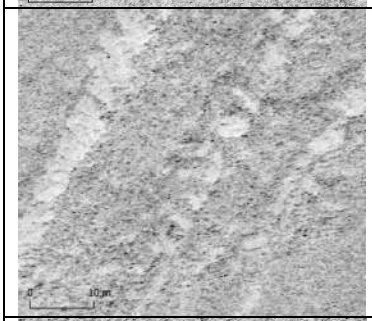
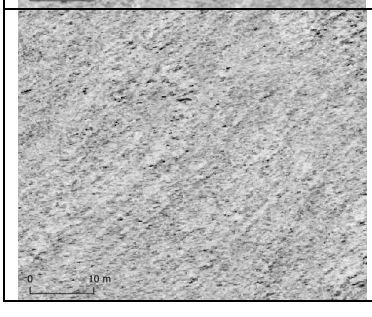
3. RESULTS

3.1. Interpretive Geomodel

3.1.1 Seabed Interpretation

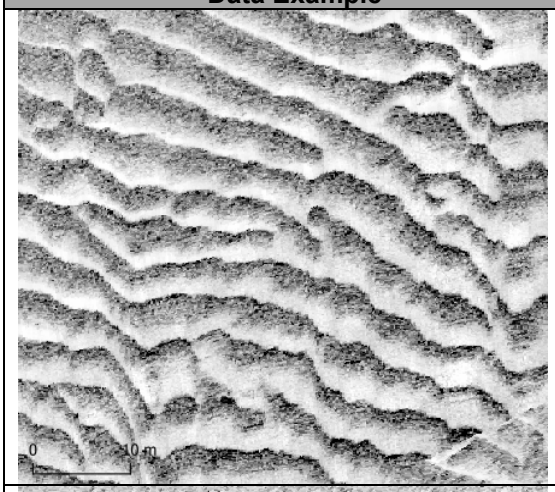
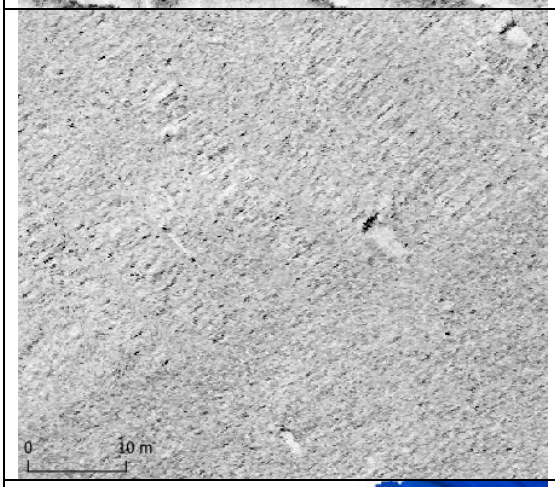
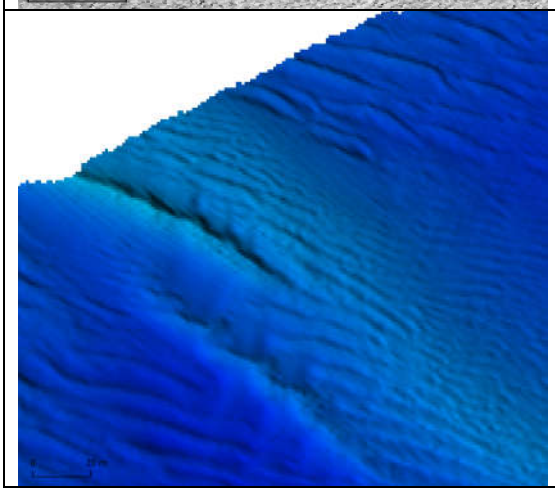
Four surficial sediment classes have been interpreted across the three cable route corridors; SAND, COARSE sediment, COASE sediment with occasional ribbons of SAND, and GLACIAL TILL. Table 1 shows an example of each classification with their respective descriptions.

Table 1: Surficial sediments interpretation

Data Example	Description	Sediment Classification
	Low to medium reflectivity, slightly textured sediment. Interpreted to be comprised of Holocene SAND.	**SAND**
	Medium reflectivity, slightly to moderately textured. Interpreted to be comprised of reworked SAND and GRAVEL derived from weathering of glacial TILL.	**COARSE SEDIMENT**
	Medium reflectivity, moderately textured with occasional ribbons of low to medium reflectivity, slightly textured sediment. Interpreted to be comprised of reworked SAND and GRAVEL derived from weathered glacial TILL overlaid with current lain ribbons of Holocene SAND.	**SAND ribbons over COARSE SEDIMENT**
	Medium to high reflectivity, highly textured sediment. Interpreted to be comprised of the Upper Till Facies of the Cardigan Bay Formation. (BGS,1990).	**GLACIAL TILL**

Additionally, three morphological features have been digitised to describe natural features that have been observed on the seabed; mobile sediments, boulder fields and sand wave crests. Table 2 shows examples of each morphology. Mobile sediment and boulder fields have primarily been identified using SSS data whilst sand wave crests have been digitised from MBES data.

Table 2: Seabed morphology interpretation

Data Example	Morphology
	**MEGARIPPLES**
	**BOULDER FIELD**
	**SAND WAVE**

3.1.2 Subsurface Interpretation

Shallow soil interpretation has been based upon British Geological Survey (BGS) and Geological Survey of Ireland (GSI) using 1:250000 series geological charts.

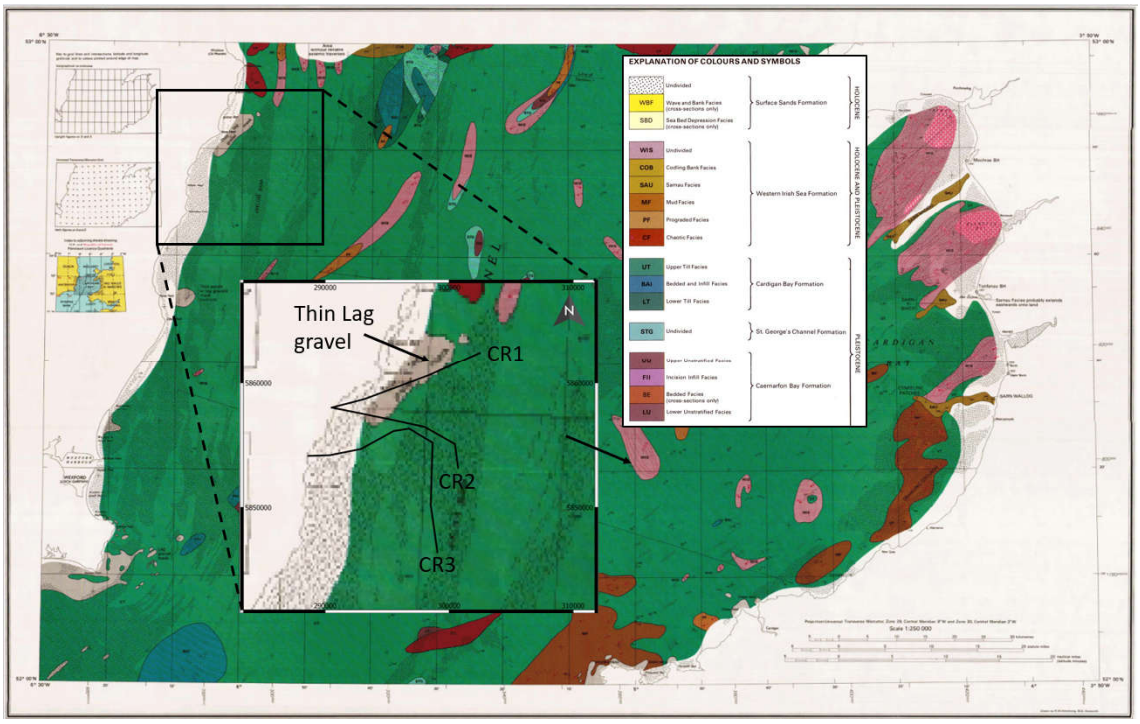


Figure 2: Quaternary geology chart of the survey area (Cardigan Bay Quaternary Geology, BGS/GSI, 1990)

From Figure 2 it is expected that glacial sediment will feature prominently across the site. These glacial sediments belong to the Upper Till Facies of the Cardigan Bay Formation. From interpretation of SSS and SBP data it is apparent that the glacial till is mostly covered with Holocene sediments, however, a few areas of TILL exposure have been identified and interpreted. From the BGS/GSI chart the Surface Sand Formation deposits are split into two facies; Wave and Bank Facies and Seabed Depression Facies, dependant on their respective nature. In this report the two facies will be grouped under “Holocene SAND”.

Each interpreted unit is described in subsections 3.1.2.1 through to 3.1.2.5.

3.1.2.1. Unit 0

This unit of surficial SAND that overlies Unit 1 is generally present as a veneer on the seabed but has accumulated in places into mobile sediment bedforms such as megaripples, sand waves and sand banks which have been associated with the “Wave

and Bank Facies". It has also been identified to fill depressions in the underlying sediment on occasion which have been associated with the "Seabed Depression Facies". In places, currents have shaped the sediment into thin ribbons overlying Unit 1. The unit is mostly acoustically blank with little to no internal reflections. The unit is interpreted to be comprised of Holocene SAND.

3.1.2.2. Unit 0A

This unit comprises of channel infill found to the east of CR1, which overlays Unit 1. Top of the unit is marked by a mostly flat and continuous strong reflector. The unit is mostly acoustically blank with little to no internal reflections. Sediment type is interpreted as reworked SAND and GRAVEL.

3.1.2.3. Unit 1

It is interpreted that Unit 1 sediment is the product of reworking of the underlying Unit 2, glacial TILL, and is comprised of SAND and GRAVEL. This is observed on seismic data as faint internal reflections with high attenuation close to the seabed. It is likely that this unit is associated with the lag gravels noted in Figure 2. It is present very close to the seabed over much of the route, covered by a veneer of Unit 0 sediments. Boundaries between upper units are often hard to distinguish and there have been conflicts of interpretation between this interpreted horizon and the presence of coarse sediments on the seabed. It is likely that in places it is very similar to the overlying Unit 0 sediments which leads to this discrepancy.

3.1.2.4. Unit 2

Unit 2 appears variable in its nature, chaotic in places and transparent in others. It is present extensively across the cable route. It is suspected to be the top of dense and compacted SAND and GRAVEL, with localised lenses of compacted sediment and/or clay. The unit is also comprised of strong isolated internal reflectors. It is interpreted that this unit is glacial TILL and is associated with the "Upper Till Facies" of the Cardigan Bay Formation.

3.1.2.5. Unit 3

In the western nearshore section, a hard substrate is identifiable within 10m of the seabed. This hard substrate is interpreted as the top of the Palaeozoic rock. This reflector is also the acoustic basement of this dataset. This strong reflector dips below 10m of the seabed around 5.5km east of coastline, with a general dip of east-

southeast. No outcrop of the unit is noted, and the maximum depth exceeds 27m, beyond which the reflector is no longer visible.

3.2. Cable Route 1

3.2.1 Route Overview

Data collected on CR1 has been interpreted and reported on using an RPL generated from coordinates stated in the SoW. KP markers have been generated from this RPL with KP0 as the most shoreward location. Figure 3 shows an overview of CR1 with bathymetry data gridded at 1m resolution.

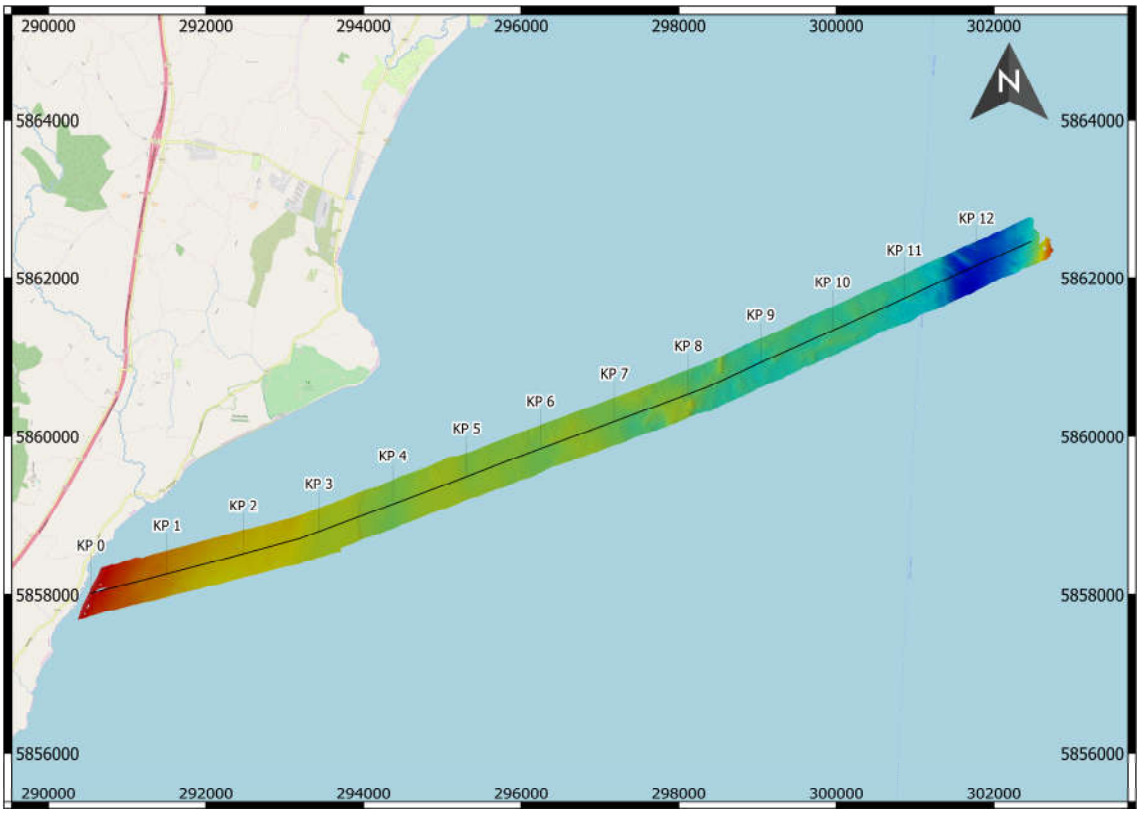


Figure 3: Overview of CR1 with bathymetry data

A profile of the bathymetry referenced to LAT along the RPL is shown in Figure 4, as well as gradients encountered. The bathymetry along the RPL varies between 2.91m at KP0 to 34.74m in a channel at KP11.826. The largest gradient along CR1 occurs at KP3.516 where the route crosses a bank of mobile sediment reaching a peak gradient of 16.3°. The high gradients encountered, from approximately KP9 to KP10 and from KP11 to the end of CR1, are the product of steep mobile sediments.

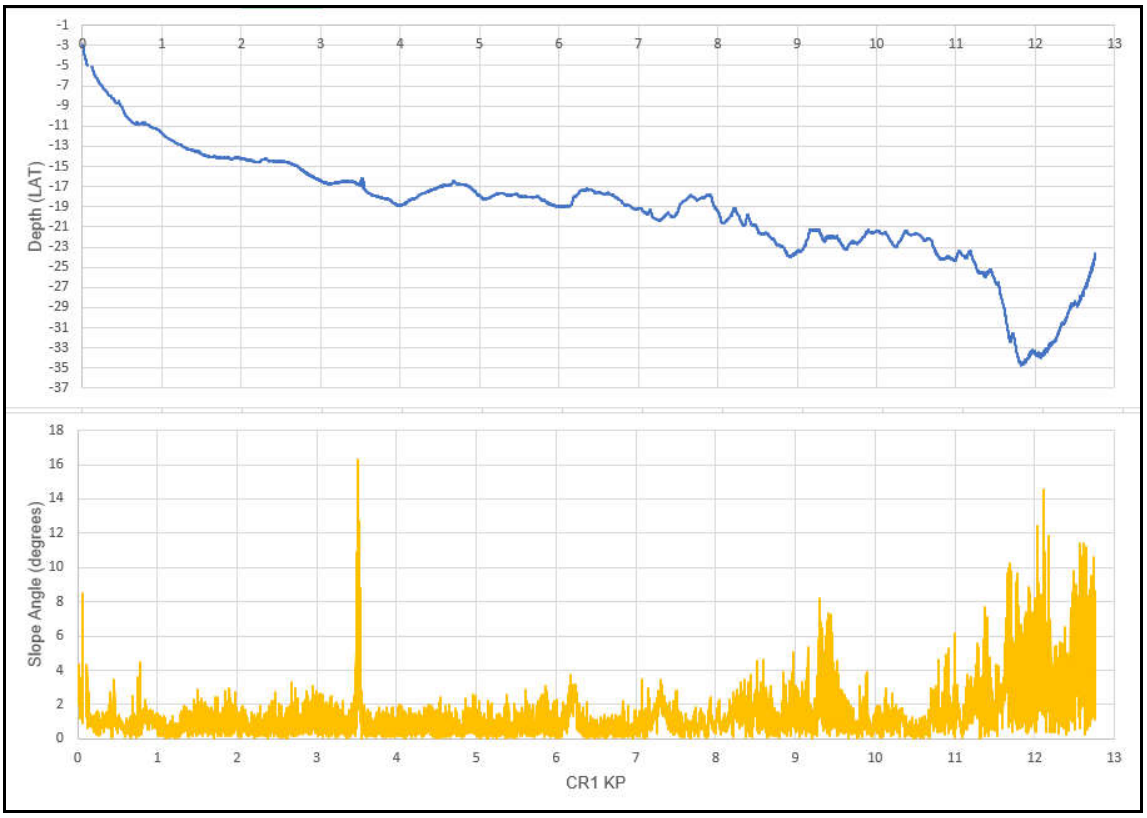


Figure 4: Bathymetry depths and slope angles along CR1

3.2.2 Surficial Geology

Details of seabed sediment and morphological features encountered along CR1 are present in “3.1.1 Seabed Interpretation”.

A full breakdown of changes in the surficial geology along the RPL are listed in section “3.2.5 Route Conditions”.

Sidescan data between KP1 and KP2 are presented in Figure 5. The sediment at KP1 transitioned from SAND to COARSE SEDIMENT. GLACIAL TILL was interpreted between KP1 and KP2. An area of SAND with mobile features was interpreted in the south west area of KP1.

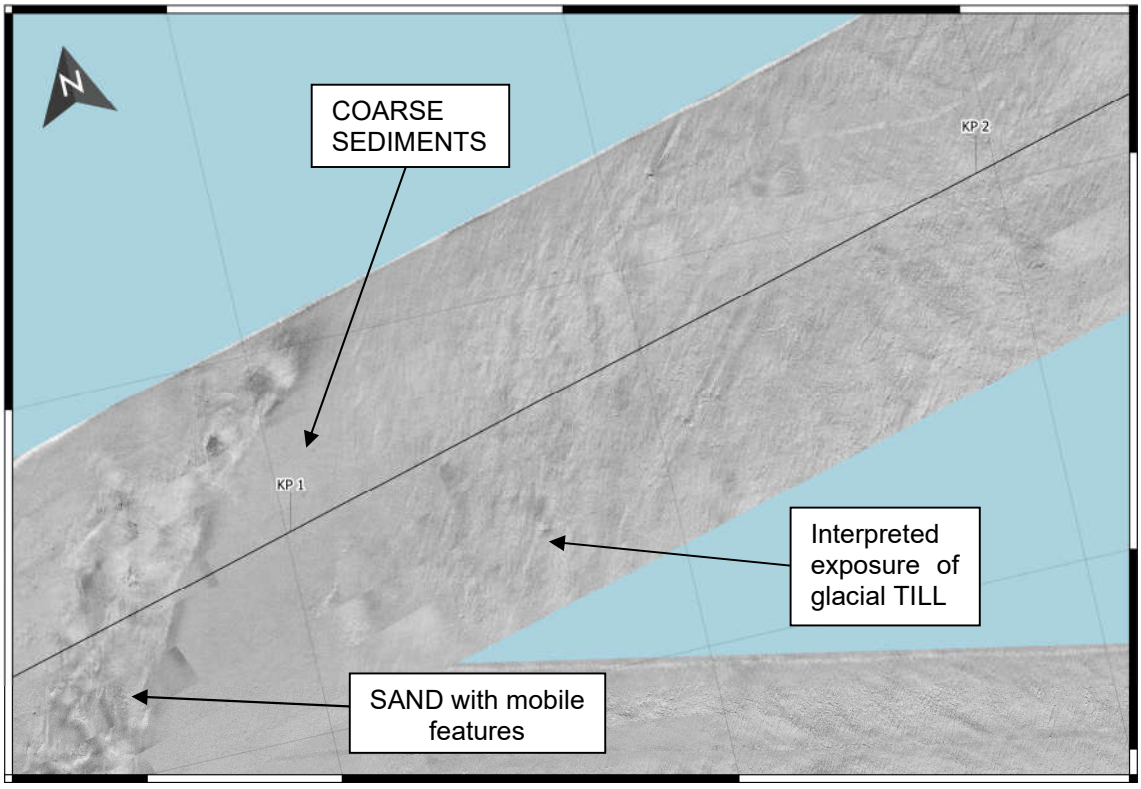


Figure 5: Sidescan data example between KP1 and KP2 on CR1

Sidescan data between KP6 and KP9 are presented in Figure 6. The sediment between KP6 and KP8 were interpreted as primarily COARSE SEDIMENT. SAND ribbons characterised by bands of low reflectivity were interpreted to intermittently overlie the COARSE SEDIMENT between KP6 and KP9. The sediment at KP9 transitioned to SAND with mobile bedforms.

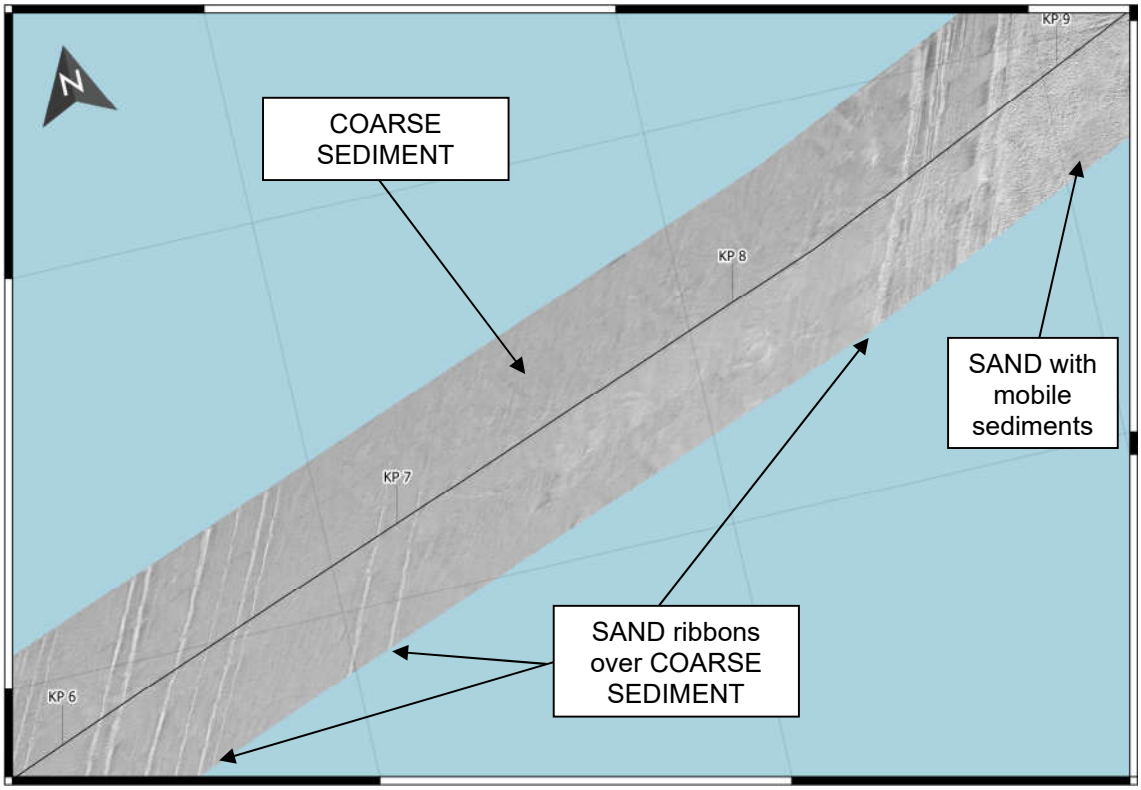


Figure 6: Sidescan data example between KP6 and KP9 on CR1

3.2.3 Contacts

In total 870 contacts have been identified on SSS; 709 have been interpreted as boulders, 159 have been interpreted as debris and 2 have been interpreted as potential UXO. In total 122 magnetic targets have been interpreted. 16 magnetic targets have been associated with SSS targets. Due to the line spacing between magnetometer lines it has not been possible to correlate any interpreted potential UXO with magnetic targets.

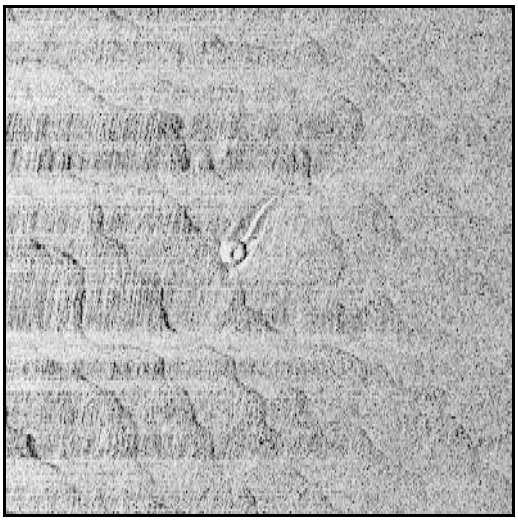


Figure 7: SSS Target "UHC19004_SSS_R1_0294" example of potential UXO

Some items of debris have been further classified as fishing gear where repeated targets appear to be joined by rope, an example of which is shown in Figure 8.

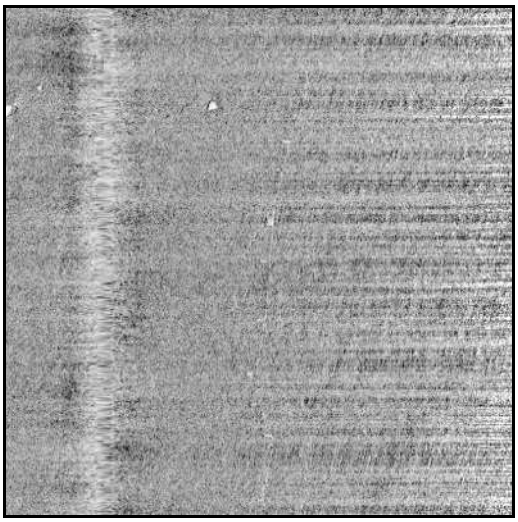


Figure 8: Example of fishing gear on SSS

3.2.4 Shallow Soils

All five units listed in “3.1.2 Subsurface Interpretation” have been interpreted on SBP data within 10m of the seabed along the CR1 corridor. A detailed listing of the occurrence of the interpreted units along the RPL has been undertaken in section “3.2.5 Route Conditions”.

An SBP data example from the mid-section of CR1 is presented in Figure 9. Units 0 to Unit 3 were interpreted in the profile. Unit 1 were the prominent seabed surficial sediment with an intermittent veneer of Unit 0 which thickens towards the north east of the profile as a reflector representing the top of Unit 1 becomes apparent. Units 2 and 3 underlay the surficial sediments and expressed a slight north east dip.

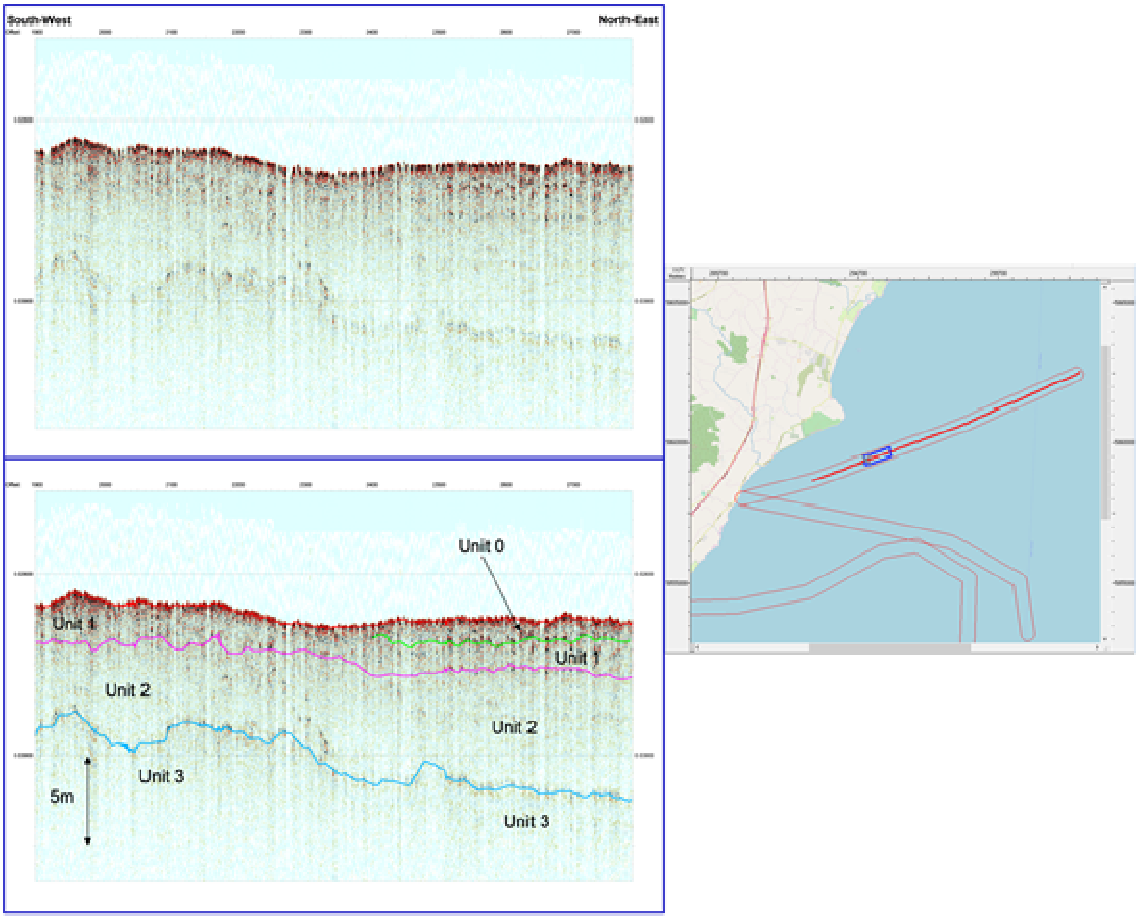


Figure 9: SBP data example from the mid-section of CR1

An SBP data example from the offshore section of CR1 is presented in Figure 10. Unit 0 overlies Unit 1 in the south west of the profile which is then incised by a palaeochannel in the north east. The palaeochannel has been infilled by Unit 0A sediments. Unit 0 is still present covering the palaeochannel and thickens to the north east as the route approaches Arklow Bank. Unit 2 is only intermittently interpreted in this section.

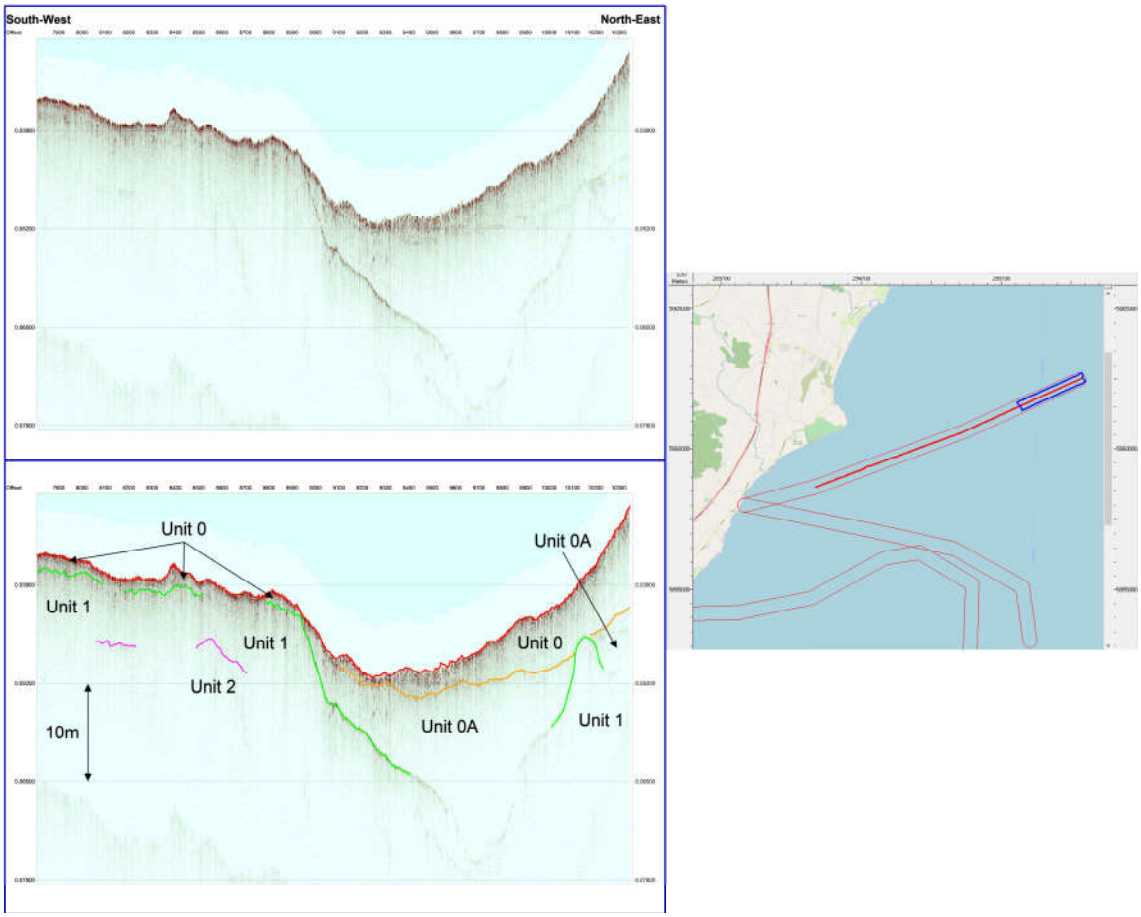


Figure 10: SBP data example from the offshore section of CR1

Isochores of Units 0A and Units 1-3 are presented in Figure 11 and Figure 12 . Unit 0A were interpreted at KP12 where a palaeochannel has been infilled. Unit 1 were interpreted in a narrow band at KP5, becoming more consistent from KP7 to KP12. Unit 2 were interpreted shallow in the nearshore, exhibiting an eastward dip towards KP11. Unit 3 were interpreted consistently from KP0 to KP9 exhibiting a gradual south eastward dip.

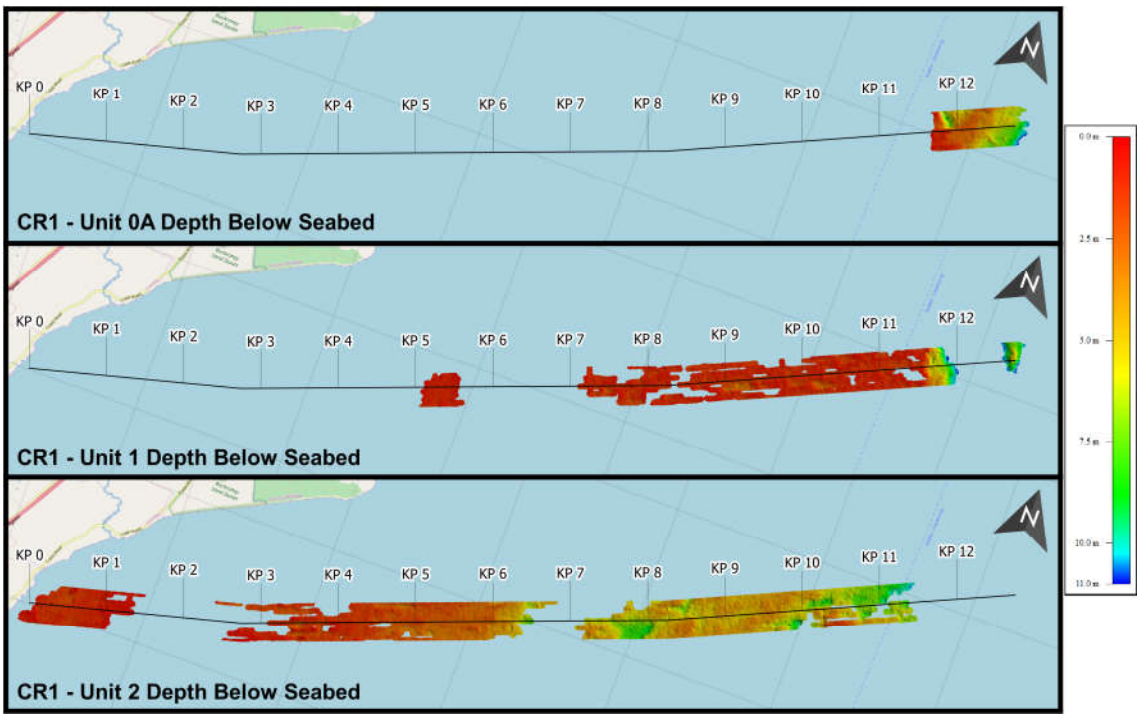


Figure 11: Gridded isochores of Units 0A, 1 and 2 on CR1

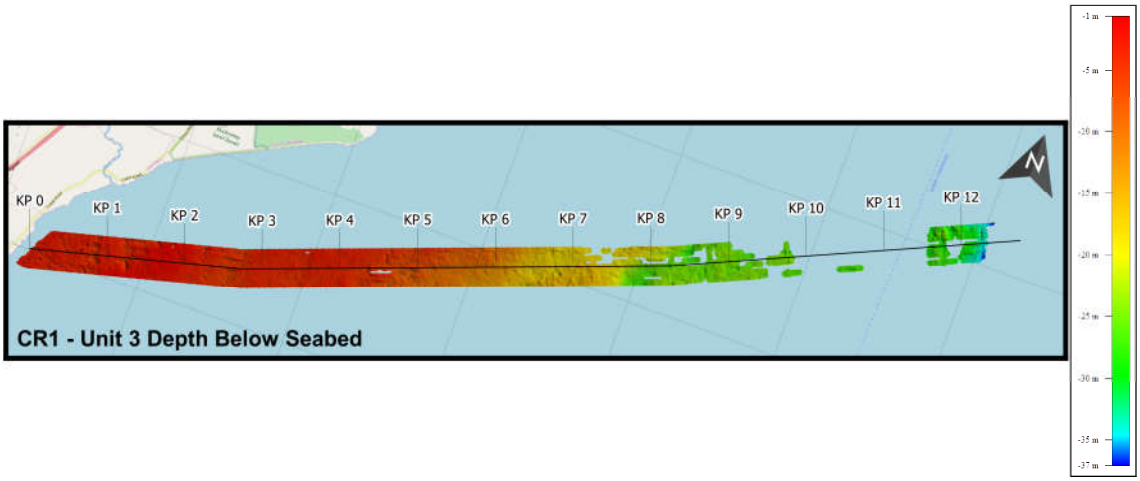


Figure 12: Gridded isochore of Unit 3 on CR1

3.2.5 Route Conditions

Table 3: Route condition listing, CR1

KP Start	KP End	SBF	Mobile Features	SBP
0.000	0.720	SAND		Unit 2 varies between 1.0 and 2.2m BSB, overlain by Unit 1 sediments on the seabed with a veneer of Unit 0 sediments. Depth to Unit 3 varies between 2.6m and 4.1m
0.720	0.833	SAND with boulder fields		Unit 2 depth BSB decreases along the cable route, with a maximum depth of 2.2m, reducing to 1.1m, overlain by Unit 1 sediments with veneers of Unit 0 sediments. Depth to Unit 3 increases along the cable route, with a minimum depth of 2.7m, increasing to 6.2m
0.833	1.255	COARSE SEDIMENT with boulder fields		Top of Unit 2 remains mostly flat, with a maximum depth of 1.3m and a minimum depth of 0.5m, overlain by Unit 1 sediments. Unit 3 undulates between 3.0m and 6.0m depth.
1.255	2.589	GLACIAL TILL exposure with boulder fields		Unit 2 nears the surface at a depth of between 0.5m and 1.2m. From KP1.300 top of Unit 2 is no longer interpretable as it outcrops. Depth to Unit 3 continues to vary between 1.0m and 5.5m
2.589	2.692	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 5.0m and up to 0.1m amplitude trending north easterly.	Surface sediments consist of Unit 1 with veneers of Unit 0 sediments. Top of Unit 2 reappears at KP3.151 with a minimum depth of 1.2m, increasing along the cable route to 3.2m. Unit 3 varies between 3.6m and 5.3m BSB.
2.692	3.123	SAND with mobile sediments	Megaripples with average wavelength of 5.0m and up to 0.1m amplitude trending north easterly.	
3.123	3.499	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 5.0m and up to 0.1m amplitude trending north easterly.	

KP Start	KP End	SBF	Mobile Features	SBP
3.499	3.548	SAND with mobile sediments	Sand bank of 0.9m amplitude with superimposed megaripples with average wavelength of 5.0m and up to 0.2m amplitude trending north easterly.	
3.548	3.567	SAND with boulder field and mobile sediments	Megaripples with average wavelength of 5.0m and up to 0.1m amplitude trending north easterly.	
3.567	4.700	COARSE SEDIMENT with boulder fields		Unit 2 varies in depths from 0.7 to 2.6m BSB and is overlain by Unit 1 sediments. Depth to Unit 3 increases along the cable route from 3.4m to 7.4m.
4.700	4.893	SAND ribbons over COARSE SEDIMENT with boulder fields		Unit 2, with a minimum depth of 1.5m and a maximum depth of 2.8m; is overlain by Unit 1 sediments with intermittent veneers of Unit 0. Unit 3 varies in depth from 6.4m to 8.7m.
4.893	5.116	SAND ribbons over COARSE SEDIMENT		
5.116	5.432	COARSE SEDIMENT		Top of Unit 1 is between 0.6m and 1.6m. Unit 2 dips eastwards along the cable route increasing from 2.1m to 3.2m depth. Unit 3 increases in depth along the cable route, from 8.7m to 10.0m.
5.432	5.912	SAND ribbons over COARSE SEDIMENT		Intermittent veneers of Unit 0 overlie Unit 1 which undulates between <1.0m and 1.5m, until KP5.575 where it is not observed. Unit 2 undulates between 2.7m and 3.2m. Depth to Unit 3 increases along the cable route from 10.0m to 11.9m.
5.912	6.094	COARSE SEDIMENT		Unit 1 overlies Unit 2. Depth to Unit 2 increases from 2.4m to 4m along the cable route. Depth to Unit 3 increases from 11.6m to 13.2m along the cable route.

KP Start	KP End	SBF	Mobile Features	SBP
6.094	6.331	SAND ribbons over COARSE SEDIMENT		Depth to Unit 2 increases from 3.4m to 8.0m, overlain by Unit 1 sediments on the seabed with veneers of Unit 0 sediments. From KP6.520 it is no longer observed. Depth to Unit 3 increases along the cable route from 12.3m to 17.2m.
6.331	6.345	SAND ribbons over COARSE SEDIMENT with mobile sediments	Ripples with average wavelength of 5.0m and <0.1m amplitude trending north easterly.	
6.345	6.517	SAND ribbons over COARSE SEDIMENT		
6.517	6.523	SAND ribbons over COARSE SEDIMENT with mobile sediments	Ripples with average wavelength of 5.0m and <0.1m amplitude trending north easterly.	
6.523	6.577	SAND ribbons over COARSE SEDIMENT		
6.577	6.925	COARSE SEDIMENT		Unit 1 and Unit 2 reflectors are not observed. Likely that Unit 1 sediments comprise the surficial geology. Depth to Unit 3 varies between 17.0m to 18.4m.
6.925	6.938	SAND ribbons over COARSE SEDIMENT		Unit 1 and Unit 2 are not observed. Likely that veneers of Unit 0 overlie Unit 1 sediments at the seabed. Depth to Unit 3 varies between 15.6m to 17.4m.
6.938	6.945	SAND ribbons over COARSE SEDIMENT with mobile sediments	Ripples with average wavelength of 5.0m and <0.1m amplitude trending north easterly.	
6.945	7.076	SAND ribbons over COARSE SEDIMENT		

KP Start	KP End	SBF	Mobile Features	SBP
7.076	7.398	COARSE SEDIMENT		Unit 1 undulates between <1.0m and 2.2m. Unit 2 can be seen again from KP7.172, where the depth decreases along the cable route from 7.4m to 4.6m. Depth to Unit 3 increases along the cable route rapidly from 15.4m to 26.4m until KP8.446, beyond which it is not resolvable in the seismic data.
7.398	8.492	COARSE SEDIMENT with boulder fields		
8.492	8.519	SAND ribbons over COARSE SEDIMENT with boulder fields		Unit 1 depths vary between 1.2m and 2.8m which is overlain by intermittent veneers of Unit 0 sediments. Unit 2 undulates between 4.1m and 6.2m. Unit 3 cannot be seen until KP 8.700, with depths between 24.5m and 25.0m.
8.519	8.532	SAND ribbons over COARSE SEDIMENT with boulder fields and mobile sediments	Ripples with average wavelength of 5.0m and <0.1m amplitude trending north easterly.	
8.532	8.774	SAND ribbons over COARSE SEDIMENT with boulder fields		
8.774	8.840	SAND with boulder fields		Depth to top of Unit 1 is between 1.3m and 2.4m, overlain by a veneer of Unit 0 sediments. Depth to Unit 2 varies between 3.2m and 6.2m. Unit 3 varies from 23.4m to 25.2m until KP9.145, where it has not been observed until KP9.500 from where it shoals from 24.7m to 23.8m BSB.
8.840	9.624	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 5.0m and up to 0.2m amplitude trending north easterly.	

KP Start	KP End	SBF	Mobile Features	SBP
9.624	10.640	COARSE SEDIMENT with boulder fields		Depth to Unit 1 varies little, with a minimum depth of <1.0m and a maximum depth of 2.2m. Unit 2, increases in depth BSB, along the cable route from 3.4m to 6.8m and is not observed from KP10.380. Depth to Unit 3 increase from 23.8m to 25.1m but is not observed beyond KP9.850.
10.640	11.561	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 4.0m and up to 0.3m amplitude trending north easterly.	Unit 1 forms a deep channel from KP11.560 to KP12.70, with depths increasing from <1.0m to at greater than 10m. Unit 0A fills the channel formed in Unit 1. Unit 0A appears at KP11.640, with the depth increasing along the route from <1.0m to 7m BSB. Unit 0 sediments overlie occurrences of Unit 1 and Unit 0A. Unit 3 appears in only small patches, with depths exceeding 27m BSB.
11.561	12.757	SAND with mobile sediments	Megaripples with average wavelength of 6.0m and up to 0.4m amplitude trending north easterly. Sand waves present to the north of the route with wavelength approximately 120m and amplitude up to 3.5m trending north easterly.	
12.757		END OF ROUTE CR1		

3.3. Cable Route 2

3.3.1 Route Overview

Data collected on CR2 has been interpreted and reported on using an RPL generated from coordinates stated in the SoW. KP markers have been generated from this RPL with KP0 as the most shoreward location. Figure 13 shows an overview of CR2 with bathymetry data gridded at 1m resolution.

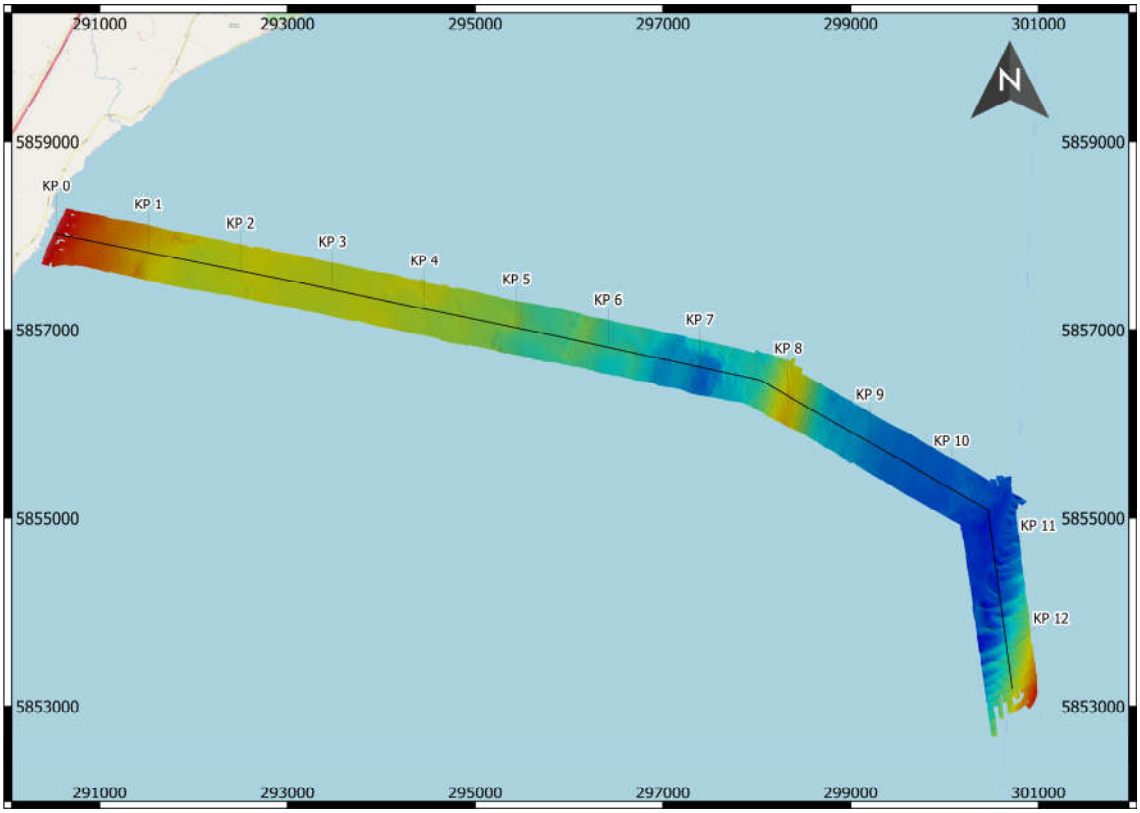


Figure 13: Overview of CR2 with bathymetry data

A profile of the bathymetry referenced to LAT along the RPL is shown in Figure 14 as well as gradients encountered. The bathymetry along the RPL varies between 2.97m at KP0 to 33.92m in a depression at KP10.993. Seven Fathom Bank is present between approximately KP7.5 and KP8.5 with a topographic amplitude of 10.0m and shoal depth below LAT of 14.05m. The largest gradient along CR2 occurs at KP11.593 where the route crosses a bank of mobile sediment reaching a peak gradient of 32.5º. The high gradients encountered, from approximately KP7 and KP10 and from KP11 to the end of CR2, are the product of steep mobile sediments.

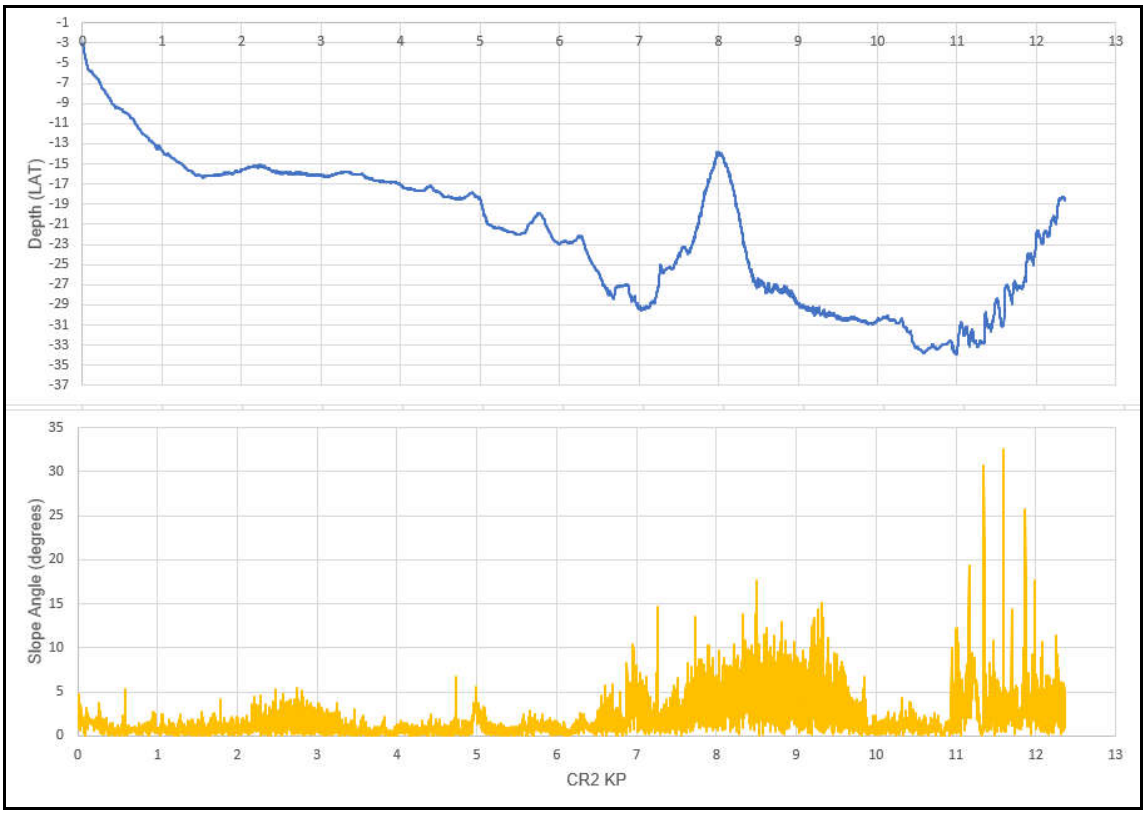


Figure 14: Bathymetry depths and slope angles along CR2

3.3.2 Surficial Geology

Details of seabed sediment and morphological features encountered along CR2 are present in “3.1.1 Seabed Interpretation”.

A full breakdown of changes in the surficial geology along the RPL are listed in section “3.3.5 Route Conditions”.

Sidescan data between KP10 and K11 are presented in Figure 15. A thick band of COARSE SEDIMENT were interpreted between KP10 and KP11, flanked by SAND with mobile sediments on the eastward side of KP10 and southward side of KP11. The sediment transition areas are separated by a band of SAND ribbons over COARSE SEDIMENT. An exposure of the existing export cable is also observed in this section.

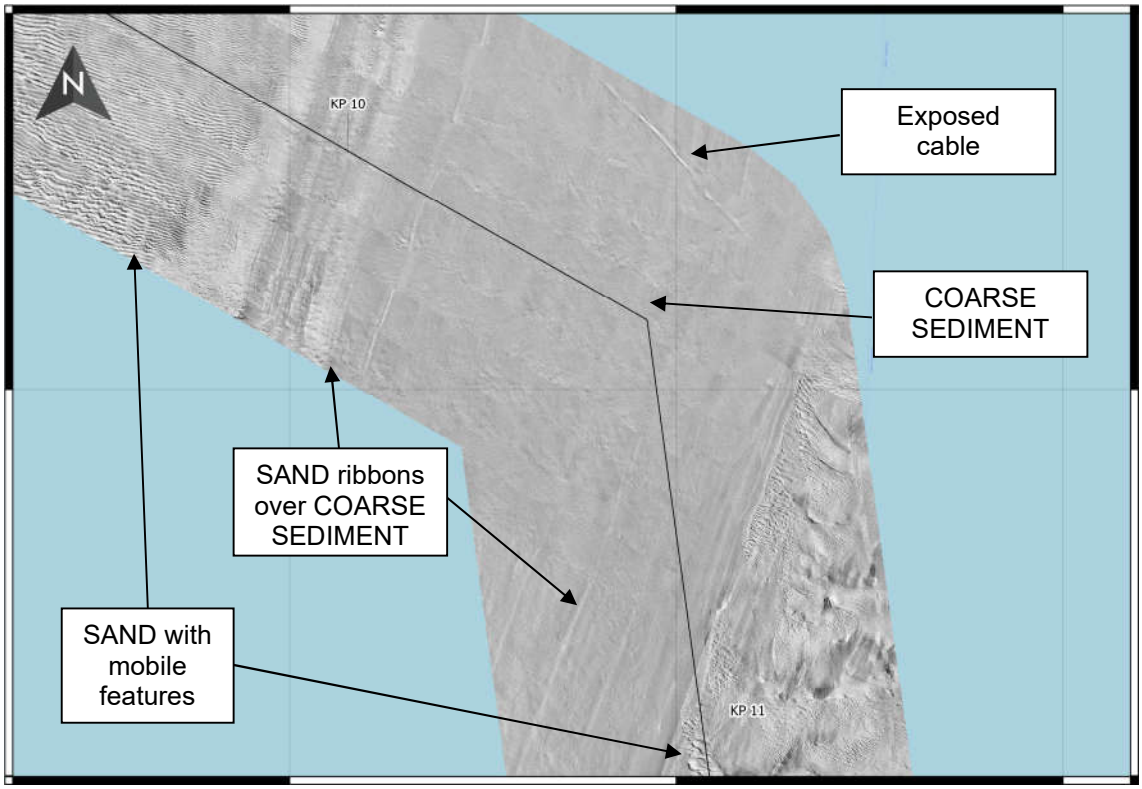


Figure 15: Sidescan data example between KP10 and KP11 on CR2

3.3.3 Contacts

In total 1075 contacts have been identified on SSS; 873 have been interpreted as boulders, 188 have been interpreted as debris, 7 have been interpreted as cables, 6 are associated with wrecks and 1 target has been interpreted as potential UXO. In total 151 magnetic targets have been interpreted. 16 magnetic targets have been associated with SSS targets.

Figure 16 shows an example of exposed cable on the seafloor on SSS and magnetic anomalies created by the cable on the gridded residual total field data. The existing export cable has been identified in the magnetic data and is observed to cross the proposed route, CR2, at KP 7.308.

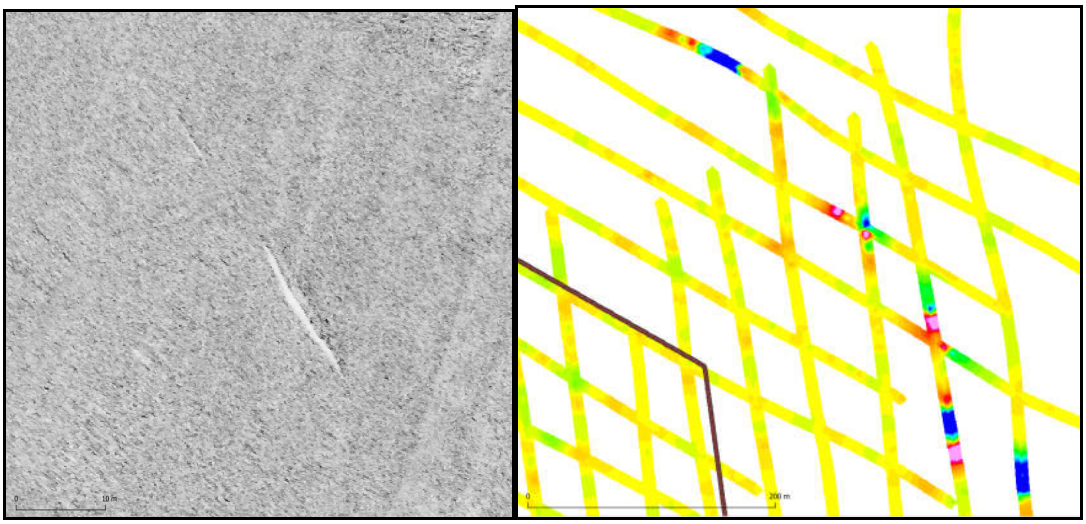


Figure 16: Example of exposed cable on SSS (left) and residual magnetic data (right)

Figure 17 shows an example of a wreck identified on SSS. One wreck with contact ID "UHC19004_SSS_R2_1014" lies 16m east of the proposed route, whilst all other wrecks identified on CR2 are greater than 100m from the route.

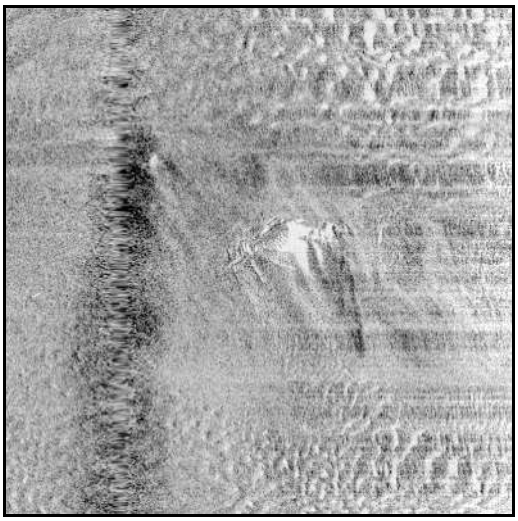


Figure 17: Example of a wreck on SSS

3.3.4 Shallow Soils

Three of the units listed in "3.1.2 Subsurface Interpretation" have been interpreted on SBP data within 10m of the seabed along the CR2 corridor. Unit 0A has not been identified on CR2. A detailed listing of the occurrence of the interpreted units along the RPL has been undertaken in section "3.3.5 Route Conditions".

An SBP data example from the nearshore section of CR2 is presented in Figure 18. Unit 1 overlies the undulating surface of the top of Unit 2, followed by Unit 3 dipping towards the south east. Unit 2 is observed to truncate in places on the erosion surface of the top of Unit 3. It is expected that a veneer of Unit 0 sediments are present over Unit 1 sediments in places.

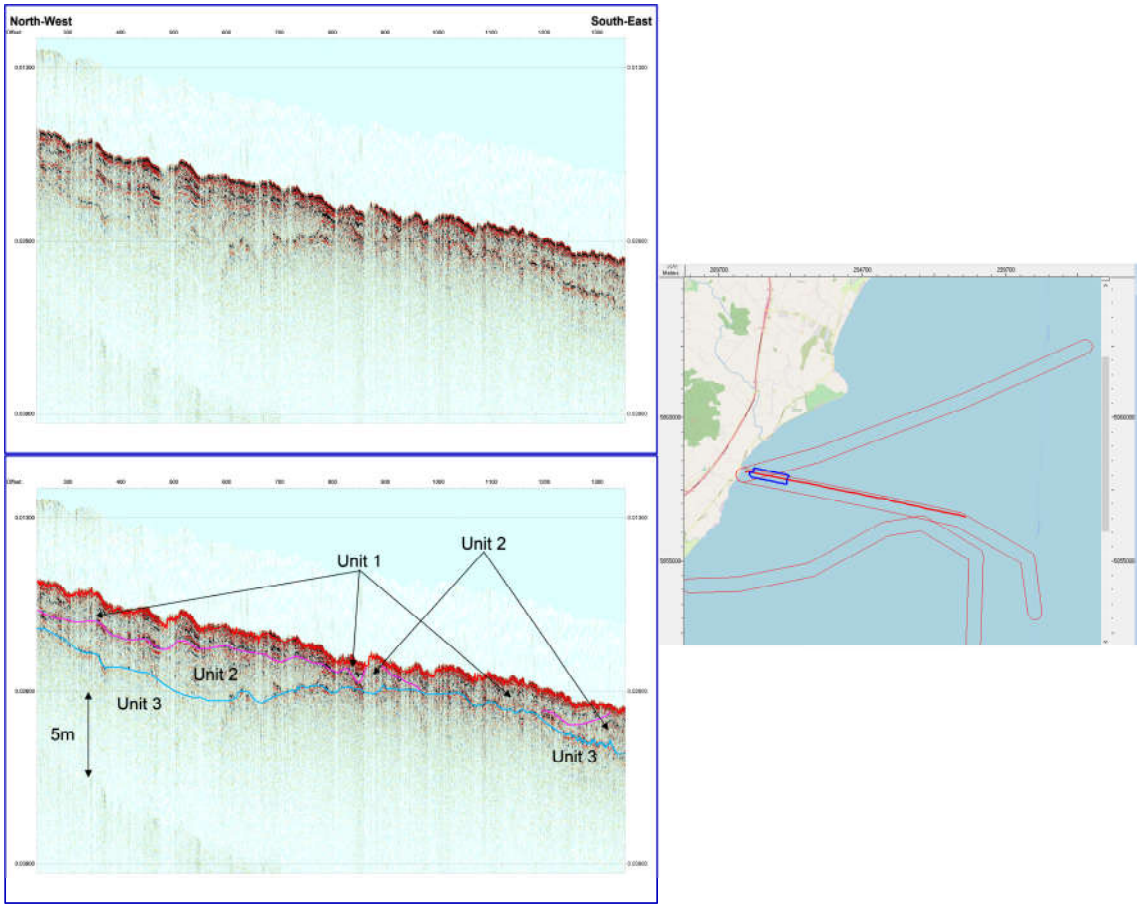


Figure 18: SBP data example from the nearshore section of CR2

An SBP data example from the offshore section of CR2 is presented in Figure 19. Seven Fathom Bank comprising of Unit 0 were identified in the north west of the profile. The bank overlies sediments from Unit 1 which is briefly exposed to the south east of the bank in a gap in the overriding mobile sediments. Unit 1 underlain by Unit 2 were interpreted towards the south east.

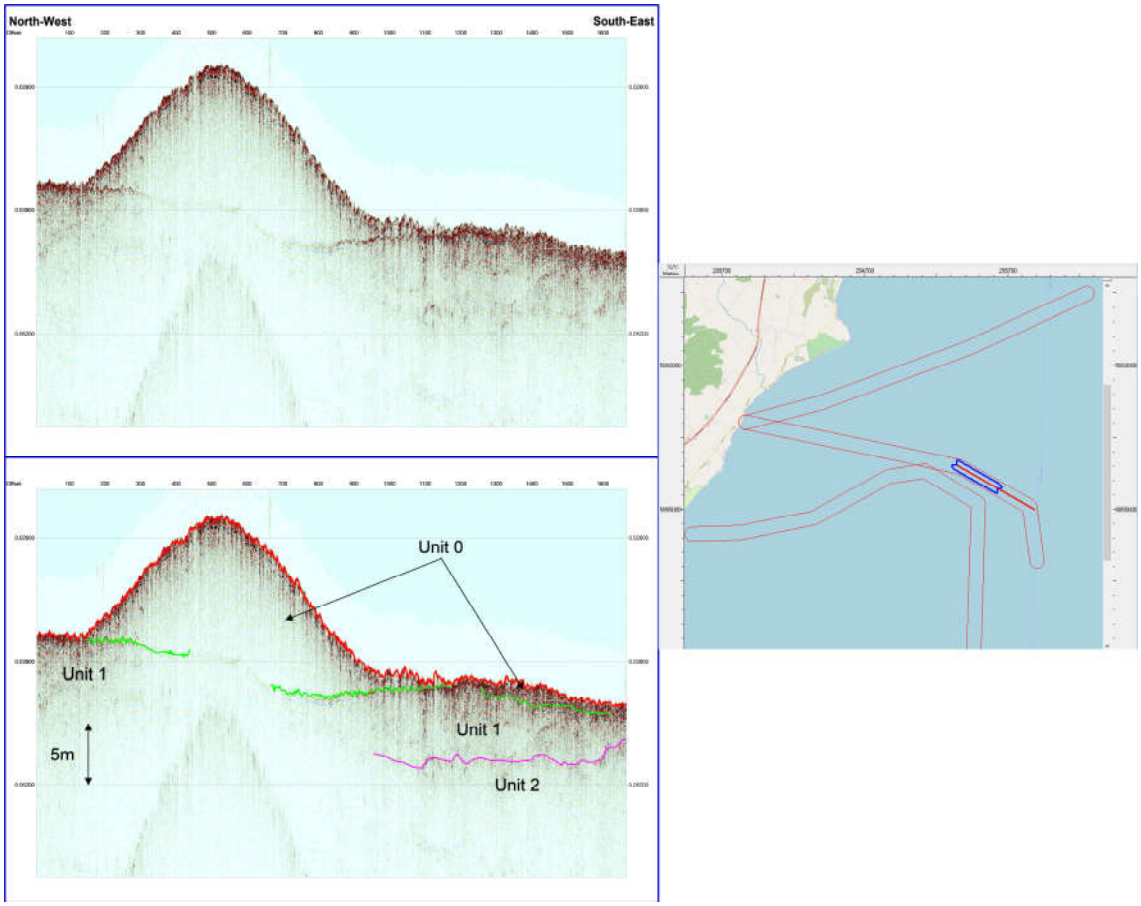


Figure 19: SBP data example from the offshore section of CR2

Isochores of Units 1 to 3 are presented in Figure 20 and Figure 21. Unit 1 was not interpreted in the nearshore but identified in localised extents at KP5, KP8 and KP11-12. Interspersed extents of Unit 2 were interpreted between KP0 and KP10. Unit 3 were present throughout the nearshore, exhibiting a south eastward dip to a maximum depth at KP8.

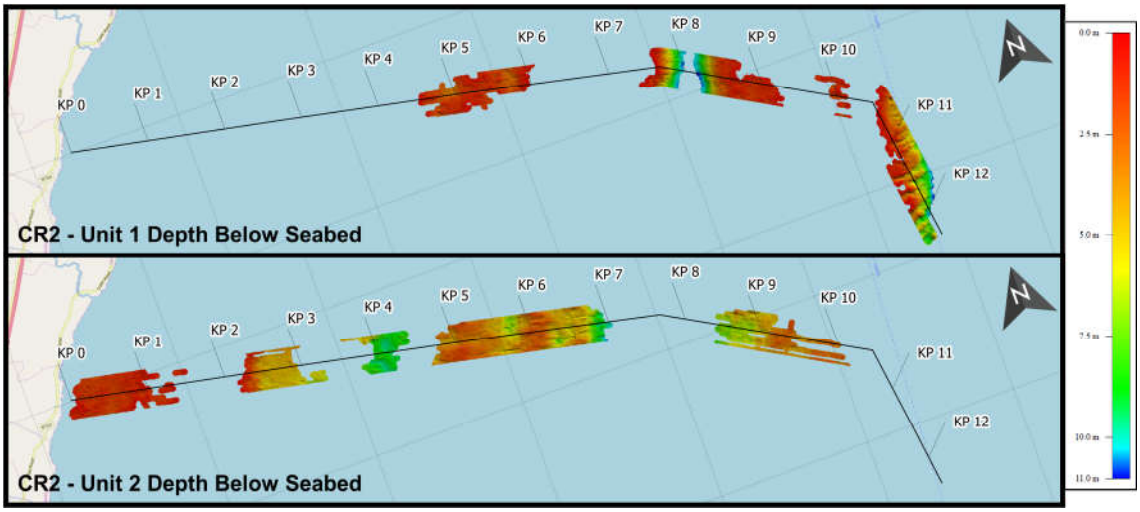


Figure 20: Gridded isochores of Units 1 and 2 at CR2

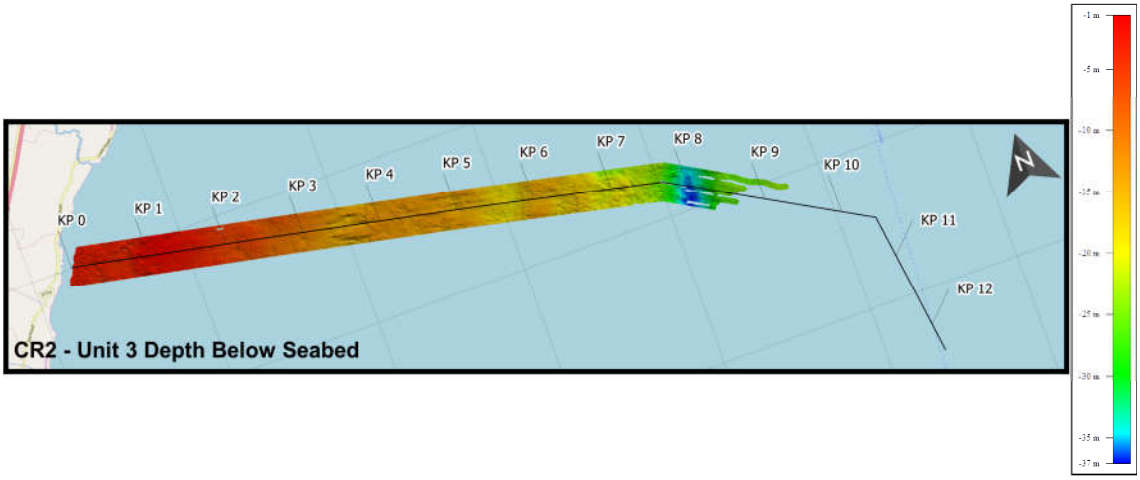


Figure 21: Gridded isochore of Unit 3 at CR2

3.3.5 Route Conditions

Table 4: Route condition listing, CR2

KP Start	KP End	SBF	Mobile Sediments	SBP
0.000	0.560	SAND		Depth to Unit 2 varies between <1.0m and 1.9m and is overlain by Unit 1 sediments on the seabed with a veneer of Unit 0 sediments. Depth to Unit 3 ranges from 3.2m to 4.7m.
0.560	0.610	SAND with mobile sediments	Megaripples with average wavelength of 24m and up to 0.2m amplitude trending north easterly	
0.610	0.616	SAND		
0.616	0.655	SAND with boulder fields		
0.655	1.276	COARSE SEDIMENT with boulder fields		Unit 2 decreases in depth from 1.7m to <1.0m and is overlain by Unit 1 sediments. The reflector is not seen between KP1.038 and KP1.250 where it is expected to be <1.0m. Unit 3 decreases in depth from 4.9m to 1.0m along the cable route.
1.276	2.177	GLACIAL TILL exposure with boulder fields		Unit 2 approaches the seabed at KP1.311 and is no longer interpretable as it continues to outcrop. Depth to unit 3 increases along the cable route from 1.2m to 7.3m.
2.177	2.192	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 6.5m and up to 0.1m amplitude trending north easterly	Intermittent veneers of mixed sediment comprised of Unit 0 and Unit 1 overlie Unit 2 which is interpreted from KP2.257 at a depth of <1.0m. Unit 3 varies between 5.6m and 6.6m
2.192	2.200	GLACIAL TILL exposure with boulder fields		
2.200	2.249	SAND with boulder fields and mobile sediments	Megaripples with wavelength between 4.0-8.0m and up to 0.2m amplitude trending north easterly	

KP Start	KP End	SBF	Mobile Sediments	SBP
2.249	2.283	COARSE SEDIMENT with boulder fields		
2.283	2.299	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 7.5m and up to 0.2m amplitude trending north easterly	
2.299	2.302	COARSE SEDIMENT with boulder fields		
2.302	2.964	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 8.5m and up to 0.3m amplitude trending north easterly	Unit 1 sediments with intermittent veneers of Unit 0 sediments overlie Unit 2 which increases in depth along the cable route, increasing from <1.0m to 5.0m. From KP2.922 Unit 2 is no longer observed. Depth to Unit 3 increases from 6.3m to 15.0m
2.964	3.461	SAND with mobile sediments	Megaripples with average wavelength of 8.5m and up to 0.3m amplitude trending north easterly	
3.461	3.494	SAND with boulder fields and mobile sediments		
3.494	3.522	COARSE SEDIMENT with boulder fields		
3.522	3.538	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 8.5m and up to 0.3m amplitude trending north easterly	Unit 2 is not observed. It is likely that Unit 1 sediments with a veneer of Unit 0 sediments overlie Unit 2. Unit 3, varies between 14.5m and 15.0m BSB.

KP Start	KP End	SBF	Mobile Sediments	SBP
3.538	3.595	SAND with mobile sediments	Megaripples with average wavelength of 8.5m and up to 0.3m amplitude trending north easterly	
3.595	3.608	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 8.5m and up to 0.3m amplitude trending north easterly	
3.608	4.008	COARSE SEDIMENT with boulder fields		Unit 1 sediments are evident at the seabed. Top of Unit 2 appears from KP3.981 at a depth of between 8.5m and 8.8m. Depth to Unit 3 decreases along the cable route from a maximum of 15.6m to 12.7m.
4.008	4.086	SAND with mobile sediments	Megaripples with average wavelength of 3.5m and up to 0.1m amplitude trending north easterly	Unit 1 sediments with a veneer of Unit 0 sediments overlie Unit 2. Depth to Unit 2 increases along the cable route from 8.4m to 9.2m. Unit 3 varies in depth BSB, between 12.5m to 13.0m.
4.086	4.510	COARSE SEDIMENT with boulder fields		Unit 1 sediments overlie Unit 2. Unit 2 undulates from 8.9m to 9.5m until KP4.208 where it is no longer observed. Depth to Unit 3 increases from 12.6m to 14.5m.
4.510	4.630	SAND ribbons over COARSE SEDIMENT with boulder fields and mobile sediments	Megaripples with average wavelength of 3.0m and <0.1m amplitude trending north easterly	Top of Unit 1 first appears at KP4.531, with a maximum depth of 3.5m and a minimum of <1m. Unit 0 overlies Unit 1 sediment but often thins to a veneer and is intermittently absent in place. Unit 2 reappears at KP4.521, varying between 2.8m and 4.8m. Unit 3 increases in depth from 12.6m to 18.2m.
4.630	4.719	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 3.0m and <0.1m amplitude trending north easterly	
4.719	4.758	SAND with mobile sediments	Megaripples with average wavelength of 3.5m and up to 0.1m amplitude trending north easterly	

KP Start	KP End	SBF	Mobile Sediments	SBP
4.758	4.778	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 3.0m and <0.1m amplitude trending north easterly	
4.778	4.827	SAND ribbons over COARSE SEDIMENT with boulder fields		
4.827	4.855	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 3.0m and <0.1m amplitude trending north easterly	
4.855	4.965	SAND ribbons over COARSE SEDIMENT with boulder fields		
4.965	4.973	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 4.0m and <0.1m amplitude trending north easterly	
4.973	5.022	SAND ribbons over COARSE SEDIMENT with boulder fields		
5.022	5.224	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 4.0m and <0.1m amplitude trending north easterly	

KP Start	KP End	SBF	Mobile Sediments	SBP
5.224	5.336	SAND ribbons over COARSE SEDIMENT with boulder fields and mobile sediments	Megaripples with average wavelength of 3.0m and <0.1m amplitude trending north easterly	
5.336	5.590	SAND ribbons over COARSE SEDIMENT with boulder fields		
5.590	5.688	COARSE SEDIMENT with boulder fields		Depth to Unit 1 increase from 1.9m to 2.4m. Depth to Unit 2 increases along the route from 4.4m to 5.8m. Unit 3 is 18.1m to 18.6m BSB.
5.688	5.768	SAND ribbons over COARSE SEDIMENT with boulder fields		Unit 1 decreases in thickness to KP5.964 where it approaches the seabed and is no longer observed. It then returns at <1.0m at KP7.611 where it starts to deepen to greater than 10m below Seven Fathom Bank comprised of Unit 0 sediments. Unit 0 overlies Unit 1 sediment but often thins to a veneer and is intermittently absent in areas away from Seven Fathom Bank. Depth to Unit 2 increases from 1.4m to 9.5m at KP6.975 from where it is no longer observed. It then reappears at KP8.208 where it decreases in depth from 8.0m to 2.2m. Depth to Unit 3 increases from 15.2m to a maximum of 36.5m below Seven Fathom Bank.
5.768	5.884	SAND with boulder fields		
5.884	6.427	SAND ribbons over COARSE SEDIMENT with boulder fields		

KP Start	KP End	SBF	Mobile Sediments	SBP
6.427	6.869	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 5.5m and up to 0.3m amplitude trending north easterly	
6.869	6.884	SAND ribbons over COARSE SEDIMENT with boulder fields		
6.884	6.983	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 5.5m and up to 0.3m amplitude trending north easterly	
6.983	7.124	SAND with mobile sediments	Megaripples with average wavelength of 4.0m and up to 0.2m amplitude trending north easterly	
7.124	7.149	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 6.0m and <0.1m amplitude trending north easterly	
7.149	7.385	SAND ribbons over COARSE SEDIMENT with boulder fields		
7.385	7.644	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 5.0m and up to 0.3m amplitude trending north easterly	

KP Start	KP End	SBF	Mobile Sediments	SBP
7.644	9.898	SAND with mobile sediments	From KP7.644 to KP8.944 megaripples with average wavelength of 5.0m and up to 0.3m amplitude trending northly with secondary megaripples with average wavelength of 12.5m and 0.2m amplitudes trending easterly. Seven Fathom Bank present as a large sand bank, of approximately 10m topographic amplitude, peaking at KP8.014. From KP8.944 megaripples with average wavelengths of 5.5m and up to 0.3m amplitude trending north easterly	
9.898	9.916	COARSE SEDIMENT with boulder fields		
9.916	9.958	SAND ribbons over COARSE SEDIMENT with boulder fields		
9.958	9.977	SAND ribbons over COARSE SEDIMENT with boulder fields and mobile sediments	Megaripples with average wavelengths of 5.5m and <0.1m amplitude trending north easterly	
9.977	10.127	SAND ribbons over		

KP Start	KP End	SBF	Mobile Sediments	SBP
		COARSE SEDIMENT with boulder fields		
10.127	10.584	COARSE SEDIMENT with boulder fields		Unit 1 appears at KP10.563 where it is <0.3m below seabed and is exposed on the seabed. Units 2 & 3 are not observed
10.584	10.903	SAND ribbons over COARSE SEDIMENT with boulder fields		Unit 1 undulates between <1.0m and 2.8m. Unit 1 is overlain by Unit 0 sediments. Unit 2 & 3 are not observed
10.903	10.941	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 7.5m and up to 0.2m amplitude trending north easterly	
10.941	11.167	SAND with mobile sediments	Sand waves with wavelength approximately 85m and amplitude up to 3.5m trending northerly. Superimposed megaripples with average wavelength of 10m and up to 0.3m amplitude trending north easterly.	
11.167	11.183	SAND with boulder fields and mobile sediments	Sand waves with wavelength approximately 85m and amplitude up to 3.5m trending northerly. Superimposed megaripples with average wavelength of 10m and up to 0.3m amplitude trending north easterly.	

KP Start	KP End	SBF	Mobile Sediments	SBP
11.183	11.249	SAND with mobile sediments	Sand waves with wavelength approximately 85m and amplitude up to 3.5m trending northerly. Superimposed megaripples with average wavelengths of 10m and up to 0.3m amplitude trending north easterly.	
11.249	11.348	COARSE SEDIMENT with boulder fields		Unit 1 has a general thickening trend along the cable route, from <1.0m to a maximum depth of greater than 10.0m. The depth to the layer undulates due to the overlying mobile sediments comprised of Unit 0 sediments. Unit 0 overlies Unit 1 sediment but often thins to a veneer and is intermittently absent in place whilst occasionally accumulating up to 3.5m at the peak of mobile features. Beyond KP12.028 the top of Unit 1 is deeper than 10.0m.
11.348	11.554	SAND with mobile sediments	Sand waves with wavelength approximately 85m and amplitude up to 3.5m trending northerly. Superimposed megaripples with average wavelengths of 5.0m and up to 0.2m amplitude trending north easterly.	
11.554	11.589	COARSE SEDIMENT		
11.589	11.784	SAND with mobile sediments	Sand waves with wavelength approximately 85m and amplitude up to 3.5m trending northerly. Superimposed megaripples with average wavelengths of 5.0m and up to 0.1m amplitude trending north easterly.	
11.784	11.871	COARSE SEDIMENT with mobile sediments	Sand waves with wavelength approximately 85m and amplitude up to 3.5m trending northerly. Superimposed megaripples with average wavelengths of 11m and up to 0.3m amplitude trending north easterly.	

KP Start	KP End	SBF	Mobile Sediments	SBP
11.871	11.967	SAND with mobile sediments	Sand waves with wavelength approximately 85m and amplitude up to 3.5m trending northerly. Superimposed megaripples with average wavelengths of 12.5m and up to 0.2m amplitude trending north easterly.	
11.967	11.985	COARSE SEDIMENT		
11.985	12.360	SAND with mobile sediments	Sand waves with wavelength approximately 85m and amplitude up to 3.5m trending northerly. Superimposed megaripples with average wavelengths of 12.5m and up to 0.2m amplitude trending north easterly.	
12.360		END OF ROUTE CR2		

3.4. Cable Route 3

3.4.1 Route Overview

Data collected on CR3 has been interpreted and reported on using an RPL generated from coordinates stated in the SoW. KP markers have been generated from this RPL with KP0 as the most shoreward location. Figure 22 shows an overview of CR3 with bathymetry data gridded at 1m resolution.

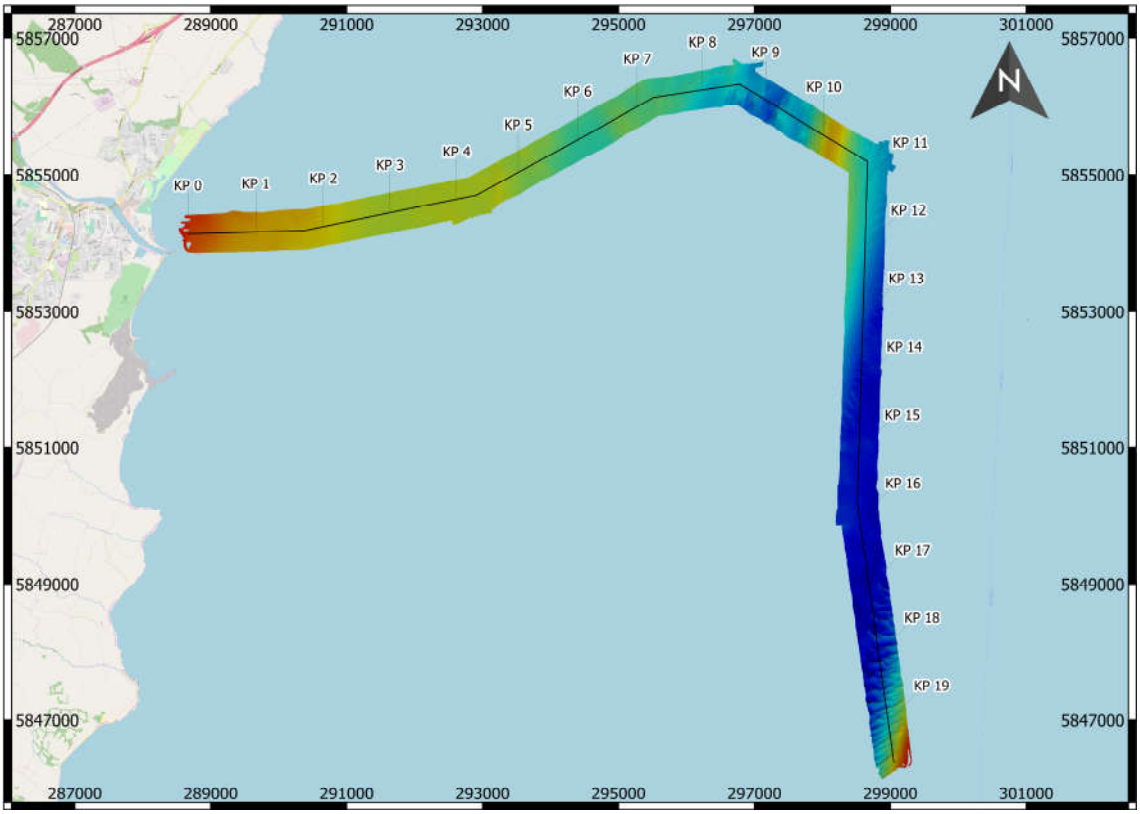


Figure 22: Overview of CR3 with bathymetry data

A profile of the bathymetry referenced to LAT along the RPL is shown in Figure 23 as well as gradients encountered. The bathymetry along the RPL varies between 7.46m at KP0 to 37.75m in a depression at KP17.583. Seven Fathom Bank is present between approximately KP9.5 and KP10.8 with a topographic amplitude of 12.2m and shoal depth below LAT of 11.29m. The largest gradient along CR3 occurs at KP17.637 where the route crosses large sand waves within mobile sediment reaching a peak gradient of 31.4°. The high gradients encountered, from approximately KP8 and KP15 and from KP17 to the end of CR3, are the product of steep mobile sediments.

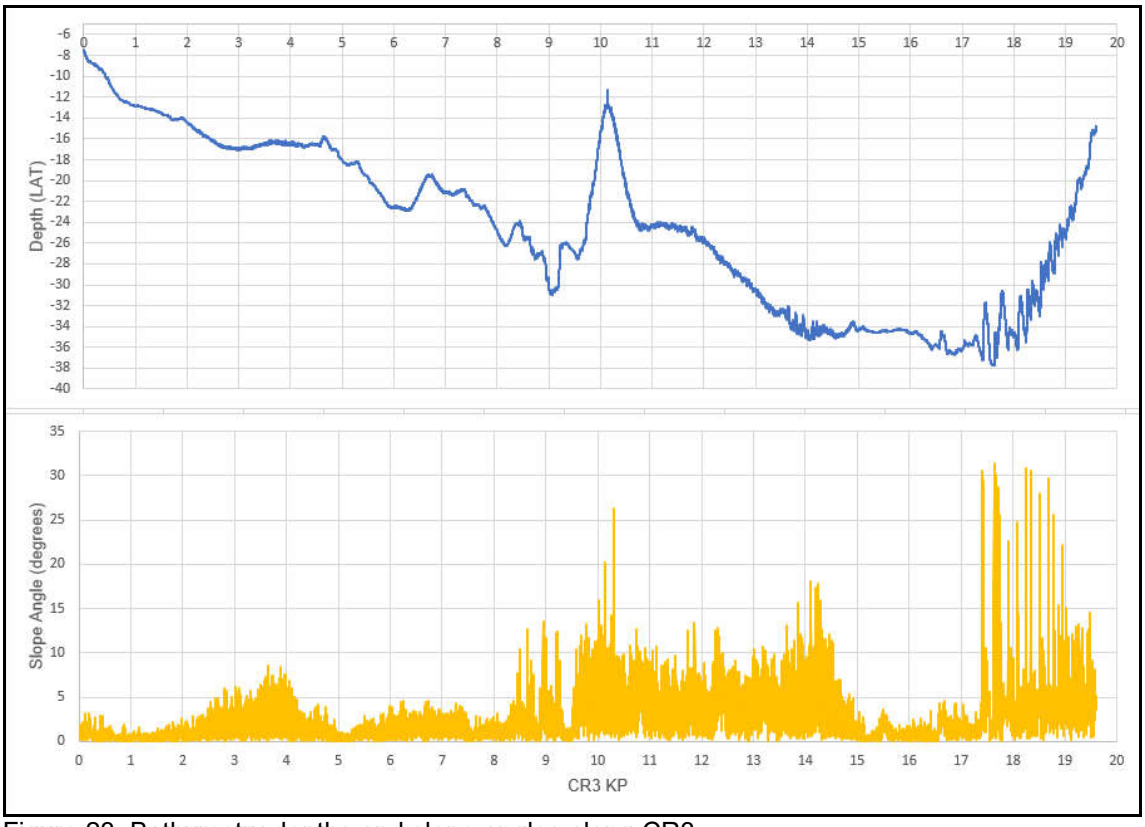


Figure 23: Bathymetry depths and slope angles along CR3

3.4.2 Surficial Geology

Details of seabed sediment and morphological features encountered along CR3 are present in “3.1.1 Seabed Interpretation”. However, no areas of glacial TILL were interpreted within the corridor for CR3.

A full breakdown of changes in the surficial geology along the RPL are listed in section “3.4.5 Route Conditions”.

Sidescan data between KP6 and KP7 are presented in Figure 24. Sand ribbons over COARSE SEDIMENT were interpreted at KP6, transitioning to SAND with mobile features at KP7 as the thickness of overlying sand increases. Mobile sediments were interpreted throughout all but the north east corner of KP6.

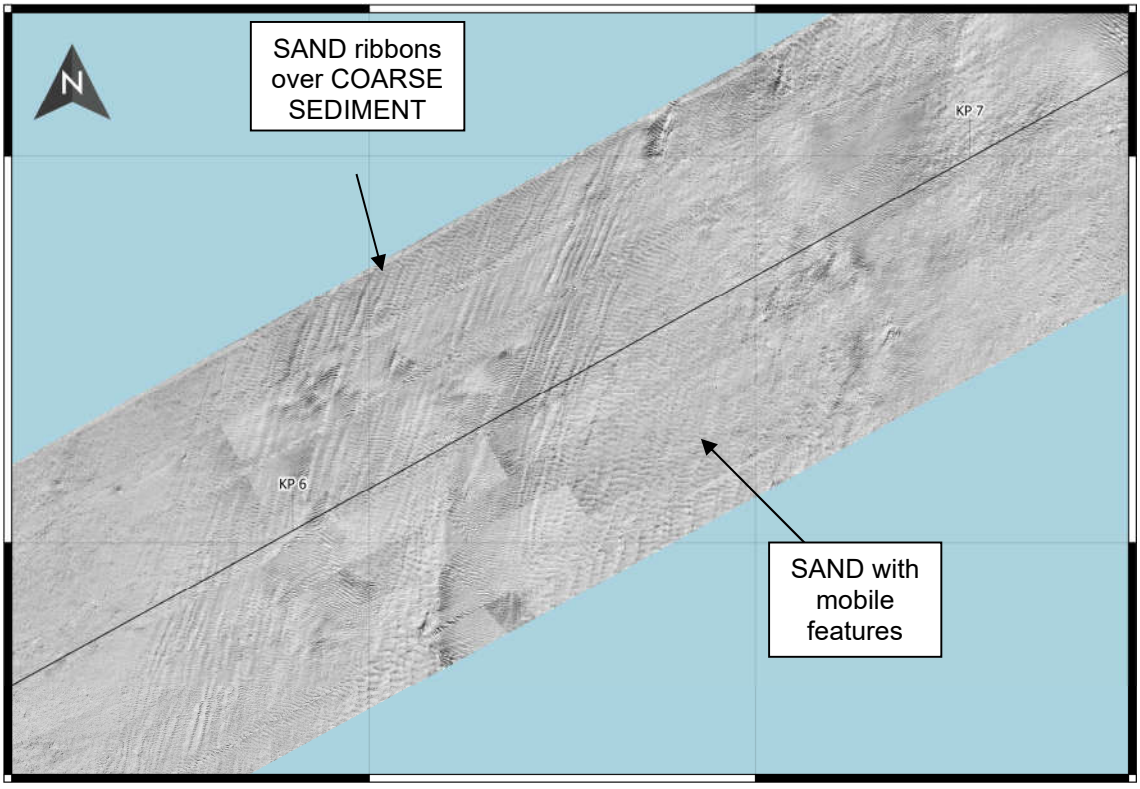


Figure 24: Sidescan data example between KP6 and KP7 on CR3

3.4.3 Contacts

In total 1524 contacts have been identified on SSS; 1372 have been interpreted as boulders, 150 have been interpreted as debris and 2 have been interpreted as cables. In total 196 magnetic targets have been interpreted. 11 magnetic targets have been associated with SSS targets.

Additionally, fishing gear and cable trenching have also been identified and interpreted along CR3. The existing export cable has been identified in the magnetic data and is observed to cross the proposed route, CR3, at KP 3.984.

3.4.4 Shallow Soils

Three of the units listed in “3.1.2 Subsurface Interpretation” have been interpreted on SBP data within 10m of the seabed along the CR3 corridor. Unit 0A has not been identified on CR3. A detailed listing of the occurrence of the interpreted units along the RPL has been undertaken in section “3.4.5 Route Conditions”.

An SBP data example from the nearshore section of CR3 is presented in Figure 25. Depressions in Unit 1 have been filled with Unit 0 sediments, it is possible that these features are representative of the Seabed Depression Facies noted in “3.1.2 Subsurface Interpretation”. Unit 2 were interpreted as the underlying unit to depth.

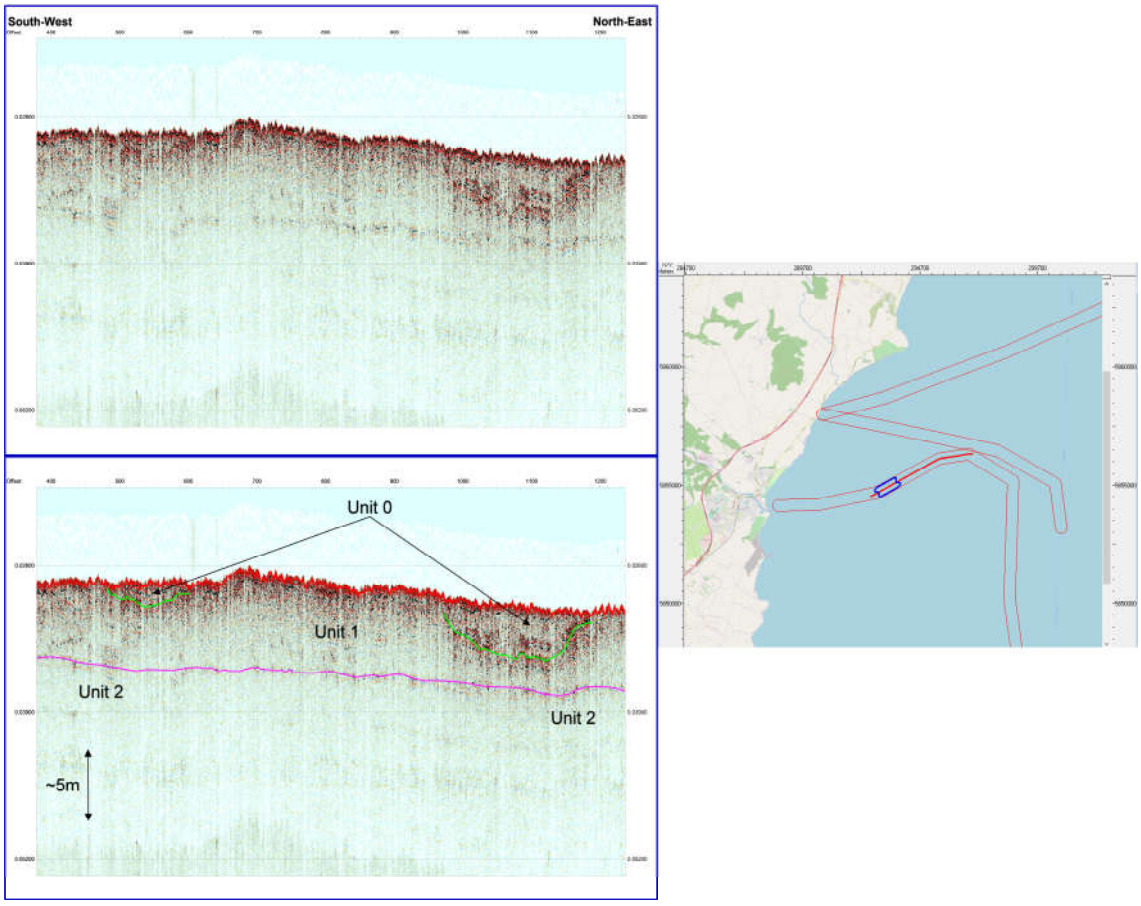


Figure 25: SBP data example from the mid-section of CR3

An SBP data example from the offshore section of CR3 is presented in Figure 26. The section presents sand waves comprising of Unit 0, possible of the Wave and Bank Facies noted in “3.1.2 Subsurface Interpretation”. These features overlie Unit 1 sediments that show a mound feature to the north of the section that has been enveloped by the overriding mobile sediments.

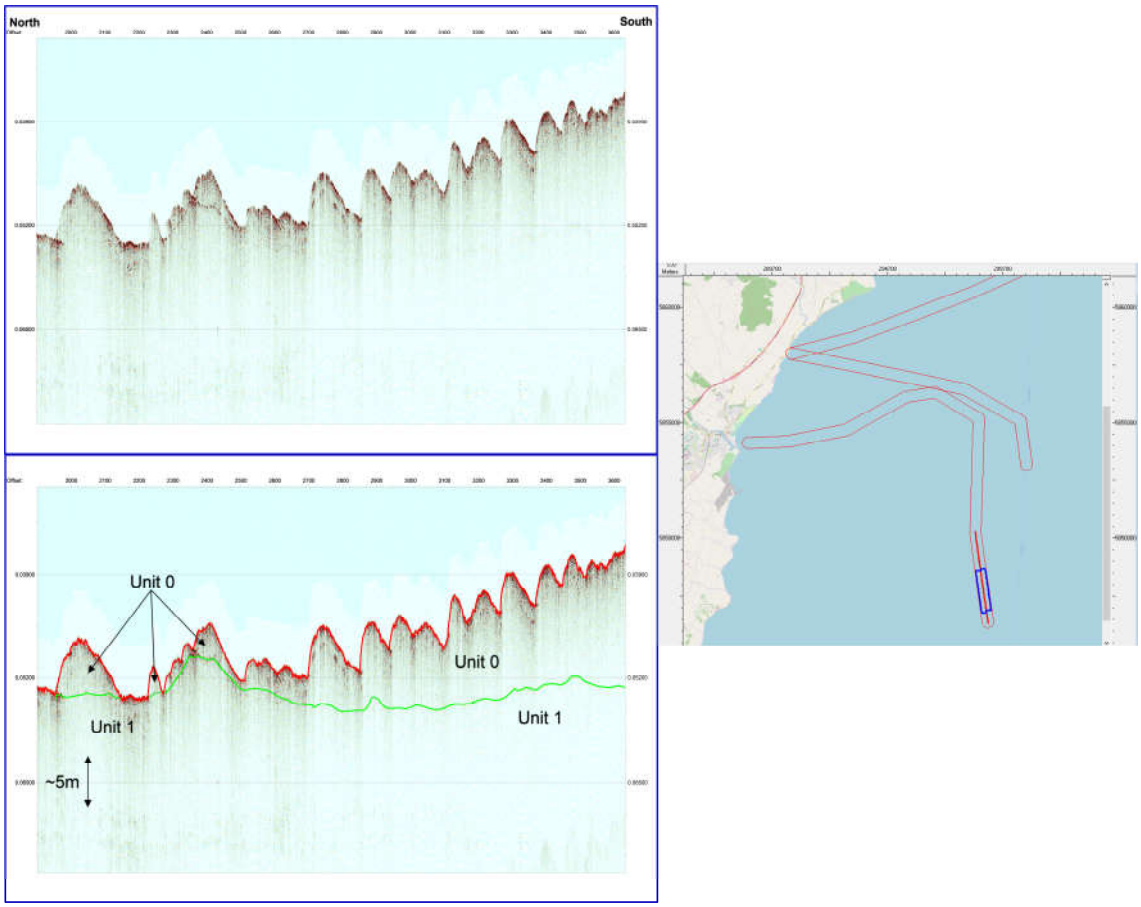


Figure 26: SBP data example from the offshore section of CR3

Isochores of Units 1-3 are presented in Figure 27, Figure 28 and Figure 29 respectively. Unit 1 were interpreted in interspersed areas in the nearshore becoming more prevalent between KP11-KP13 and between KP17-KP19. Unit 2 were interpreted between KP2 and KP9. Unit 3 were interpreted with a south eastward dip between KP0-KP4 and KP8-KP11.

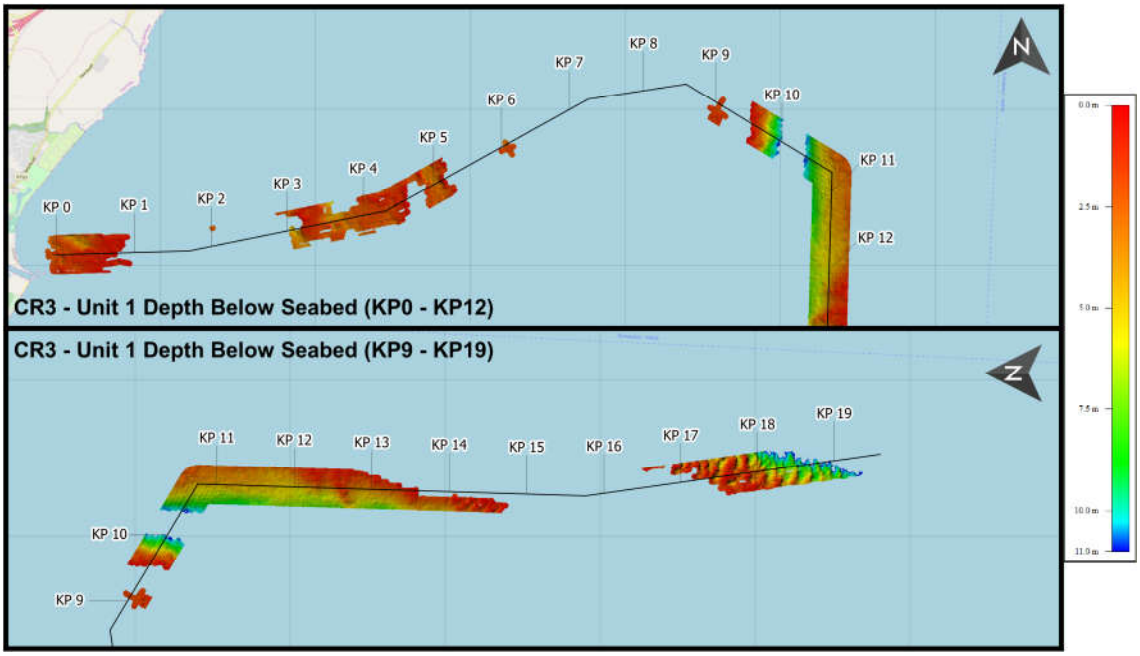


Figure 27: Gridded isochore of Unit 1 at CR3

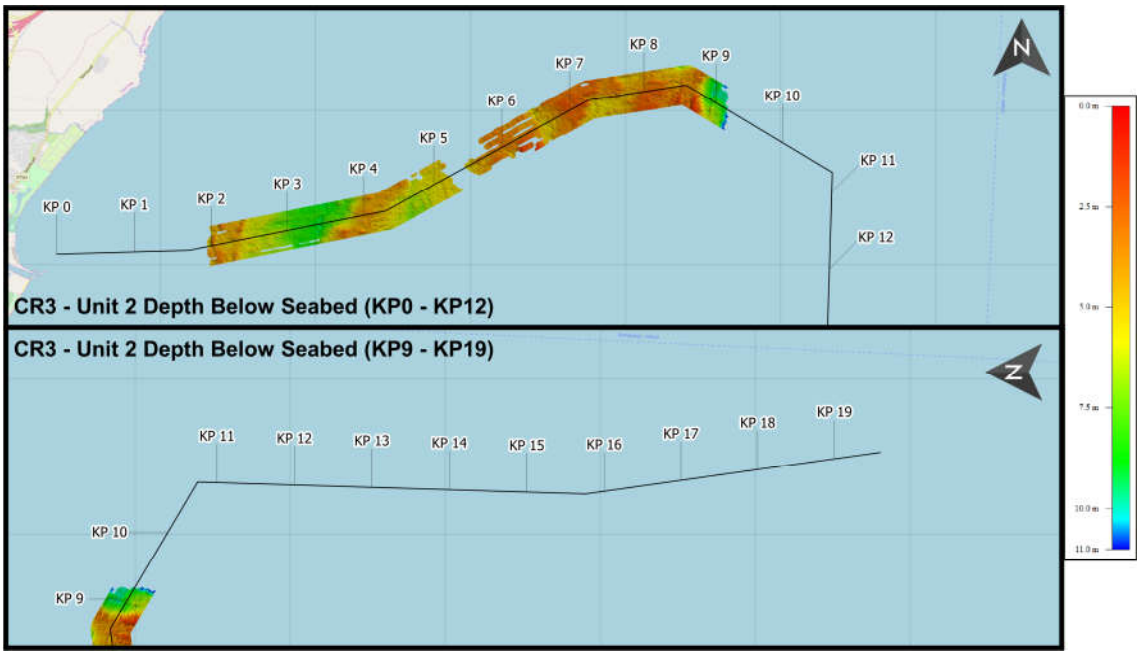


Figure 28: Gridded isochore of Unit 2 at CR3

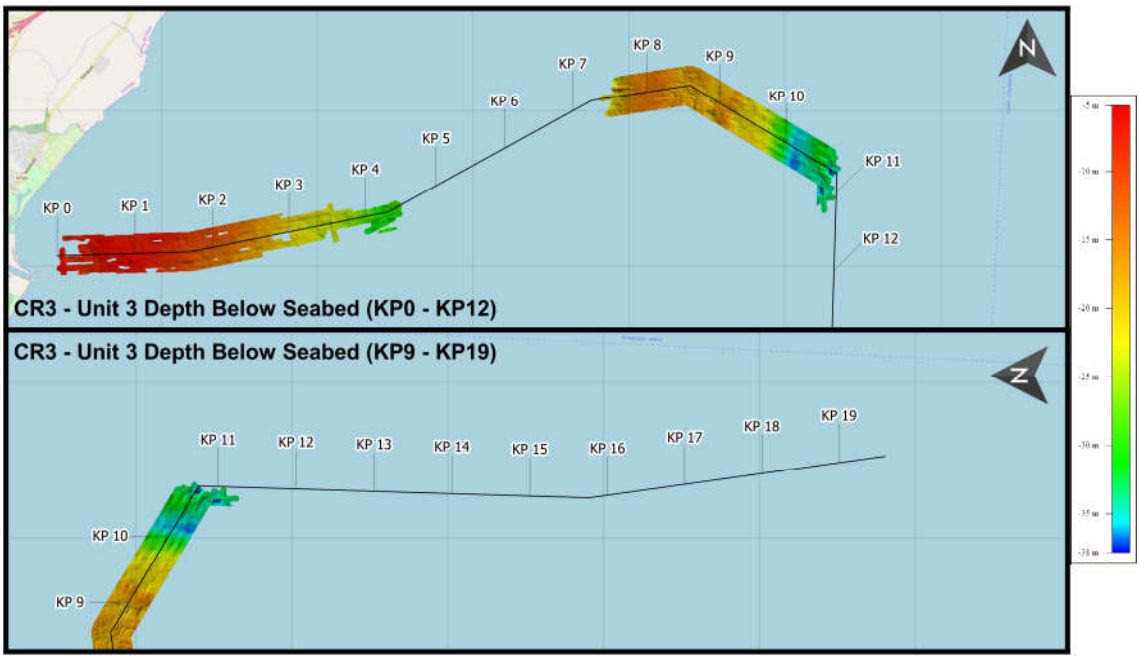


Figure 29: Gridded isochore of Unit 3 at CR3

3.4.5 Route Conditions

Table 5: Route condition listing, CR3

KP Start	KP End	SBF	Mobile features	SBP
0.000	0.055	SAND		Unit 1 is visible from the start of the section at KP0, decreasing in depth from 2.2m to <1.0m. Unit 0 sediments overlie Unit 1. Unit 2 is not observed. Unit 3 increase in depth from 6.2m to 8.0m.
0.055	0.108	SAND with mobile sediments	Megaripples with average wavelength of 1.5m and <0.1m amplitude trending north westerly.	
0.108	0.366	SAND		
0.366	0.489	SAND with boulder fields		Unit 1 decreases in depth from 1.3m to <1.0m. Unit 0 sediments overlie Unit 1. Unit 2 is not observed. Unit 3 decreases in depth from 8.2m to 5.9m.
0.489	0.758	SAND		
0.758	1.791	SAND with boulder fields		Unit 1 appears briefly at a depth of <1.0m, before becoming uninterpretable from KP0.778 until KP3.029 where it thins along the cable from 5.2m to < 1.0m depth. Unit 0 sediments overlie Unit 1. Unit 2 is visible from KP1.945 and undulates between 3.3m and 9.0m. Unit 3 increases in depth from 6.0m to 30.7m
1.791	2.932	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 8.5m and up to 0.3m amplitude trending northerly.	
2.932	4.689	SAND with mobile sediments	Megaripples with average wavelength of 7.5m and up to 0.3m amplitude trending north/north easterly.	
4.689	4.793	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 3.0m and <0.1m amplitude trending north easterly.	Unit 1 is not observed. Unit 2 varies between 6.0 and 6.6m. Unit 3 is not observed.
4.793	4.940	COARSE SEDIMENT with boulder fields		Unit 1 forms a shallow channel between KP 4.891 and KP 5.160, with a minimum depth of <1.0m, and a maximum of 3.7m. Veneers of Unit 0 are occasionally present. Unit 2 decreases in depth from 6.2m to 5.2m, at KP5.225 it is no longer observed.
4.940	5.357	COARSE SEDIMENT		

KP Start	KP End	SBF	Mobile features	SBP
5.357	5.421	SAND with boulder fields and mobile sediments	Megaripples with average wavelengths of 3.0m and <0.1m amplitude trending north easterly	
5.421	5.684	COARSE SEDIMENT with boulder fields		Unit 1 is not observed. Depth to Unit 2 decreases along the cable route from 5.6m to 3.4m.
5.684	5.758	COARSE SEDIMENT		
5.758	6.501	SAND ribbons over COARSE SEDIMENT with mobile sediments	Megaripples with average wavelength of 3.5m and up to 0.2m amplitude trending north easterly	Top of Unit 1 appears occasionally in shallow channels up until KP9.539 where it greater than 10.0m BSB, due to Seven Fathom Bank which is comprised of Unit 0 sediments. After the bank the top of Unit 1 approaches the seabed at KP13.598. Unit 0 overlies Unit 1 sediment but often thins to a veneer and is intermittently absent in place away from Seven Fathom Bank. Unit 2 undulates between 1.7m and 5.8m before a channel has incised the horizon to a depth of greater than 10.0m at KP9.170. It is not observed again for the remainder of the cable route. Unit 3 increases in depth from 14.0m to greater than 36.0m at KP10.760, beyond which it is no longer observed.
6.501	6.631	SAND with mobile sediments	Megaripples with average wavelength of 6.0m and <0.1m amplitude trending north easterly	
6.631	6.806	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 5.5m and up to 0.2m amplitude trending north easterly	
6.806	7.348	SAND with mobile sediments	Megaripples with average wavelength of 5.0m and up to 0.2m amplitude trending north easterly	
7.348	7.468	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 6.0m and <0.1m amplitude trending north easterly	
7.468	7.792	SAND ribbons over COARSE		

KP Start	KP End	SBF	Mobile features	SBP
		SEDIMENT with boulder fields		
7.792	8.037	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 4.0m and <0.1m amplitude trending north easterly	
8.037	8.263	SAND with mobile sediments	Megaripples with average wavelength of 5.5m and <0.1m amplitude trending north easterly	
8.263	8.803	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 5.0m and up to 0.2m amplitude trending north easterly	
8.803	8.876	SAND with mobile sediments	Megaripples with average wavelength of 4.0m and <0.1m amplitude trending north easterly	
8.876	8.972	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 5.5m and <0.1m amplitude trending north easterly	
8.972	9.185	SAND with mobile sediments	Megaripples with average wavelength of 4.5m and up to 0.3m amplitude trending north easterly	
9.185	9.303	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 6.5m and <0.1m amplitude trending north easterly	
9.303	9.349	SAND ribbons over COARSE SEDIMENT with boulder		

KP Start	KP End	SBF	Mobile features	SBP
		fields		
9.349	9.469	SAND ribbons over COARSE SEDIMENT		
9.469	14.263	SAND with mobile sediments	From KP9.469 to KP9.555 megaripples with average wavelength of 4.5m and up to 0.3m amplitude trending north easterly From KP9.555 to KP9.686 megaripples with average wavelength of 16m and up to 0.7m amplitude trending north easterly Fom KP9.686 to KP13.631 megaripples with average wavelength of 6.0m and up to 0.3m amplitude trending northly with secondary megaripples with wavelengths of 15-30m and up to 0.3m amplitudes trending south easterly. Seven Fathom Bank present as a large sand bank of approximately 14m amplitude, peaking at KP10.111 From KP13.631 sand waves with wavelength approximately 90m and amplitude up to 3.0m trending north easterly	
14.263	14.489	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 5.5m and 0.4m amplitude trending north easterly	

KP Start	KP End	SBF	Mobile features	SBP
14.489	14.934	SAND with mobile sediments	Megaripples with average wavelength of 4.0m and 0.2m amplitude trending north easterly	
14.934	14.967	SAND with boulder fields and mobile sediments	Megaripples with average wavelength of 4.0m and <0.1m amplitude trending north easterly	
14.967	17.351	SAND ribbons over COARSE SEDIMENT with boulder fields		No reflectors were observed in this section, Unit 1 present at the seabed with veneers of Unit 0 sediments.
17.351	17.407	COARSE SEDIMENT with boulder fields		Unit 1 is at the seabed until KP17.359 where it intermittently increases in depth BSB due to mobile seabed features, reaching a maximum depth of 5.2m. Unit 0 overlies Unit 1 and is occasionally reduced to veneers and complete absent in some places.
17.407	17.419	SAND with boulder fields and mobile sediments	Sand waves with wavelength approximately 130m and amplitude up to 6m trending north easterly	
17.419	17.513	SAND with mobile sediments	Sand waves with wavelength approximately 130m and amplitude up to 6m trending north easterly	
17.513	17.631	COARSE SEDIMENT with boulder fields		
17.631	17.658	SAND with mobile sediments	Sand waves with wavelength approximately 130m and amplitude up to 6m trending north easterly	
17.658	17.673	COARSE SEDIMENT		

KP Start	KP End	SBF	Mobile features	SBP
17.673	17.835	SAND with mobile sediments	Sand waves with wavelength approximately 130m and amplitude up to 6m trending north easterly	
17.835	17.891	COARSE SEDIMENT		
17.891	18.067	SAND with mobile sediments	Sand waves with wavelength approximately 130m and amplitude up to 6m trending north easterly	Unit 1 begins to thicken along the cable route below the sand waves, from a depth of <1.0m to greater than 10m from KP18.790. Unit 0 overlies Unit 1.
18.067	18.079	COARSE SEDIMENT		
18.079	18.167	SAND with mobile sediments	Sand waves with wavelength approximately 130m and amplitude up to 6m trending north easterly	
18.167	18.207	COARSE SEDIMENT		
18.207	18.246	COARSE SEDIMENT with mobile features	Sand waves with wavelength approximately 130m and amplitude up to 6m trending north easterly	
18.246	18.495	SAND with mobile sediments	Sand waves with wavelength approximately 130m and amplitude up to 6m trending north easterly	
18.495	18.511	COARSE SEDIMENT		
18.511	18.756	SAND with mobile sediments	Sand waves with wavelength approximately 130m and amplitude up to 6m trending north easterly	
18.756	18.785	COARSE SEDIMENT		
18.785	19.367	SAND with mobile sediments	Sand waves with wavelength approximately 130m and amplitude up to 6m trending north easterly	

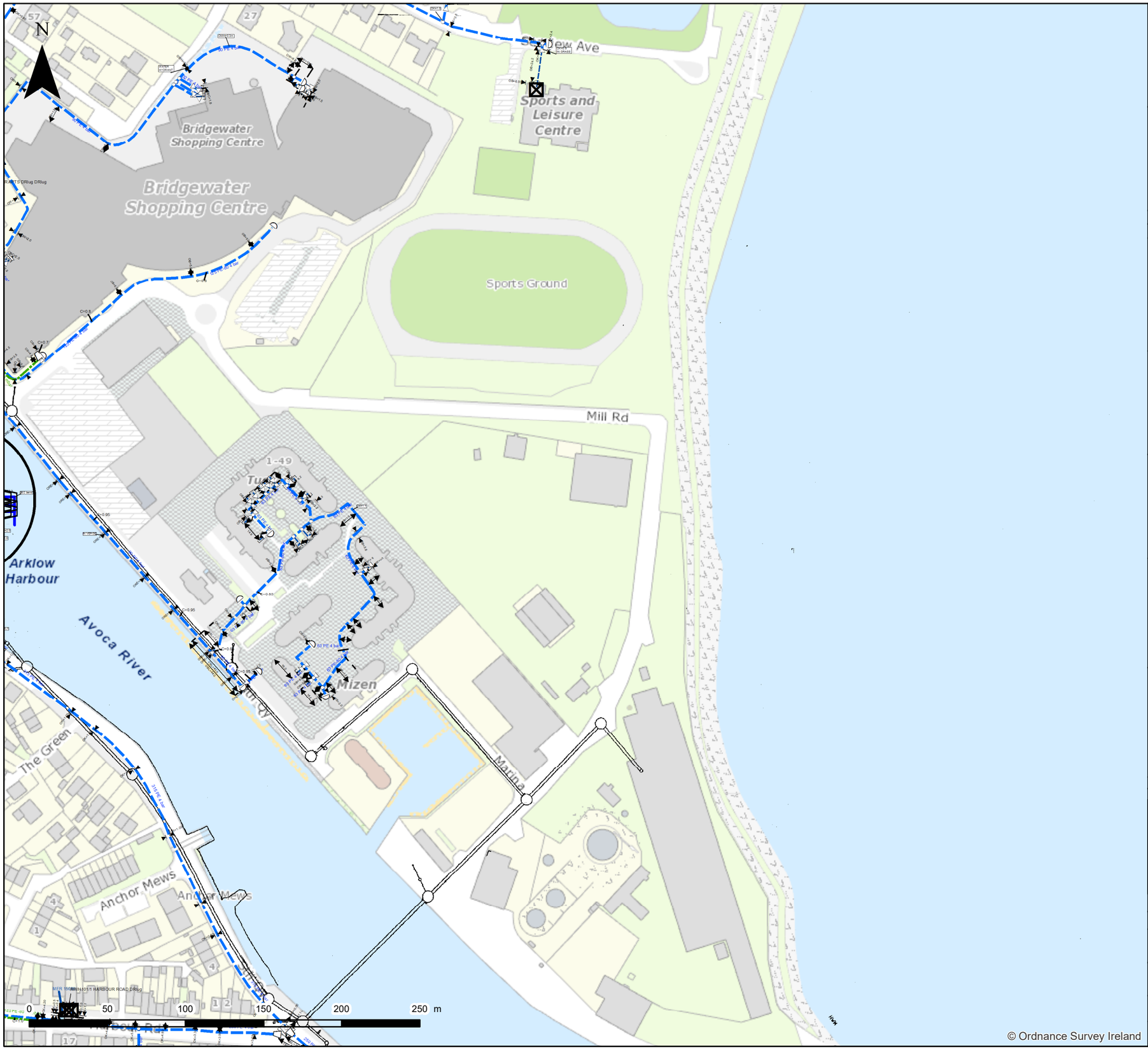
KP Start	KP End	SBF	Mobile features	SBP
19.367	19.407	COARSE SEDIMENT		
19.407	19.595	SAND with mobile sediments	Sand waves with wavelength approximately 130m and amplitude up to 6m trending north easterly	
19.595		END OF ROUTE CR3		

4. REFERENCES

British Geological Survey & Geological Survey of Ireland. (1990). Cardigan Bay sheet (1:250000 series) 52°N-06°W Quaternary Geology.

D. Utilities Drawings (Available to Date)

- LF100034-817_14012020151150-Southern_Gas_Network
- LF100034-817_14012020151716-Northern_Gas_Network
- LF100034-20200121-038_MAP 1_A3-Southern
- LF100034-20200121-038_MAP 2_A3-Northern
- LF100034-eircom_CBYD-Southern
- LF100034-ESB Construction Safety 28th 11.40
- LF100034-Virgin-Southern



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- Distribution Pipe (Medium Pressure)
- Distribution Pipe (Low Pressure)
- Service Pipe (Medium Pressure)
- Service Pipe (Low Pressure)
- Strategic Pipe (Medium Pressure)
- Strategic Pipe (Low Pressure)
- Inserted
- Abandoned Pipe

C=?	Cover (depth in metres)		Pressure Monitor
CP	CP Test Point		Protection (Slabbing)
	End Cap		Protection (Sleeve)
	Hot Tap		Reducer
	Installation		Service Terminator
	Valve		Tee
	Mains Verification**		Transition

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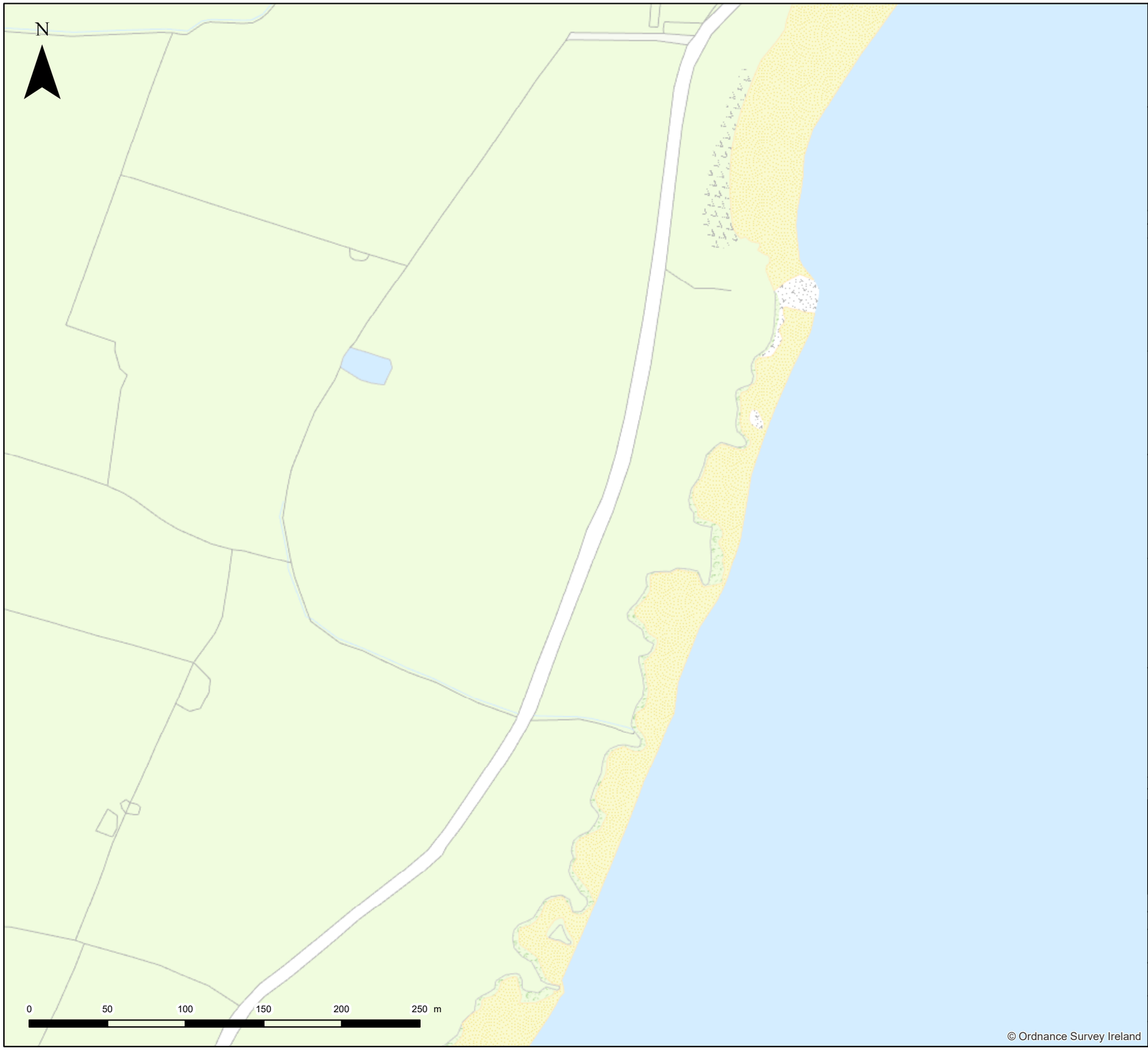
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GAS NETWORK INFORMATION

Description: Arklow HDD-South

Location: 725178,673412

Plot Date: 14/01/2020 15:11	Scale: 2500 @ A3
Plotted By: 817	Ref ID: *817_14012020151150*



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- Transmission Pipe (Construction Issue)
- Distribution Pipe (Medium Pressure)
- Distribution Pipe (Low Pressure)
- Service Pipe (Medium Pressure)
- Service Pipe (Low Pressure)
- Strategic Pipe (Medium Pressure)
- Strategic Pipe (Low Pressure)
- Inserted
- Abandoned Pipe

C=?	Cover (depth in metres)		Pressure Monitor
CP	CP Test Point		Protection (Slabbing)
	End Cap		Protection (Sleeve)
	Hot Tap		Reducer
	Installation		Service Terminator
	Valve		Tee
	Mains Verification**		Transition

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GAS NETWORK INFORMATION

Description: Arklow HDD-North

Location: 727220,677351

Plot Date: 14/01/2020 15:17	Scale: 2500 @ A3
Plotted By: 817	Ref ID: *817_14012020151716*

ESB Networks

TITLE: 20200121-038_MAP 1_A3

COLOUR CODE:

- BLACK - 38KV & HIGHER VOLTAGE OVERHEAD LINES
- GREEN - MV(10KV/20KV) OVERHEAD LINES
- BLUE - LV (400V/230V) OVERHEAD LINES
- CYAN - 38KV & HIGHER VOLTAGE UNDERGROUND CABLE ROUTES
- RED - MV/LV (10KV/20KV/400V/230V) UNDERGROUND CABLE ROUTES

DATE: 21-Jan-2020

** SCALE: 1:2500

** SCALE WHEN PRINTED ON AN A3 PAGE
XY COORDINATES DISPLAYED IN IRISH GRID COORDINATE SYSTEM

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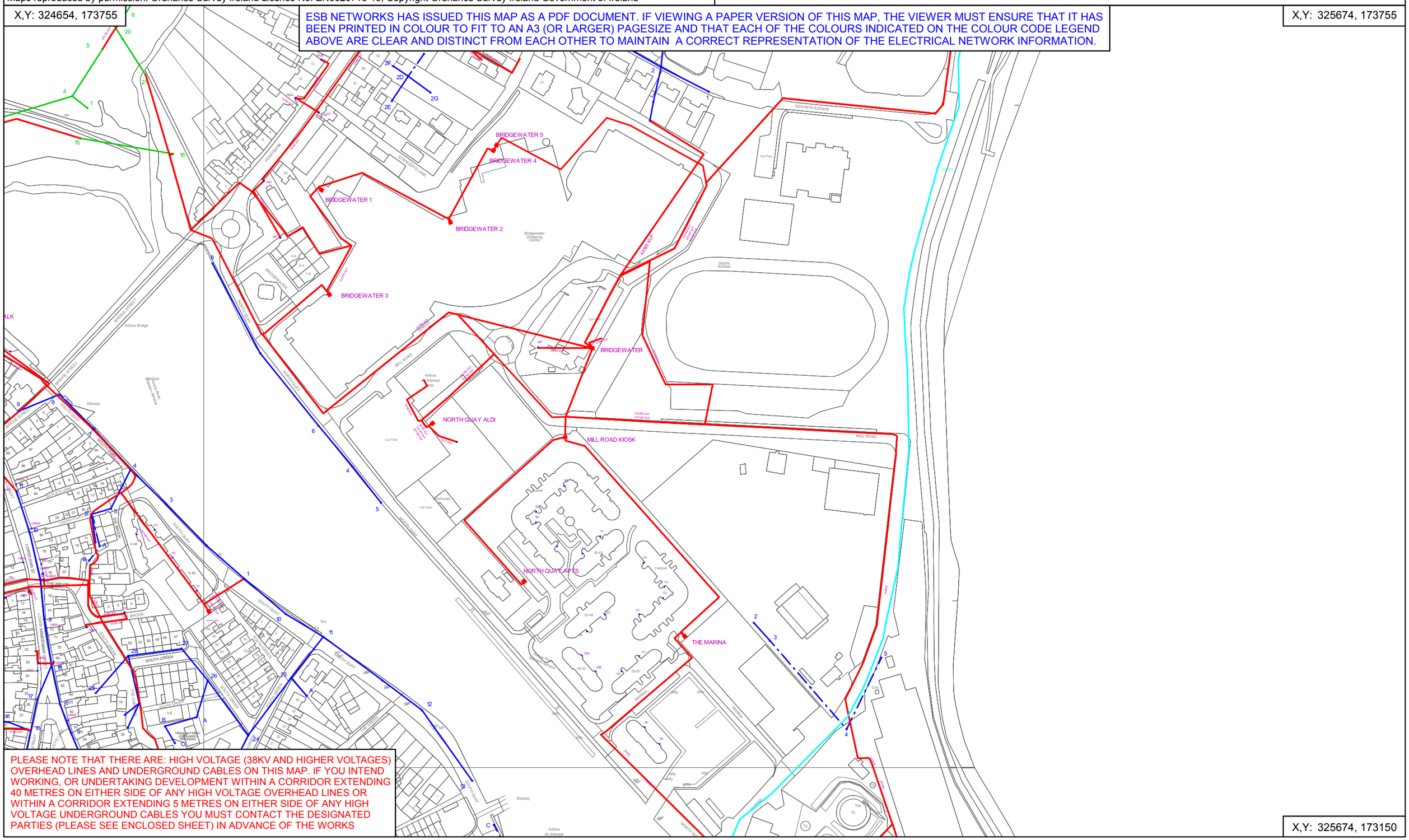
WARNING

THIS MAP INDICATES THE APPROXIMATE LOCATION OF ESB TRANSMISSION (400KV, 220KV, 110KV, 38KV) AND DISTRIBUTION (20KV, 10KV, 230V/400V) UNDERGROUND CABLES AND OVERHEAD LINES IN THE GENERAL AREA OF THE PROPOSED WORKS. ESB NETWORKS TAKES NO RESPONSIBILITY FOR THE ACCURACY OR COMPLETENESS OF THE MAP. IT IS THE USER'S RESPONSIBILITY TO INDEPENDENTLY VERIFY THE INFORMATION AND THE LOCATION OF UNDERGROUND CABLES AND OVERHEAD LINES. LOW VOLTAGE (230V/400V) SERVICE CABLES (E.G. HOUSE SERVICES, FACTORY/SHOP SERVICES, PUBLIC LIGHTING LAMP SERVICES, ETC) ARE NOT INCLUDED BUT THEIR PRESENCE SHOULD BE ANTICIPATED. THE DEPTHS OF UNDERGROUND CABLES MUST NEVER BE ASSUMED. ADDITIONAL MORE DETAILED INFORMATION IS AVAILABLE FOR HIGH VOLTAGE TRANSMISSION UNDERGROUND CABLES (38KV, 110KV, 220KV, 400KV) FROM THE LOCAL ESB NETWORKS TRANSMISSION REPRESENTATIVE - SEE ATTACHED LIST FOR CONTACT DETAILS OR CALL 1850 372 757. NO WORK SHOULD BE CARRIED OUT IN THE VICINITY OF 38KV OR HIGHER VOLTAGE UNDERGROUND CABLES WITHOUT PRIOR CONSULTATION WITH ESB NETWORKS. BEFORE ANY MECHANICAL EXCAVATION IS UNDERTAKEN, THE ACTUAL LOCATION OF ALL UNDERGROUND ELECTRICITY CABLES MUST BE ESTABLISHED AND VERIFIED ON THE SITE USING: (A) UP-TO-DATE MAP RECORDS; (B) CABLE LOCATER EQUIPMENT OPERATED IN BOTH POWER AND RADIO MODES; (C) CAREFUL HAND DIGGING OF TRIAL HOLES USING 'SAFE DIGGING PRACTICE'. REFER ALSO TO 'HSA CODE OF PRACTICE FOR AVOIDING DANGER FROM UNDERGROUND SERVICES'. ESB TAKES NO RESPONSIBILITY FOR AND SHALL BEAR NO LIABILITY, HOWSOEVER ARISING, IN RELATION TO ANY DAMAGE, INJURY/DEATH OR LOSS OF SUPPLY AS A RESULT OF DAMAGE OR INTERFERENCE WITH ITS NETWORKS.

X,Y: 324654, 173755

ESB NETWORKS HAS ISSUED THIS MAP AS A PDF DOCUMENT. IF VIEWING A PAPER VERSION OF THIS MAP, THE VIEWER MUST ENSURE THAT IT HAS BEEN PRINTED IN COLOUR TO FIT TO AN A3 (OR LARGER) PAGESIZE AND THAT EACH OF THE COLOURS INDICATED ON THE COLOUR CODE LEGEND ABOVE ARE CLEAR AND DISTINCT FROM EACH OTHER TO MAINTAIN A CORRECT REPRESENTATION OF THE ELECTRICAL NETWORK INFORMATION.

X,Y: 325674, 173755



PLEASE NOTE THAT THERE ARE: HIGH VOLTAGE (38KV AND HIGHER VOLTAGES) OVERHEAD LINES AND UNDERGROUND CABLES ON THIS MAP. IF YOU INTEND WORKING, OR UNDERTAKING DEVELOPMENT WITHIN A CORRIDOR EXTENDING 40 METRES ON EITHER SIDE OF ANY HIGH VOLTAGE OVERHEAD LINES OR WITHIN A CORRIDOR EXTENDING 5 METRES ON EITHER SIDE OF ANY HIGH VOLTAGE UNDERGROUND CABLES YOU MUST CONTACT THE DESIGNATED PARTIES (PLEASE SEE ENCLOSED SHEET) IN ADVANCE OF THE WORKS

X,Y: 325674, 173150

TITLE: 20200121-038_MAP 2_A3

ESB Networks

COLOUR CODE:

- BLACK - 38KV & HIGHER VOLTAGE OVERHEAD LINES
- GREEN - MV(10KV/20KV) OVERHEAD LINES
- BLUE - LV (400V/230V) OVERHEAD LINES
- CYAN - 38KV & HIGHER VOLTAGE UNDERGROUND CABLE ROUTES
- RED - MV/LV (10KV/20KV/400V/230V) UNDERGROUND CABLE ROUTES

DATE: 21-Jan-2020

** SCALE: 1:2500

** SCALE WHEN PRINTED ON AN A3 PAGE
XY COORDINATES DISPLAYED IN IRISH GRID COORDINATE SYSTEM

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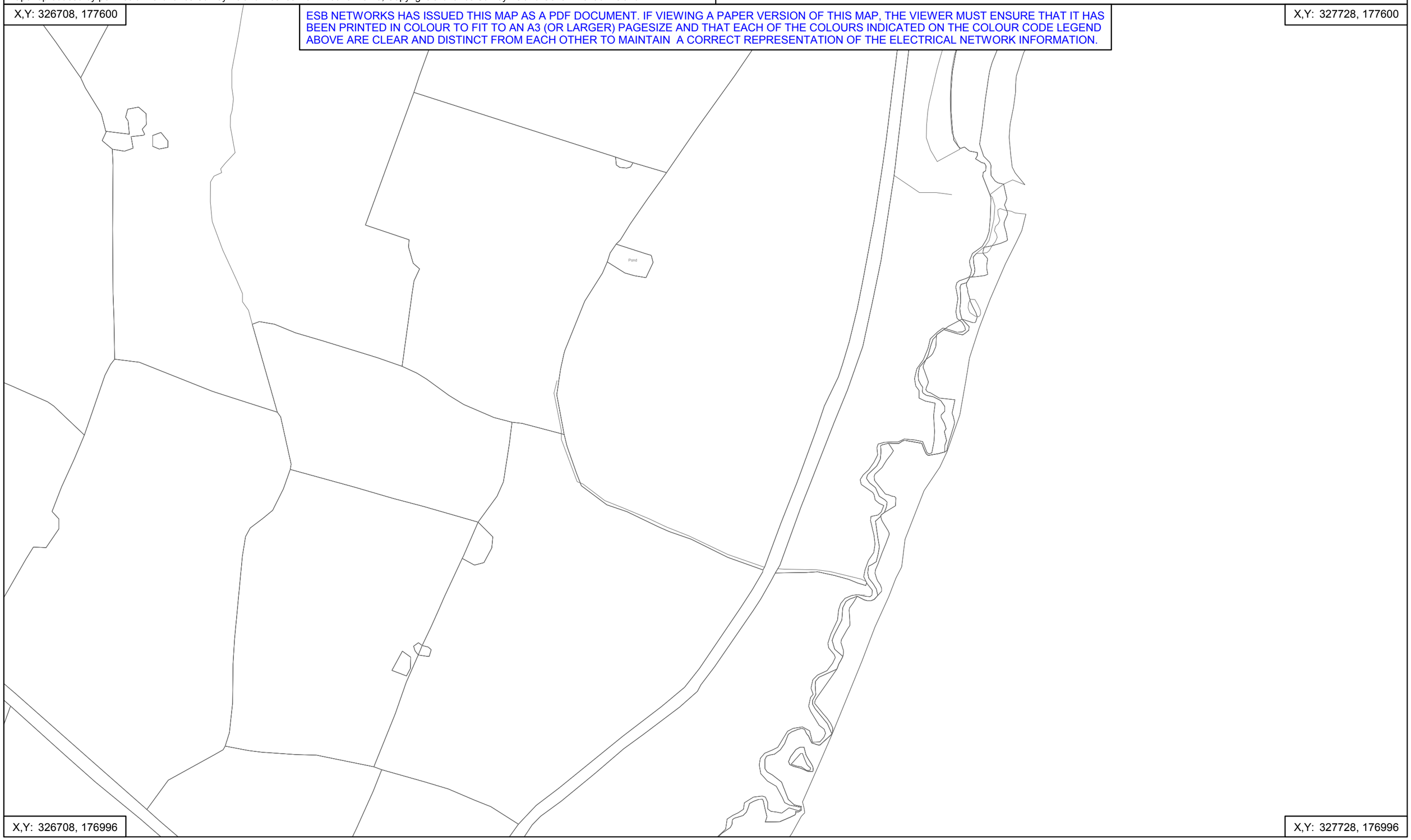
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X,Y: 326708, 177600

X,Y: 327728, 177600



X,Y: 326708, 176996

X,Y: 327728, 176996

A3

Tennis
Ground

4x100PP

3777

3778

4x100PP

4x100PP

PLANT REQUESTED FROM eircom emaps CBYD SERVICE

https://cbyd.emaps.eircom.ie/

Scale: 1:750

Irish National Grid Co-Ordinates
Centre XY: 325234 m, 173515 m

Date
03/02/2020

emaps CBYD

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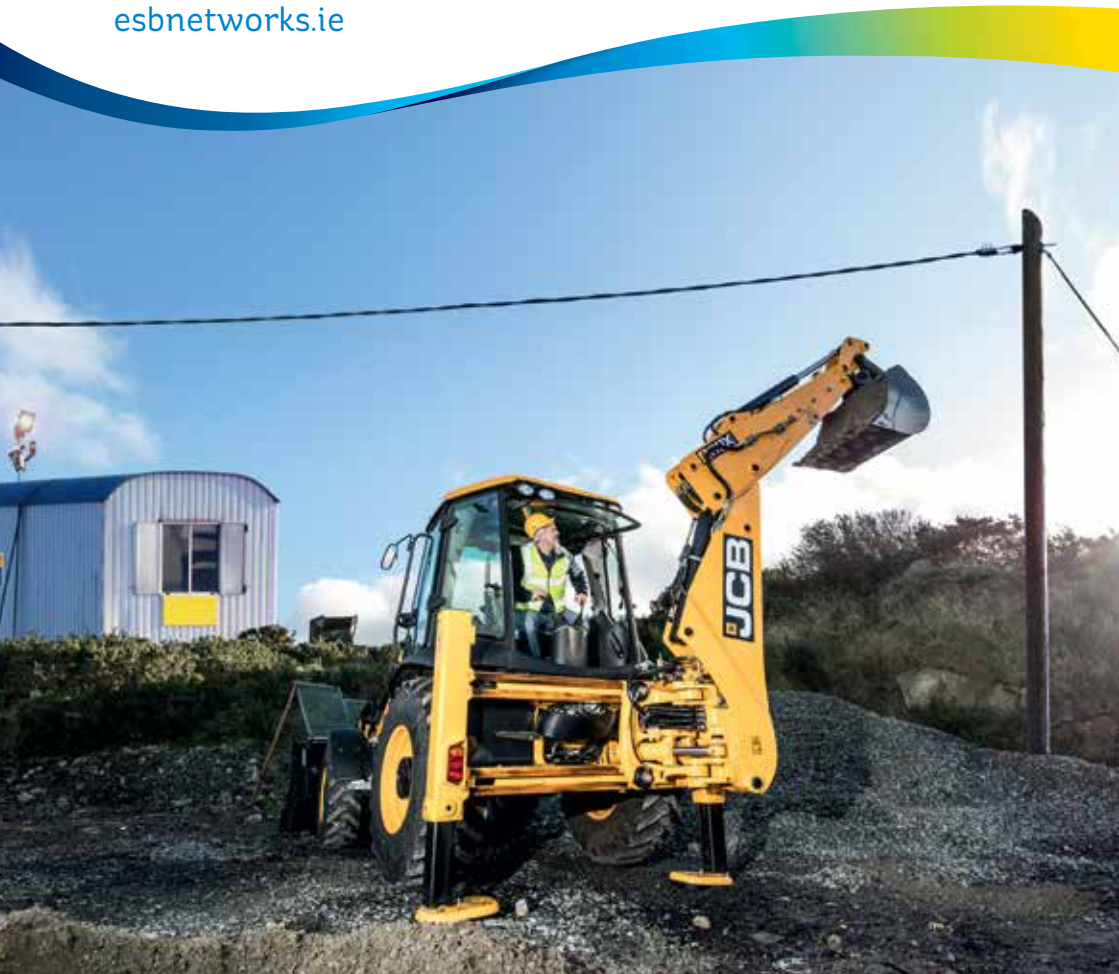
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NETWORKS

Serving all electricity customers

SAFE CONSTRUCTION WITH ELECTRICITY

esbnetworks.ie



INTRODUCTION

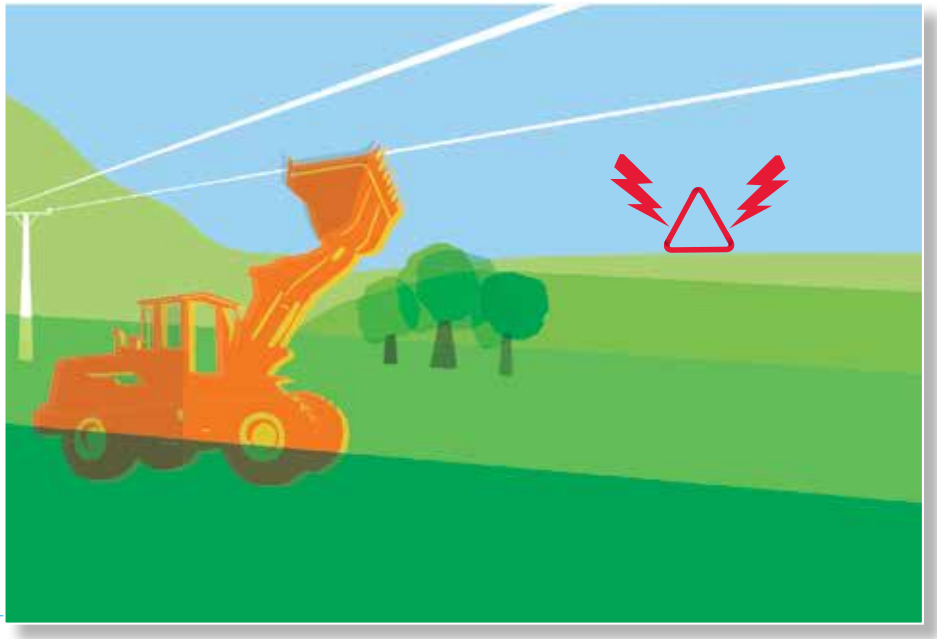
Electricity is essential for our economy and so much part of modern living that we often take it for granted. This booklet provides important safety and customer service information to help you stay safe when working near electricity networks and to explain the key steps when you require services from ESB Networks.

SAFETY ADVICE WHEN WORKING NEAR OVERHEAD ELECTRICITY WIRES AND UNDERGROUND CABLES



Electricity is delivered across the country using both overhead wires and buried cables. It is a powerful and versatile source of energy but it can be dangerous unless we use safe systems of work.

Serious accidents, including fatal electrical accidents have occurred where construction work is involved. In the past 21 years there have been 16 electrical fatalities due to accidental contact with overhead electricity wires and cables.



Overhead Electricity Wires – Keep Your Distance

The power of electricity is such that any accidental contact with overhead wires, or coming too close, will cause serious injury and can be fatal. Serious accidents have occurred when using cranes, concrete delivery trucks, tipper lorries and scaffolding near overhead wires.

It is important to note the existence of overhead wires and to plan to safely carry out work. If possible keep machinery clear and guard against working close to the live wires. Always allow enough clearance to avoid contact and remember that electricity can jump gaps.

For more detailed information please refer to the ESB Networks Code of Practice For Avoiding Danger from Overhead Electricity Wires which can be downloaded from the www.esbnetworks.ie

If the worst happens – take these steps and stay safe:

If a machine or its attachments come into contact with an overhead line, it could be fatal for anyone who touches the machine. Do not rely on rubber tyres or rubber-soled boots for protection – they will not insulate against a high-voltage shock. Tyres can burst into flames and boots can be destroyed. These are the steps that should be taken in the event of a hit on an overhead power line.

Step 1: Keep Clear

- The driver of a vehicle that comes into contact with overhead lines will usually remain safe in the cab of the vehicle. Other people are at risk if they make simultaneous contact with the vehicle (and anything attached to it) and the ground.

Step 2: Get Help

- You, or someone else, should contact ESB Networks' emergency number (1850 372 999) immediately.

Step 3: Jump Clear

- If you have to leave the cab, jump well clear so that no simultaneous contact is made between you, the vehicle and the ground. Land on your feet and do not touch the ground with your hands. Move away at once using short steps or bunny hop with both feet together.

Step 4: Stay Clear

- Do not go back to the vehicle, even if you think it is safe to do so. It may still be live.
- Nobody should approach the vehicle until ESB Networks has confirmed that it is safe to do so.

Step 5: Safe Operation

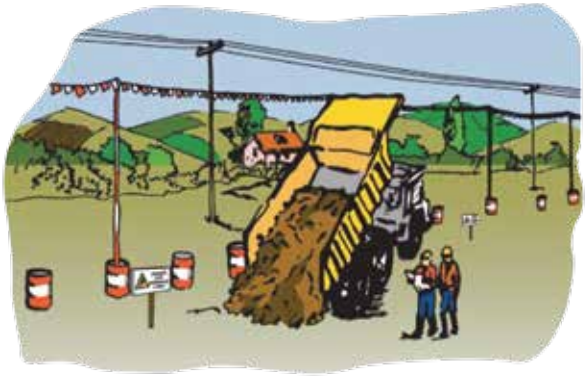
- If the vehicle is not tangled with the overhead line, reverse away until contact is broken. Do not climb out of the vehicle or attempt to operate the vehicle while standing on the ground outside the vehicle.

Avoidance of electrical hazards when working near overhead lines

At the planning stage and before starting work near an overhead line, consult ESB Networks.

THERE ARE TWO GENERAL CASES

Site where there will be no work or passage of plant under a live overhead line.



- A barrier should run parallel to the line (See below for distance from line)
- This may be fixed post fencing or steel drums filled with rubble spaced 1.5 metres apart.
- If cranes are in use a line of bunting at a height of 3 metres should supplement the barriers. (See below for distance from line)
- Danger notice stating "Danger Live Overhead Line" should be spaced at intervals.

Site where plant will pass under a live overhead line

In addition to the above, Goal Posts should be erected as shown.



Dimensions as follows:

- Height of goalposts – *As advised by ESB*
- Width of Goalposts - *Max. 10 metres.*
- Height of bunting - *3 metres*
- Distance between steel drums - *1.5 metres*
- Distance between danger notices - *20 metres*
- Horizontal distance of barrier to outside conductor on line
  - *6 metres minimum for LV, 10kV, 20kV, 38kV.*
  - *10 metres minimum for 110kV, 220kV, 400kV.*

In general if work is to be undertaken directly under the line, ESB will insist that the line is switched off for the duration of the work.

Underground Electricity Cables and Services – Do You Know

Damage to underground cables is extremely hazardous. Serious accidents have occurred resulting in life-threatening injuries when electricity cables have been struck or disturbed. Use of hand tools, and not just heavy machinery, has been responsible for serious safety incidents.

It is important to always take the essential safety precautions before carrying out digging work. There may be buried electricity cables close by.

Always check and identify the route and location of electricity cables, using competent and trained people. It is never safe to disturb or handle electricity cables . Always contact ESB Networks immediately.

When planning work which involves digging, always contact the Dial before U Dig service at dig@esb.ie or alternatively phone 1850 928 960.

For more detailed information please refer to the H.S.A Code of Practice For Avoiding Danger from Underground Services which can be downloaded from the H.S.A. website.

Safe System of Work for Digging

These Guidelines apply to all work that involves penetrating the ground at or below surface level

When working near buried services USE

- Maps
- CAT - Cable Avoidance Tool
- Safe Digging Practice
- Company Policies & Procedures

All 4 complement each other

Always be aware that the depth of cover may be very shallow and that there may no bricks, warning tape or other protection in place. Always assume that there will be more services than you expect to find.

BEFORE You Start Digging

Manhole Covers, Valve Covers, Lamp Posts, Houses/buildings, Meters, Communications Network, Signs of Previous Digging

- ✓ Complete Risk Assesmant
- ✓ Ensure you have appropriate Maps
- ✓ Remember that service cables & public lights may not be shown.
- ✓ Look out for Services
- ✓ Always use Cable Locator (CAT) to trace all services
- ✓ Mark the positions of the cables using waterproof crayon, chalk or paint

ESB NETWORKS

Serving all electricity customers

DO YOU KNOW WHAT LIES BELOW?

Always dial before you dig

Avoid the dangers of underground electricity cables.
Contact us to get maps which show the locations of ESB Networks' underground cables.

PHONE: **1850 928 960**
EMAIL: **dig@esb.ie**
FAX: **01 6388169**

In case of emergency, phone
1850 372 999 (24 HOUR/7 DAY SERVICE)

www.esbnetworks.ie

HSA HEALTH AND SAFETY AUTHORITY

IMPORTANT: Please refer to the HSA "Code of Practice For Avoiding Danger From Underground Services" on how to safely carry out excavation work in the vicinity of underground cables. Available at www.hsa.ie



INFORMATION AND RESOURCES:

ESB Networks proves a range of safety materials.

Cab stickers should be displayed prominently on the vehicle to remind everyone of the dangers.

Log on to www.esbnetworks.ie and find out more about safety and electricity.

In an emergency or where there is a public safety concern with electricity wires or cables, contact us immediately on our 24/7 emergency number: 1850 372 999

Safety DVD's, Cab stickers and keyrings - please contact us for materials at 1850 372 757

ESB Networks safety website: esbnetworks.ie

H.S.A website: www.hsa.ie





HOW TO CONTACT ESB NETWORKS

- ### If you have a general query

  You can contact us at 1850 372 757 or +353 21 2386555
  Lines are open Monday to Friday 8.30am to 6pm and Saturday 8.30am to 1.30pm .
  If possible please have your MPRN number to hand when calling us.
  Email: esbnetworks@esb.ie
  Our target is to have your query addressed within two working days.

- ### Faults/Emergencies and Interruptions in Supply

  For Real Time Information on Faults and Outages go to ESB PowerCheck www.powercheck.ie
  For Faults/Emergencies (24 hours/7days service) Ring 1850 372 999 or +353 21 2382410
  Follow us on www.twitter.com/esbnetworks

- ### Safe Digging

  Email your request , with your site map to dig@esb.ie
  Call 1850 928960
  Fax 01 6388169
  Alternatively, you can make a postal request to:
  Central Site
  ESB Networks
  St. Margaret's Road
  Finglas
  Dublin 11

- ### Meter Reading

  You can send in a meter reading online www.esbnetworks/readings.
  Or ring our 24 hour automated meter reading service 1850 33 77 77 or +353 21 2386444
  You can also text us a reading at 087 9609223 in the format:
  MPRN (space) reading
  Or Email: reading@esb.ie

- ### Feedback & Complaints

  How do I register a complaint?
  You can register your complaint with us in the following ways:

  - You can phone our National Customer Care Centre on 1850 372 757 or +353 21 2386555 (outside of Ireland)

NEW CONNECTIONS PROCESS

STEP BY STEP GUIDE

Step 1 - Get an Ordnance Survey Map and Site Plan

- You need an ordnance survey map (scale 1:2500-1:10560) showing the location of your new unit/premise. Mark the location of your new premises with a red pen.
- You will also need a detailed site plan (scale 1:100-1:500) showing your new premises.
- Your builder or architect should be able to provide you with both of these. Photocopies are acceptable.
- For multi-unit developments you will also need a letter from the Local Authority confirming the final name of your development.

Step 2 - Apply

Apply by post. Download the New Connection or Increased/Reduced Capacity (MIC) Application form from www.esbnetworks.ie or call 1850 372 757 or +353 21 2386555 to request a copy.

Send the completed form together with the ordnance survey map and the site plan to:

ESB Networks DAC, Customer Services Bureau,
PO Box 29, Garrycastle, Athlone, Westmeath, Ireland

Step 3 - Receive an Acknowledgement

Once we get your completed application, we put your details on the system and send you an acknowledgement and reference number.

Step 4 - After this preparatory work, network installation work can be planned and scheduled.

Step 5 - Make a payment and send back the Agreement

After this preparatory work, network installation work can be planned and scheduled.



KEY SAFETY MESSAGES

- Watch out for overhead electricity wires
- Identify the location of buried cables
- Follow the requirements set down in the Codes of Practice
- Never work close to overhead wires
- Never disturb cables
- Never undermine pole/mast foundations.
- Electricity wires are always live
- Never touch fallen wires.
- Never handle anything that may be in contact with electricity wires.
- Display safety stickers on machinery to remind everyone to be “electricity safe”.
- In an emergency, phone immediately 1850 372 999.

ESB Networks Emergency Number:

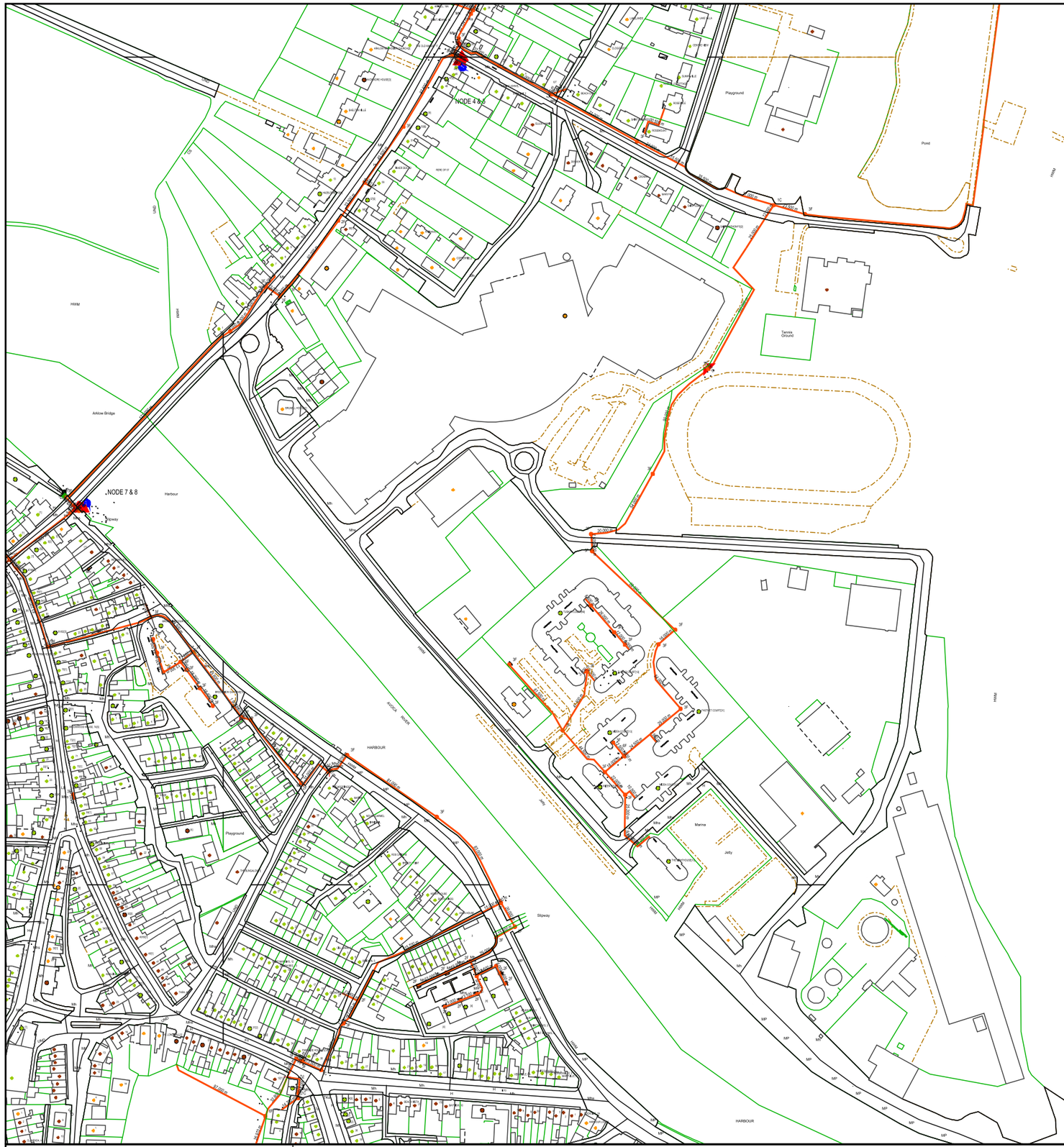
In case of emergency

phone 1850 372 999

(24 hour/7 day service)

www.esbnetworks.ie

NETWORKS



Unit 7,
Westgate Business Park,
Ballymount,
Dublin 24.

PROJECT NAME

DESIGNED BY:

Ordnance Survey Ireland Licence No. EN0023805
(c) Ordnance Survey Ireland and Government of Ireland

Produced on: 20/01/2020

@ A3

E. Concept Design Drawings and DRA Northern Landfall



HDD PLAN

Scale 1:1000

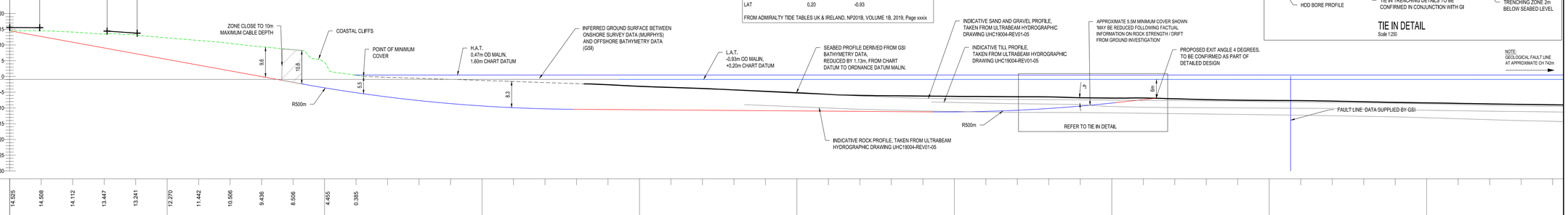
1:1000 0 10m 20m 30m 40m 50m 60m 70m 80m 90m 100m

1:1 0 10 20 30 40 50 60 70 80 90 100

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

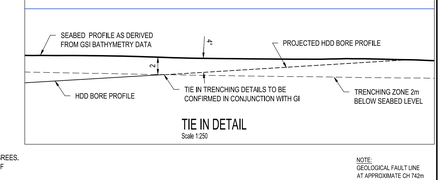
THE FOLLOWING ARE SIGNIFICANT RESIDUAL HAZARDS IDENTIFIED BY THE DESIGNER. TYPICAL HAZARDS THAT SHOULD BE IDENTIFIED BY A COMPETENT CONTRACTOR ARE NOT INCLUDED. THE CONTRACTOR SHALL CARRY OUT THE WORKS USING AN APPROVED SAFE SYSTEM OF WORK. FURTHER INFORMATION ON HAZARDS CAN BE FOUND IN THE DRA AND/OR CSM HAZARDS LOGO

REF	HAZARD	STAGE	MITIGATION MEASURES
HAZ001	WORKING AT HEIGHT	C D	CONTRACTOR TO HAVE SUITABLE MEASURES IN PLACE. DESIGNER OPTED FOR TRENCHLESS TECHNIQUE KEEPING WORKS AWAY FROM CLIFF
HAZ002	DROWNING	C D	OFFSHORE CONTRACTOR TO HAVE SUITABLE MEASURES IN PLACE. DESIGNER OPTED FOR TRENCHLESS TECHNIQUE KEEPING WORKS AWAY FROM CLIFF
HAZ003	LIVE TRAFFIC	C	TRAFFIC MANAGEMENT AGREED WITH ROAD AUTHORITY
HAZ004	EARTHWORKS / POLLUTION CONTROL	C	CONTRACTOR TO MONITOR WEATHER AND SEQUENCE WORKS ACCORDINGLY. CONTRACTOR TO WORK WITH ENVIRONMENTAL REGULATOR REQUIREMENTS. CONTRACTOR TO UNDERTAKE FULL SERVICES SURVEY PRIOR TO WORKS AND CAT SCAN ALL LOCATIONS



ARKLOW HARBOUR	Chart Datum (m CD)	Malin Head (m OD) conversion factor between CD and OD is -1.13m
HAT	1.60	0.47
MHWS	1.40	0.27
MHWN	1.20	0.07
MSL	1.03	-0.10
MLWN	0.90	-0.23
MLWS	0.60	-0.53
LAT	0.20	-0.93

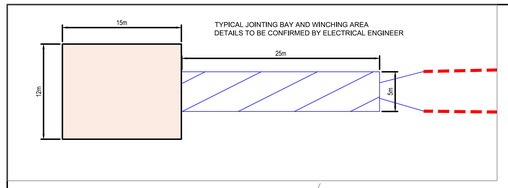
FROM ADMIRALTY TIDE TABLES UK & IRELAND, NP201B, VOLUME 1B, 2019, Page xxxix



TIE IN DETAIL

Scale 1:250

| | | |



SITE ENTRANCE BELLMOUTH FORMED TO L.A. REQUIREMENTS

TEMPORARY ROAD SURFACING OF TYPE A IN ACCORDANCE WITH CLAUSE 801 (TRANSPORT INFRASTRUCTURE IRELAND, SPECIFICATION FOR ROAD WORKS, SERIES 800) PLACED ON GEOTEXTILE

HAZARD 03

SURFACING OF TYPE A IN ACCORDANCE WITH CLAUSE 801 (TRANSPORT INFRASTRUCTURE IRELAND, SPECIFICATION FOR ROAD WORKS, SERIES 800) PLACED ON GEOTEXTILE

1:200 CROSSFALL TO COMPOUND

DESIGN TO CONSIDER HEAVE OR POTENTIAL SETTLEMENT OF ROAD

VEHICLE ACCESS

CAR PARKING AREA

HARDSTANDING REQUIRED (TYPE A)

HAZARD 01

HDD1
NG REF:
727168
677281

HDD2
NG REF:
727167
677276

STRINGING AREA IF REQUIRED (AIDED WITH STILTS AND ROLLERS) NOTE INTENTION IS TO PULL DUCT IN FROM OFFSHORE

52m

HAZARD 04

113m

HAZARD 01

HAZARD 02

50

100

200

TEMPORARY FOOTPRINT AREA = 4479m²
TEMPORARY WORKS SHOULD BE REINSTATED AS FAR AS PRACTICABLE, TO MINIMISE IMPACT

INDICATIVE JOINTING BAY. FINAL DETAILS BY ELECTRICAL ENGINEER

HDD SPACING 5m CENTRES AT ENTRY

INDICATIVE ON-SHORE CABLE ROUTE
PRECISE ON-SHORE CABLE ROUTE (TBC).

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

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HAZ002	DROWNING	C D	OFFSHORE CONTRACTOR TO HAVE SUITABLE MEASURES IN PLACE. DESIGNER OPTED FOR TRENCHLESS TECHNIQUE KEEPING WORKS AWAY FROM CLIFF
HAZ003	LIVE TRAFFIC	C	TRAFFIC MANAGEMENT AGREED WITH ROAD AUTHORITY
HAZ004	EARTHWORKS / POLLUTION CONTROL	C	CONTRACTOR TO MONITOR WEATHER AND SEQUENCE WORKS ACCORDINGLY. CONTRACTOR TO WORK WITH ENVIRONMENTAL REGULATOR REQUIREMENTS. CONTRACTOR TO UNDERTAKE FULL SERVICES SURVEY PRIOR TO WORKS AND CAT SCAN ALL LOCATIONS

This drawing should not be scaled. Dimensions to be verified on site.
Any discrepancies should be referred to the Engineer prior to work being put in hand.

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Pickfords Wharf, Clink Street, London SE1 9DG t 020 7928 7888 f 03333 444 501

GENERAL NOTES

1) DRAWING TO BE VIEWED IN CONJUNCTION WITH WATERMAN REPORT LF100034-WIE16435-100-2-3-FS
2) DRAWING IS NOT FOR CONSTRUCTION, AND PRESENTS A CONCEPTUAL DESIGN ONLY
3) THE CO-ORDINATE REFERENCE SYSTEM USED IN THE DRAWING IS ORDNANCE SURVEY (IRELAND) IRISH GRID, WITH A VERTICAL DATUM TO MALIN HEAD.
4) SITE SPECIFIC BATHYMETRICAL SURVEYS WOULD BE RECOMMENDED AS PART OF DESIGN DEVELOPMENT.
5) ON-SHORE AND NEARSHORE INTRUSIVE GROUND INVESTIGATION WILL BE REQUIRED IN ORDER TO CONFIRM GROUND CONDITIONS AND ALLOW FINALISATION OF DESIGN PROFILE.
6) DEPENDANT ON OVERBURDEN THICKNESS AT ENTRY POINT, TO BE CONFIRMED BY GROUND INVESTIGATION, A REINFORCED CONCRETE HDD RIG ANCHOR BLOCK OR SHEET PILES MAY BE REQUIRED.
7) ALL WORK IS TO BE CARRIED OUT IN COMPLIANCE WITH THE REQUIREMENTS OF THE RELEVANT STATUTORY AUTHORITIES AND REGULATIONS NOTING THAT ENVIRONMENTAL LICENSES AND APPROVALS MAY BE REQUIRED.
8) COMPOUND LAYOUT INDICATIVE + SUBJECT TO INDIVIDUAL CONTRACT REQUIREMENTS.
9) MAPPING IMAGERY TAKEN FROM BING MAPS.

KEY:

1. 50 KVA GENERATOR 2M X 2M
2. TOILET BLOCK 6M X 2M
3. DRY/CHANGE ROOM 6M X 2M
4. CANTEEN 6M X 2M
5. OFFICE 6M X 2M
6. OFFICE 6M X 2M
7. 21 TON TRACKED 360 EXCAVATOR
8. DRILL PIPE STORAGE 10M X 2M
9. HDD DRILL RIG 16M X 2M
10. POWER PACK 6M X 2M
11. CONTROL CABIN 6M X 2M
12. MUD LAB 3M X 2M
13. MUD ENTRY PIT 3M X 4M
14. HIGH PRESSURE MUD PUMP 6M X 2M
15. MUD MIXING TANK 7M X 2M
16. 350 KVA GENERATOR 5M X 2M
17. RECYCLING UNIT 6M X 2M
18. WATER STORAGE TANK 6M X 2M
19. DRY DRILLING FLUID STORAGE 4M X 10M
20. WORKSHOP 6M X 2M
21. STORES 6M X 2M

KEY:

PROPOSED HDD ALIGNMENTS

INDICATIVE TRANSITION JOINT BAY (25m x 5m x 1.2m)

Rev	Date	Description	By
P04	09.04.20	DRAWING UPDATED FOLLOWING SSE COMMENTS. RE-ISSUED FOR INFORMATION	MC
P03	13.03.20	DRAWING TITLE AMENDED. REISSUED FOR INFORMATION	MC
P02	24.02.20	DRAWING AMENDED FOLLOWING SSE COMMENTS. DRAWING NUMBER CHANGED TO SUIT SSE REFERENCE.	MC
P01	31.01.20	FIRST ISSUE	MC

Amendments

Project: ARKLOW BANK WIND PARK PH2

Title: NORTHERN CABLE LANDFALL: SITE LAYOUT (CABLE ROUTE 2)

Client: SURE PARTNERS LTD

Broxden House Broxden Business Park Lamberkine Drive Perth PH1 1RA
t 01738 448 821
mail@watermangroup.com www.watermangroup.com

Status: PRELIMINARY

Designed By	Checked By	Waterman Ref
GA	CG	WIE16435
Drawn By	Date	Scales @ A0
MC	31.01.20	AS SHOWN

Project · Originator · Volume · Level · Type · Role · Number: LF100034-WIE-ZZ-XX-DR-C-90002

Revision: P04

1, A0-Wat-BS-S, MSL34362_T_ITM_2d_Rev0

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Pickfords Wharf, Clink Street, London SE1 9DG t 020 7928 7888 f 03333 444 501

GENERAL NOTES

1) DRAWING TO BE VIEWED IN CONJUNCTION WITH WATERMAN DESK STUDY REPORT WIE12731-113-R-1-3-3.

2) DRAWING IS NOT FOR CONSTRUCTION, AND PRESENTS AN INDICATIVE HDD PLAN AND SECTION ONLY, BASED ON INFORMATION AVAILABLE AT DESK STUDY STAGE AND USING DIGITAL TOPOGRAPHICAL AND BATHYMETRICAL DATA SUPPLIED BY GEOLOGICAL SURVEY OF IRELAND.

3) THE CO-ORDINATE REFFRENCE SYSTEM USED IN THE DRAWING IS ORDNANCE SURVEY (IRELAND) IRISH GRID, WITH A VERTICAL DATUM TO MALIN HEAD.

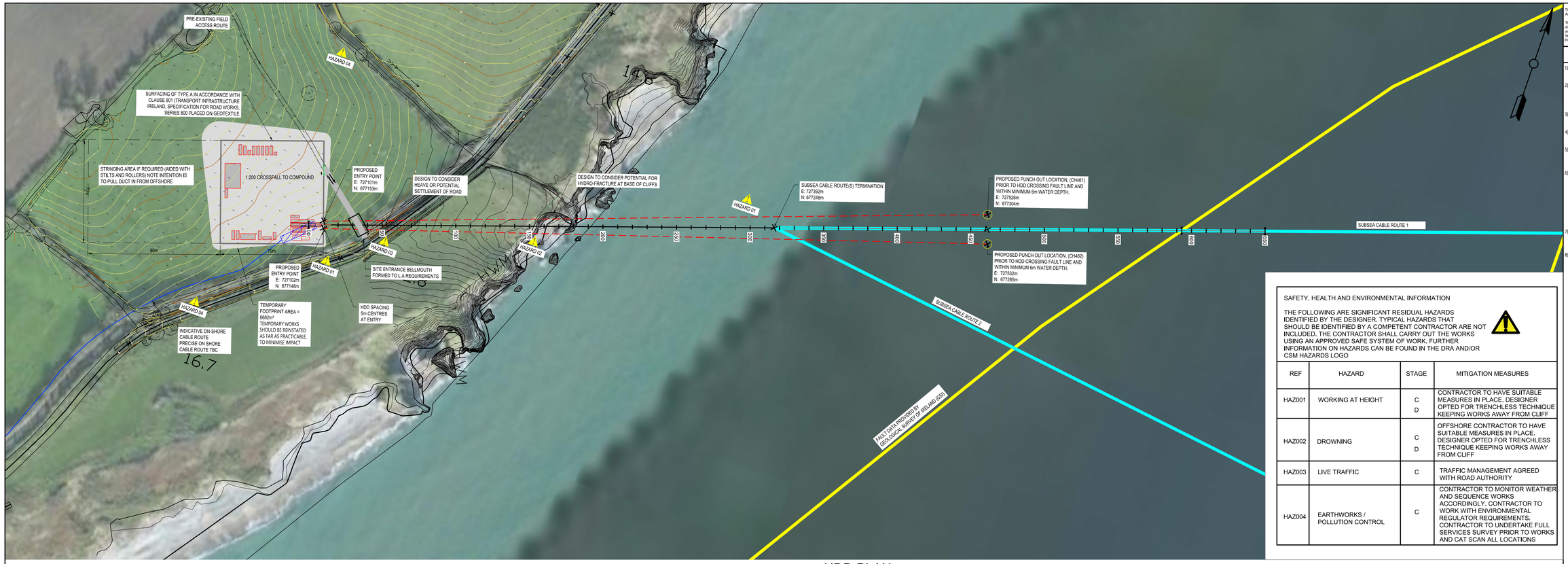
4) SITE SPECIFIC BATHYMETRICAL SURVEYS WOULD BE RECOMMENDED AS PART OF DESIGN DEVELOPMENT.

5) ON-SHORE AND NEARSHORE INTRUSIVE GROUND INVESTIGATION WILL BE REQUIRED IN ORDER TO CONFIRM GROUND CONDITIONS AND ALLOW FINALISATION OF DESIGN PROFILE.

6) PRIOR TO CONSTRUCTION, DETAILED DESIGN WILL REQUIRE TO BE UNDERTAKEN TO CONFIRM THE SUITABILITY OF THE PROPOSED DRILL PROFILE. THIS MUST INCLUDE PUSHING / PULLING CALCULATIONS TO CONFIRM THAT FORCES REMAIN WITHIN THE YIELD / COMPRESSION STRENGTH OF THE PRODUCT PIPE, AND HYDRO-FRACTURE CALCULATIONS TO CONFIRM SUFFICIENT DEPTH OF COVER TO PREVENT FRAC-OUT OF DRILL FLUIDS TO THE MARINE ENVIRONMENT. FURTHER CONSIDERATION SHOULD ALSO BE GIVEN TO THE INFLUENCE OF BEDDING AND JOINT SETS ON THE DRILL STEERING, TO CONFIRM THE SUITABILITY OF THE PROPOSED MINIMUM RADIUS R500m.

7) DEPENDANT ON OVERBURDEN THICKNESS AT ENTRY POINT, TO BE CONFIRMED BY GROUND INVESTIGATION, A REINFORCED CONCRETE HDD RIG ANCHOR BLOCK MAY BE REQUIRED.

8) ALL WORK IS TO BE CARRIED OUT IN COMPLIANCE WITH THE REQUIREMENTS OF THE RELEVANT STATUTORY AUTHORITIES AND REGULATIONS NOTING THAT ENVIRONMENTAL LICENSES AND APPROVALS MAY BE REQUIRED.



HDD PLAN
Scale 1:1000

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

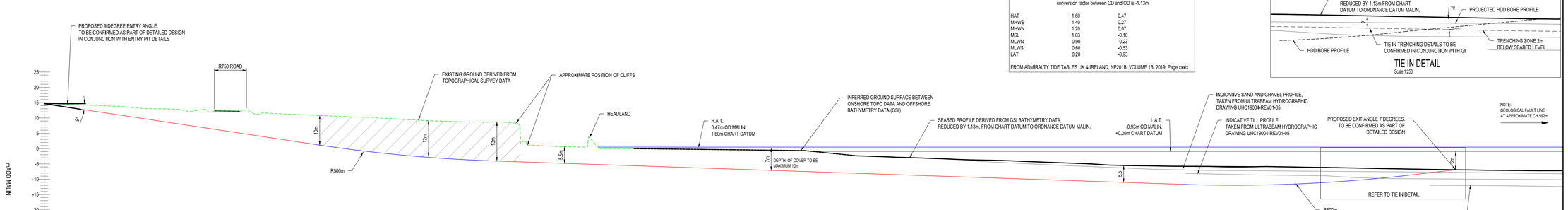
THE FOLLOWING ARE SIGNIFICANT RESIDUAL HAZARDS IDENTIFIED BY THE DESIGNER. TYPICAL HAZARDS THAT SHOULD BE IDENTIFIED BY A COMPETENT CONTRACTOR ARE NOT INCLUDED. THE CONTRACTOR SHALL CARRY OUT THE WORKS USING AN APPROVED SAFE SYSTEM OF WORK. FURTHER INFORMATION ON HAZARDS CAN BE FOUND IN THE DRA AND/OR CSM HAZARDS LOGO

REF	HAZARD	STAGE	MITIGATION MEASURES
HAZ001	WORKING AT HEIGHT	C D	CONTRACTOR TO HAVE SUITABLE MEASURES IN PLACE. DESIGNER OPTED FOR TRENCHLESS TECHNIQUE KEEPING WORKS AWAY FROM CLIFF
HAZ002	DROWNING	C D	OFFSHORE CONTRACTOR TO HAVE SUITABLE MEASURES IN PLACE. DESIGNER OPTED FOR TRENCHLESS TECHNIQUE KEEPING WORKS AWAY FROM CLIFF
HAZ003	LIVE TRAFFIC	C	TRAFFIC MANAGEMENT AGREED WITH ROAD AUTHORITY
HAZ004	EARTHWORKS / POLLUTION CONTROL	C	CONTRACTOR TO MONITOR WEATHER AND SEQUENCE WORKS ACCORDINGLY. CONTRACTOR TO WORK WITH ENVIRONMENTAL REGULATOR REQUIREMENTS. CONTRACTOR TO UNDERTAKE FULL SERVICES SURVEY PRIOR TO WORKS AND CAT SCAN ALL LOCATIONS

KEY:
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2. TOILET BLOCK 6M X 2M
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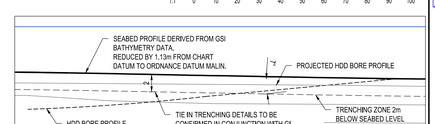
KEY:
- PROPOSED HDD ALIGNMENTS
- INDICATIVE TRANSITION JOINT BAY (25m x 5m x 1.2m)

1:1000 0 10m 20m 30m 40m 50m 60m 70m 80m 90m 100m
1:1 0 10 20 30 40 50 60 70 80 90 100



ARKLOW HARBOUR	Chart Datum (m CD)	Malin Head (m OD) conversion factor between CD and OD is -1.13m
HAT	1.60	0.47
MHWS	1.40	0.27
MHWN	1.20	0.07
MSL	1.03	-0.10
MLWN	0.90	-0.23
MLWS	0.60	-0.53
LAT	0.20	-0.93

FROM ADMIRALTY TIDE TABLES UK & IRELAND, NP201B, VOLUME 1B, 2019, Page xxxix



TIE IN DETAIL
Scale 1:250

| | | |

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

THE FOLLOWING ARE SIGNIFICANT RESIDUAL HAZARDS IDENTIFIED BY THE DESIGNER. TYPICAL HAZARDS THAT SHOULD BE IDENTIFIED BY A COMPETENT CONTRACTOR ARE NOT INCLUDED. THE CONTRACTOR SHALL CARRY OUT THE WORKS USING AN APPROVED SAFE SYSTEM OF WORK. FURTHER INFORMATION ON HAZARDS CAN BE FOUND IN THE DRA AND/OR CSM HAZARDS LOGO

REF	HAZARD	STAGE	MITIGATION MEASURES
HAZ001	WORKING AT HEIGHT	C D	CONTRACTOR TO HAVE SUITABLE MEASURES IN PLACE. DESIGNER OPTED FOR TRENCHLESS TECHNIQUE KEEPING WORKS AWAY FROM CLIFF
HAZ002	DROWNING	C D	OFFSHORE CONTRACTOR TO HAVE SUITABLE MEASURES IN PLACE. DESIGNER OPTED FOR TRENCHLESS TECHNIQUE KEEPING WORKS AWAY FROM CLIFF
HAZ003	LIVE TRAFFIC	C	TRAFFIC MANAGEMENT AGREED WITH ROAD AUTHORITY
HAZ004	EARTHWORKS / POLLUTION CONTROL	C	CONTRACTOR TO MONITOR WEATHER AND SEQUENCE WORKS ACCORDINGLY. CONTRACTOR TO WORK WITH ENVIRONMENTAL REGULATOR REQUIREMENTS. CONTRACTOR TO UNDERTAKE FULL SERVICES SURVEY PRIOR TO WORKS AND CAT SCAN ALL LOCATIONS

PRE-EXISTING FIELD ACCESS ROUTE

HAZARD 04

SURFACING OF TYPE A IN ACCORDANCE WITH CLAUSE 801 (TRANSPORT INFRASTRUCTURE IRELAND, SPECIFICATION FOR ROAD WORKS, SERIES 800 PLACED ON GEOTEXTILE

HDD CASING REQUIRED AND TEMPORARY PLATING REQUIRED OVER PROPOSED DRILL PATHS OR ALTERNATIVE ACCESS ROUTE USED

VEHICLE ACCESS

DESIGN TO CONSIDER HEAVE OR POTENTIAL SETTLEMENT OF ROAD

1:200 CROSSFALL TO COMPOUND

CAR PARKING AREA

PROPOSED ENTRY POINT
E: 727101m
N: 677153m

PROPOSED ENTRY POINT
E: 727102m
N: 677148m

HAZARD 03

SITE ENTRANCE BELLMOUTH FORMED TO L.A REQUIREMENTS

HDD SPACING 5m CENTRES AT ENTRY

STRINGING AREA IF REQUIRED (AIDED WITH STILTS AND ROLLERS) NOTE INTENTION IS TO PULL DUCT IN FROM OFFSHORE

70m

90m

HAZARD 01

TEMPORARY FOOTPRINT AREA = 6682m²
TEMPORARY WORKS SHOULD BE REINSTATED AS FAR AS PRACTICABLE, TO MINIMISE IMPACT

HAZARD 04

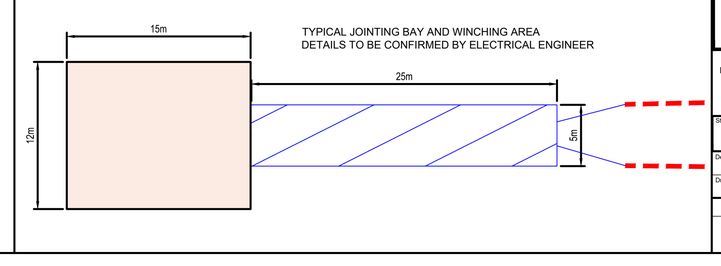
INDICATIVE ON-SHORE CABLE ROUTE
PRECISE ON SHORE CABLE ROUTE TBC

16.7

12.8

1:500 0 10m 20m 30m 40m 50m

1:1 0 10 20 30 40 50 60 70 80 90 100



TYPICAL JOINTING BAY AND WINCHING AREA
DETAILS TO BE CONFIRMED BY ELECTRICAL ENGINEER

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4. ALL WORK BY THE CONTRACTOR MUST BE CARRIED OUT IN SUCH A WAY THAT ALL REQUIREMENTS UNDER THE SAFTEY, HEALTH AND WELFARE AT WORK REGULATIONS (2013) ARE SATISFIED.
5. ALL WORK IS TO BE CARRIED OUT IN COMPLIANCE WITH THE REQUIREMENTS OF THE RELEVANT STATUTORY AUTHORITIES AND REGULATIONS.

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20. WORKSHOP 6M X 2M
21. STORES 6M X 2M

KEY:

PROPOSED HDD ALIGNMENTS

INDICATIVE TRANSITION JOINT BAY (25m x 5m x 1.2m)

Rev	Date	Description	By
P03	09.04.20	AMENDED FOLLOWING SSE COMMENTS. RE-ISSUED FOR INFORMATION	MC
P02	18.3.20	CABLE JUNCTION BOX GEOMETRY AMENDED.	MC
P01	17.03.20	FIRST ISSUE	MC

Amendments

Project
ARKLOW BANK WIND PARK PH2

Title
NORTHERN CABLE LANDFALL: SITE LAYOUT (CABLE ROUTE 1)

Client
SURE PARTNERS LTD

Broxden House Broxden Business Park Lamberkine Drive Perth PH1 1RA
t 01738 449 801
mail@watermangroup.com www.watermangroup.com

Status
PRELIMINARY

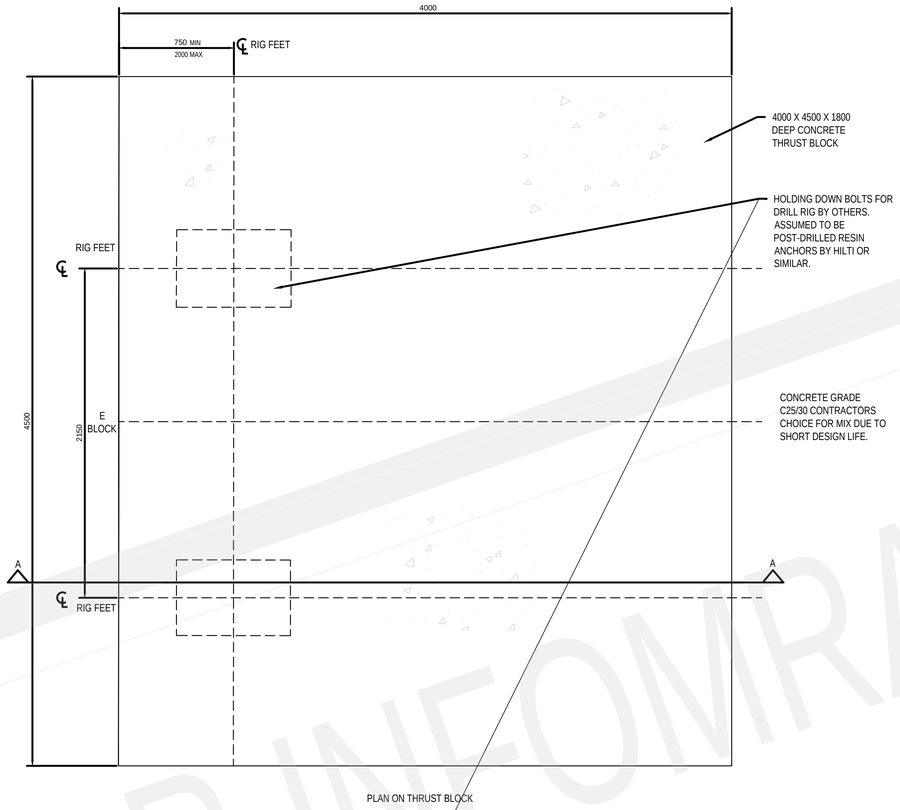
Designed By	Checked By	Waterman Ref
GA	CG	WIE16435
Drawn By	Date	Scales @ A1
MC	13.03.20	1:500

Project - Originator - Volume - Level - Type - Role - Number
LF100034-WIE-ZZ-XX-DR-C-90006

Revision
P03

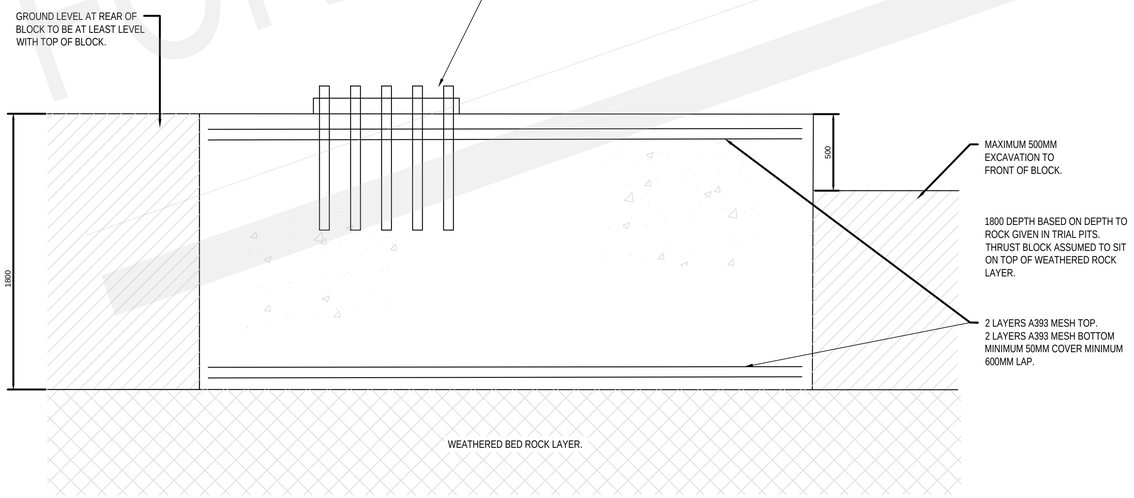
File Path
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A1-Wat-BS-S



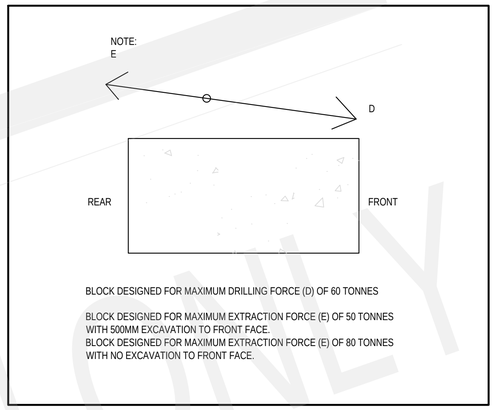
PLAN ON THRUST BLOCK

SCALE 1:20



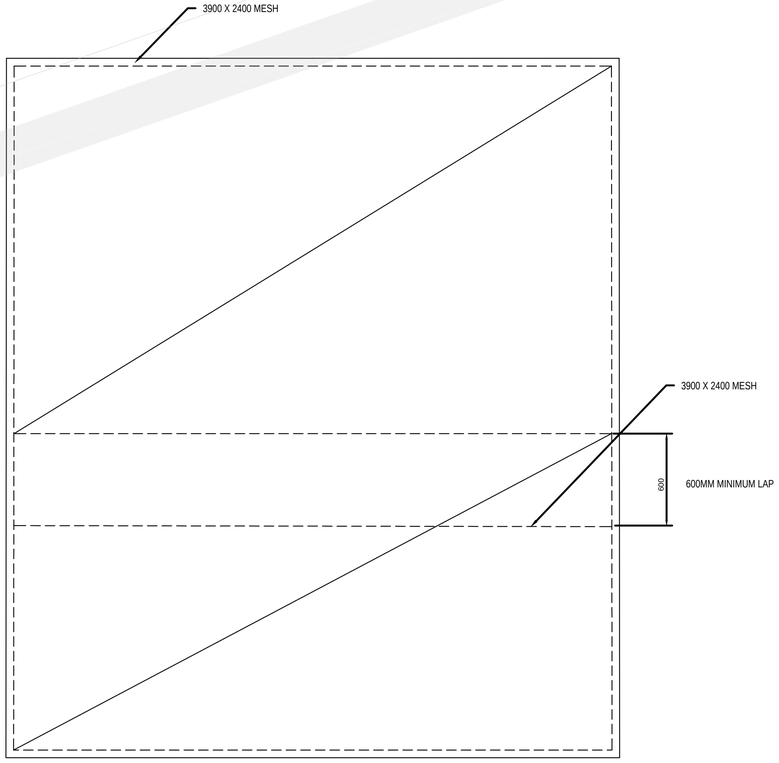
SECTION A-A

SCALE 1:20



BLOCK DESIGNED FOR MAXIMUM DRILLING FORCE (D) OF 60 TONNES

BLOCK DESIGNED FOR MAXIMUM EXTRACTION FORCE (E) OF 50 TONNES WITH 500MM EXCAVATION TO FRONT FACE.
BLOCK DESIGNED FOR MAXIMUM EXTRACTION FORCE (E) OF 80 TONNES WITH NO EXCAVATION TO FRONT FACE.



PLAN ON MESH REINFORCEMENT

SCALE 1:20

TOTAL = 8 NO. SHEETS 3900 X 2400MM A393 MESH

CONTRACTOR TO CONFIRM QUANTITIES

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Rev	Date	Description	By
P02	09.04.20	NOTES AMENDED. RE-ISSUED FOR INFORMATION	MC
P01	17.03.20	ISSUED FOR INFORMATION ONLY	LP

Amendments

Project

ARKLOW BANK WIND PARK PH2

Title

HDD ANCHOR BLOCK
TYPICAL ARRANGEMENT

Client

SURE PARTNERS LTD

Broxden House Broxden Business Park Lamberkine Drive Perth PH1 1RA
t: 01738 449 801
mail@watermangroup.com www.watermangroup.com

Suitability		
	INFORMATION	S2

Designed By	Checked By	Waterman Ref
AG	GA	WIE16435
Drawn By	**Date**	**Scales @ A1**
LP	MARCH 20	AS SHOWN

Project - Originator - Volume - Level - Type - Role - Number	Revision
LF100034-WIE-ZZ-ZZ-DR-C-90300	P02

File Path N:\Projects\WIE16435_Arklow_Phase2\1000\7_CAD\90\

A1-Wat-BS-S

FOR INFORMATION ONLY

Designers Risk Assessment

Project Title: Arklow Phase II Cable Landfall: **Northern Site** – Rev03 Project No: WIE16435-100 Date: 17th March 2020

Prepared By: L. Phin Checked By: G. Anton Approved By: C. Gell

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**LF100034-16435-100-WIE-ZZ-XX-DR-C-90001-P01 & LF100034-16435-100-WIE-ZZ-XX-DR-C-90002-P01**										
1	Falls from height – sea cliffs launch pits	Construction Maintenance	4	5	20	**Designer** has undertaken options appraisal and determined trenchless technique as the favored option. This keeps all works away from the cliff line, with dedicated entry compound to the west site of public road. Refer to Report	1 (a)	1	5	5	Contractor Client

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**LF100034-16435-100-WIE-ZZ-XX-DR-C-90001-P01 & LF100034-16435-100-WIE-ZZ-XX-DR-C-90002-P01**										
						LF100034-WIE16435-100-2-1-3-FS for details. Works in accordance with Part 4 “General Safety Provisions” **Contractor** to ensure clearly demarcated working areas and suitable fencing in place. **Client** to position access chambers for jointing bays at suitable location, which will most likely be within extents					

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**LF100034-16435-100-WIE-ZZ-XX-DR-C-90001-P01 & LF100034-16435-100-WIE-ZZ-XX-DR-C-90002-P01**										
						of temporary HDD compound.					
2	Drowning	Construction Maintenance	4	5	20	**Designer** has undertaken options appraisal and determined trenchless technique as the favored option. This minimizes operations in the marine environment for cable landfall, with the exception of punch out and duct pulling which will require support from	5	2	5	10	Contractor

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**LF100034-16435-100-WIE-ZZ-XX-DR-C-90001-P01 & LF100034-16435-100-WIE-ZZ-XX-DR-C-90002-P01**										
						offshore marine vessels / barges. Works in accordance with Part 10 "Construction Works on or Adjacent to Water" **Contractor** to undertake all offshore works in full accordance with all recognised safety standards and using suitably qualified staff. **Contractor** to undertake offshore support works					

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**LF100034-16435-100-WIE-ZZ-XX-DR-C-90001-P01 & LF100034-16435-100-WIE-ZZ-XX-DR-C-90002-P01**										
						during appropriate weather and sea conditions.					
3	Full or partial collapse of HDD borehole.	Construction	3	5	15	**Designer** has undertaken geotechnical desk study and site walkover survey to identify likely ground conditions and deemed HDD feasible with final design subject to Ground Investigation outputs. Works in accordance	1 (b)	1	5	5	Client Contractor

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**LF100034-16435-100-WIE-ZZ-XX-DR-C-90001-P01 & LF100034-16435-100-WIE-ZZ-XX-DR-C-90002-P01**										
						with Part 2 "Design & Management" **Client** to undertake campaign of onshore and nearshore ground investigation and provide factual data to Contractor. **Contractor** to undertake final design of HDD bores and select appropriate tooling for ground conditions proven.					
4	Hydro-Fracture ('Frac-Out') of drill fluids to the environment.	Construction	3	5	15	**Designer** has undertaken preliminary hydro-fracture		1	5	5	Client Contractor

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**LF100034-16435-100-WIE-ZZ-XX-DR-C-90001-P01 & LF100034-16435-100-WIE-ZZ-XX-DR-C-90002-P01**										
						calculations for conceptual HDD profile and determined that annular pressures are likely to be within acceptable limits on basis of assumed ground conditions. Works in accordance with Part 2 “Design & Management” **Client** to undertake campaign of onshore and nearshore ground investigation					

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
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						and provide factual data to Contractor. **Contractor** to undertake final design of HDD bores including final hydro-fracture calculations based on ground conditions proven. **Contractor** to select drill fluids which are self-flocculating and approved for use by Environmental Regulatory Authorities.					
5	Live roadway / conflict with site traffic.	Construction Maintenance	4	4	16	**Designer** has indicated Site Compound		1	4	4	Contractor Client

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**LF100034-16435-100-WIE-ZZ-XX-DR-C-90001-P01 & LF100034-16435-100-WIE-ZZ-XX-DR-C-90002-P01**										
						utilising existing field access point. Works in accordance with Part 4 "General Safety Provisions" **Client** to consider temporary or permanent upgrade to site access point including signage. **Client** to consider access requirements for future inspection / maintenance of jointing bays and					

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**LF100034-16435-100-WIE-ZZ-XX-DR-C-90001-P01 & LF100034-16435-100-WIE-ZZ-XX-DR-C-90002-P01**										
						allow for easement and demarcation of access manholes within final design of works. **Contractor** to implement all required Traffic Management measures during the works as per Local Roads Authority Requirements and Approvals.					
6	Earthworks excavation working adjacent to existing watercourse/drain.	Construction	4	4	16	**Designer:** Location of entry compound is set by HDD alignment	1 (b)	2	4	8	Contractor

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**LF100034-16435-100-WIE-ZZ-XX-DR-C-90001-P01 & LF100034-16435-100-WIE-ZZ-XX-DR-C-90002-P01**										
						which in turn is set by cable route as consented by client. Works in accordance with Part 5 "Excavations, Shafts, Earthworks, Underground Works and Tunnels" **Contractor** to monitor weather conditions and sequence works accordingly. **Contractor** to work in accordance with Environmenta					

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**LF100034-16435-100-WIE-ZZ-XX-DR-C-90001-P01 & LF100034-16435-100-WIE-ZZ-XX-DR-C-90002-P01**										
						l Regulator requirements.					
7	Moving drill rig plant / support vehicles through site - collision with workforce.	Construction	3	5	15	**Designer** Works in accordance with Part 4 "General Safety Provisions" **Contractor** to employ safe systems of works including use of segregated walkways and reverse parking.		1	5	5	Contractor
8	Earthworks excavation and replacement: Services recorded and unrecorded.	Construction	3	5	15	**Designer** has undertaken statutory authority searches and presented outputs with Report		1	5	5	Contractor Client

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**LF100034-16435-100-WIE-ZZ-XX-DR-C-90001-P01 & LF100034-16435-100-WIE-ZZ-XX-DR-C-90002-P01**										
						LF100034-WIE16435-100-2-1-3-FS. Works in accordance with Part 5 "Excavations, Shafts, Earthworks, Underground Works and Tunnels" **Client** to provide contractor with up to date service plans (less than 3 months old) at time of construction. **Contractor** to undertake full services survey prior to works to					

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**LF100034-16435-100-WIE-ZZ-XX-DR-C-90001-P01 & LF100034-16435-100-WIE-ZZ-XX-DR-C-90002-P01**										
						verify information shown on plans. **Contractor** to scan all excavation locations prior to breaking ground.					
9	Waste/ rubbish potentially feeding rats leading to Leptospirosis	Construction	2	5	10	**Designer** Works in accordance with Part 5 "Excavations, Shafts, Earthworks, Underground Works and Tunnels" **Contractor** to ensure safe systems of works such as: appropriate PPE,		1	5	5	Contractor

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**LF100034-16435-100-WIE-ZZ-XX-DR-C-90001-P01 & LF100034-16435-100-WIE-ZZ-XX-DR-C-90002-P01**										
						minimizing exposure, hand washing and covering cuts etc.					

Quantification

Likelihood	*1 = Highly Unlikely*	*2 = Unlikely*	*3 = Likely*	*4 = Highly Likely*	*5 = Certainty*
Severity	*1 = Property Damage*	*2 = Minor Injury (medical assistance required)*	*3 = Short Term Absence (< 3 days)*	*4 = Long Term Injury (> 3 days)*	*5 = Fatality*

Risk Rating *(Severity x Likelihood)*	1–4 = Acceptable	5–9 = Low	10–14 = Medium	15–19 = High	20–25 = Unacceptable

F. Concept Design Drawings and DRA Southern Landfall



SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

THE FOLLOWING ARE SIGNIFICANT RESIDUAL HAZARDS IDENTIFIED BY THE DESIGNER. TYPICAL HAZARDS THAT SHOULD BE IDENTIFIED BY A COMPETENT CONTRACTOR ARE NOT INCLUDED. THE CONTRACTOR SHALL CARRY OUT THE WORKS USING AN APPROVED SAFE SYSTEM OF WORK. FURTHER INFORMATION ON HAZARDS CAN BE FOUND IN THE DRA AND/OR CSM HAZARDS LOGO

REF	HAZARD	STAGE	MITIGATION MEASURES
HAZ001	EXIT POINT DROWNING	C D	OFFSHORE CONTRACTOR TO HAVE SUITABLE MEASURES IN PLACE. DESIGNER OPTED FOR TRENCHLESS TECHNIQUE KEEPING WORKS AWAY FROM CLIFF
HAZ002	EARTHWORKS / DRILLING IN PUBLIC PLACE	C D	CONTRACTOR TO MONITOR WEATHER AND SEQUENCE WORKS ACCORDINGLY. CONTRACTOR TO WORK WITH ENVIRONMENTAL REGULATOR REQUIREMENTS. CONTRACTOR TO UNDERTAKE FULL SERVICES SURVEY PRIOR TO WORKS AND CAT SCAN ALL LOCATIONS
HAZ003	FALL FROM HEIGHT	C	CONTRACTOR TO HAVE SUITABLE MEASURES IN PLACE. DESIGNER OPTED FOR TRENCHLESS TECHNIQUE KEEPING WORKS AWAY FROM CLIFF
HAZ004	LIVE TRAFFIC	C	TRAFFIC MANAGEMENT AGREED WITH ROAD AUTHORITY
HAZ005	SERVICES	C	CONTRACTOR TO MONITOR WEATHER AND SEQUENCE WORKS ACCORDINGLY. CONTRACTOR TO WORK WITH ENVIRONMENTAL REGULATOR REQUIREMENTS. CONTRACTOR TO UNDERTAKE FULL SERVICES SURVEY PRIOR TO WORKS AND CAT SCAN ALL LOCATIONS
HAZ006	EARTHWORKS STABILITY LAUNCH PIT	C	CONTRACTOR TO MONITOR WEATHER AND SEQUENCE WORKS ACCORDINGLY. CONTRACTOR TO WORK WITH ENVIRONMENTAL REGULATOR REQUIREMENTS. CONTRACTOR TO UNDERTAKE FULL SERVICES SURVEY PRIOR TO WORKS AND CAT SCAN ALL LOCATIONS
HAZ007	INTERFACE WITH OUTFALL PIPE	C	CONTRACTOR TO MONITOR PROGRESS OF OUTFALL PIPE INSTALLATION AND LIAISE WITH RELEVANT AUTHORITY DURING CONSTRUCTION

This drawing should not be scaled. Dimensions to be verified on site.
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2) DRAWING IS NOT FOR CONSTRUCTION, AND PRESENTS A CONCEPTUAL DESIGN ONLY
3) THE CO-ORDINATE REFERENCE SYSTEM USED IN THE DRAWING IS ORDNANCE SURVEY (IRELAND) IRISH GRID, WITH A VERTICAL DATUM TO MALIN HEAD.
4) SITE SPECIFIC BATHYMETRICAL SURVEYS WOULD BE RECOMMENDED AS PART OF DESIGN DEVELOPMENT.
5) ON-SHORE AND NEARSHORE INTRUSIVE GROUND INVESTIGATION WILL BE REQUIRED IN ORDER TO CONFIRM GROUND CONDITIONS AND ALLOW FINALISATION OF DESIGN PROFILE.
6) DEPENDANT ON OVERBURDEN THICKNESS AT ENTRY POINT, TO BE CONFIRMED BY GROUND INVESTIGATION, A REINFORCED CONCRETE HDD RIG ANCHOR BLOCK MAY BE REQUIRED.
7) ALL WORK IS TO BE CARRIED OUT IN COMPLIANCE WITH THE REQUIREMENTS OF THE RELEVANT STATUTORY AUTHORITIES AND REGULATIONS NOTING THAT ENVIRONMENTAL LICENSES AND APPROVALS MAY BE REQUIRED.
8) COMPOUND LAYOUT INDICATIVE + SUBJECT TO INDIVIDUAL CONTRACT REQUIREMENTS.
9) MAPPING IMAGERY TAKEN FROM BING MAPS.

KEY:
1. ACTIVE TANK 7x2m
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3. GENERATOR 2x2m
4. FLOCULATION TANK 2x5m
5. MUD LAB 2x3m
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21. GENERATOR 2x2m
22. OPERATION CABIN 6x2m
23. GENERATOR

INDICATIVE TRANSITION JOINT BAY(25m x 5m x 1.2m)

ARKLOW_SOUTHERN SITE - LONGSECTION
SCALE: H 1:1000,V 1:200. DATUM: -20.000

ARKLOW HARBOUR	Chart Datum (m CD)	Malin Head (m OD) conversion factor between CD and OD is -1.13m
HAT	1.60	0.47
MHWS	1.40	0.27
MHWN	1.20	0.07
MSL	1.03	-0.10
MLWN	0.90	-0.23
MLWS	0.60	-0.53
LAT	0.20	-0.93

FROM ADMIRALTY TIDE TABLES UK & IRELAND, NP201B, VOLUME 1B, 2019, Page xxxix

Rev	Date	Description	By
P04	09.04.20	AMENDED FOLLOWING SSE COMMENTS. RE-ISSUED FOR INFORMATION	MC
P03	17.03.20	LAUNCH PIT AMENDED. RE-ISSUED FOR INFORMATION	MC
P02	24.02.20	DRAWING AMENDED FOLLOWING SSE COMMENTS. DRAWING NUMBER CHANGED TO SUIT SSE REFERENCE	MC
P01	31.01.20	FIRST ISSUE	MC

Amendments

1:1000 0 10m 20m 30m 40m 50m 60m 70m 80m 90m 100m
1:1 0 10 20 30 40 50 60 70 80 90 100

Project: ARKLOW BANK WIND PARK PH2

Title: SOUTHERN CABLE LANDFALL: CONCEPTUAL DIRECT PIPE PLAN & SECTION (CABLE ROUTE 1)

Client: SURE PARTNERS LTD

Waterman
Broxden House Broxden Business Park Lamberkine Drive Perth PH1 1RA
t 01738 449 801
mail@watermangroup.com www.watermangroup.com

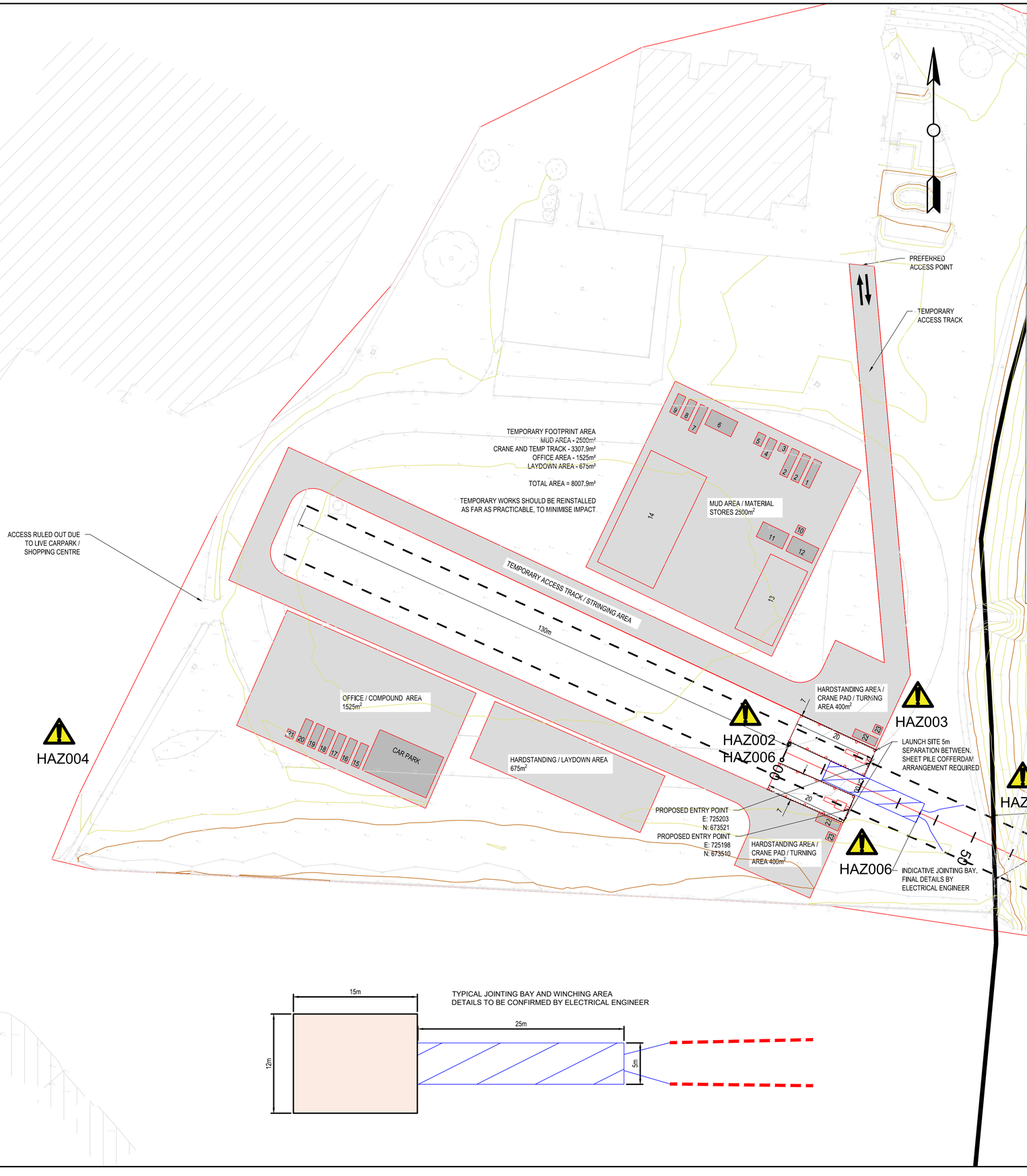
Status: PRELIMINARY

Designed By	GA	Checked By	CG	Waterman Ref	WIE16435
Drawn By	MC	Date	31.01.20	Scales @ A0	1:1000

Project - Originator - Volume - Level - Type - Role - Number: LF100034-WIE-ZZ-XX-DR-C-90003
Revision: P04

A0-Wat-BS-S

File Path: N:\Projects\WIE16435_ARklw_Phase2\006_Design\02\TECH\



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22. OPERATION CABIN 6x2m
23. GENERATOR

INDICATIVE TRANSITION JOINT BAY(25m x 5m x 1.2m)

Rev	Date	Description	By
P04	09.04.20	AMENDED FOLLOWING SSE COMMENTS. RE-ISSUED FOR INFORMATION	MC
P03	17.03.20	CABLE JUNCTION AND WINCHING AREA DETAIL ADDED. RE-ISSUED FOR INFORMATION	MC
P02	24.02.20	DRAWING AMENDED FOLLOWING SSE COMMENTS. DRAWING NUMBER CHANGED TO SUIT SSE REFERENCE	MC
P01	31.01.20	FIRST ISSUE	MC

Amendments

Project: ARKLOW BANK WIND PARK PH2

Title: SOUTHERN CABLE LANDFALL: SITE LAYOUT (CABLE ROUTE 1)

Client: SURE PARTNERS

Broxden House Broxden Business Park Lamberkine Drive Perth PH1 1RA
t:01738 449 801
mail@watermangroup.com www.watermangroup.com

Status: PRELIMINARY

Designed By	Checked By	Waterman Ref
GA	CG	WIE16435
Drawn By	Date	Scales @ A1
MC	31.01.20	1:500

Project - Originator - Volume - Level - Type - Role - Number: LF100034-WIE-ZZ-XX-DR-C-90004

Revision: P04

File Path: N:\Projects\WIE16435_Arklow_Phase2\10\6_Design\GEOTECH\

A1-Wat-BS-S

Designers Risk Assessment

Project Title: Arklow Phase II Cable Landfall: **Southern Site**_Rev03 Project No: WIE16435-100 Date: 17th March 2020

Prepared By: L. Phin Checked By: G. Anton Approved By: C. Gell

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
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1	Drowning	Construction Maintenance	4	5	20	**Designer** has undertaken options appraisal and determined trenchless technique as the favored option. This minimizes operations in the marine environment for cable landfall, with the exception of reception pit and duct pulling which will require	5	2	5	10	Contractor

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**16435-100-WIE-ZZ-XX-DR-C-90003-P01 & 16435-100-WIE-ZZ-XX-DR-C-90004-P01**										
						support from offshore marine vessels / barges. Works in accordance with Part 10 "Construction Works on or Adjacent to Water" **Contractor** to undertake all offshore works in full accordance with all recognised safety standards and using suitably qualified staff. **Contractor** to undertake offshore support works during					

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
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						appropriate weather and sea conditions.					
2	Earthworks & Direct Pipe Operations positioned within an area of public space	Construction Maintenance	4	5	20	**Designer:** Launch area for Direct Pipe is set largely by need to intersect consented cable route, whilst maximising area for stringing out casing behind the launch pit. **Contractor** to delineate Launch Pit Area and Site Compound by	6	1	5	5	Contractor Client

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
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						using appropriate security measures and demarcation to separate public from all working areas. Works in accordance with Part 5 “Excavations, Shafts, Earthworks, Underground Works and Tunnels” **Contractor** to identify access route and place appropriate signage with demarcated access route for site vehicles /					

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**16435-100-WIE-ZZ-XX-DR-C-90003-P01 & 16435-100-WIE-ZZ-XX-DR-C-90004-P01**										
						segregation from public areas. **Contractor** to ensure any plant/ vehicle movement shall be carried out only under the control of a banksman. **Client** to seek all required approvals from Local Authority / Relevant Stakeholders.					
3	Fall from height	Construction	3	5	15	**Contractor** to ensure that launch pits are suitably fenced off. Designer Works in accordance	1	1	5	5	Contractor

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**16435-100-WIE-ZZ-XX-DR-C-90003-P01 & 16435-100-WIE-ZZ-XX-DR-C-90004-P01**										
						with Part 4 "General Safety Provisions"					
4	Full or partial collapse of trencheless borehole.	Construction	3	5	15	**Designer** has undertaken geotechnical desk study and site walkover survey to identify likely ground conditions and deemed Direct Pipe as feasible with final design subject to Ground Investigation outputs. Works in	6	1	5	5	Client Contractor

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**16435-100-WIE-ZZ-XX-DR-C-90003-P01 & 16435-100-WIE-ZZ-XX-DR-C-90004-P01**										
						accordance with Part 2 "Design & Management" **Client** to undertake campaign of onshore and nearshore ground investigation and provide factual data to Contractor. **Contractor** to undertake final design cable landfall / Direct Pipe and select appropriate tooling for ground conditions proven.					

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**16435-100-WIE-ZZ-XX-DR-C-90003-P01 & 16435-100-WIE-ZZ-XX-DR-C-90004-P01**										
5	Hydro-Fracture ('Frac-Out') of drill fluids to the environment.	Construction	3	5	15	**Designer** has specified use of Direct Pipe which cases drill hole as works advanced providing mitigation of frac-out risk. Works in accordance with Part 2 "Design & Management" **Client** to undertake campaign of onshore and nearshore ground investigation and provide factual data to Contractor. **Contractor** to	6	1	5	5	Client Contractor

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**16435-100-WIE-ZZ-XX-DR-C-90003-P01 & 16435-100-WIE-ZZ-XX-DR-C-90004-P01**										
						select lubricants which are self-flocculating and approved for use by Environmental Regulatory Authorities.					
6	Live roadway / conflict with site traffic.	Construction Maintenance	4	4	16	**Designer** has indicated Site Compound utilising existing access point. Works in accordance with Part 4 "General Safety Provisions" **Client** to consider temporary or permanent upgrade to site access point		1	4	4	Contractor Client

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**16435-100-WIE-ZZ-XX-DR-C-90003-P01 & 16435-100-WIE-ZZ-XX-DR-C-90004-P01**										
						including signage. **Client** to consider access requirements for future inspection / maintenance of jointing bays and allow for easement and demarcation of access manholes within final design of works. **Contractor** to implement all required Traffic Management measures during the works as per Local Roads					

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**16435-100-WIE-ZZ-XX-DR-C-90003-P01 & 16435-100-WIE-ZZ-XX-DR-C-90004-P01**										
						Authority Requirements and Approvals.					
7	Earthworks excavation: stability of launch pit.	Construction	4	4	16	**Designer** has indicated sheet piling for launch pit. Works in accordance with Part 5 “Excavations, Shafts, Earthworks, Underground Works and Tunnels” **Client** to undertake campaign of ground investigation to confirm ground conditions at proposed launch pit location.	1 (b)	2	4	8	Client Contractor

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**16435-100-WIE-ZZ-XX-DR-C-90003-P01 & 16435-100-WIE-ZZ-XX-DR-C-90004-P01**										
						Contractor to assess temporary works requirements and complete design by approved temporary works designer.					
8	Moving drill rig plant / support vehicles through site - collision with workforce.	Construction	3	5	15	**Contractor** to employ safe systems of works including use of segregated walkways and reverse parking. **Designer** Works in accordance with Part 4 “General Safety Provisions”		1	5	5	Contractor

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**16435-100-WIE-ZZ-XX-DR-C-90003-P01 & 16435-100-WIE-ZZ-XX-DR-C-90004-P01**										
9	Earthworks excavation and replacement: Services recorded and unrecorded.	Construction	3	5	15	**Designer** has undertaken statutory authority searches and presented outputs with Report WIE16435-100-2-1-3-FS. Works in accordance with Part 5 "Excavations, Shafts, Earthworks, Underground Works and Tunnels" **Designer** has based Direct Pipe alignment on basis of passing below existing Arklow Phase 1 HV export cable		1	5	5	Contractor Client

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**16435-100-WIE-ZZ-XX-DR-C-90003-P01 & 16435-100-WIE-ZZ-XX-DR-C-90004-P01**										
						for an assumed cable depth of maximum 1.2m bgl. **Client** to confirm actual depth of Arklow Phase 1 HV export cable, through commissioning of further surveys if required. **Client** to provide contractor with up to date service plans (less than 3 months old) at time of construction. **Contractor** to undertake full services					

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**16435-100-WIE-ZZ-XX-DR-C-90003-P01 & 16435-100-WIE-ZZ-XX-DR-C-90004-P01**										
						survey prior to works to verify information shown on plans. **Contractor** to scan all excavation locations prior to breaking ground.					
9	Waste/ rubbish potentially feeding rats leading to Leptospirosis being passed to workforce.	Construction	2	5	10	**Designer** Works in accordance with Part 9 “General Health Hazards” **Contractor** to ensure safe systems of works such as: appropriate PPE, minimizing exposure, hand washing		1	5	5	Contractor

Hazard No.	Hazard *Potential to cause harm*	Phase *Construction/ Operation/ Maintenance*	Occurrence Likelihood	Likely Severity	Risk Rating	Action of Designer & remaining actions on Client / Contractor	Safety, Health & Welfare at Work (Construction) Regulations 2013, Schedule 1 Reference No.	Residual Occurrence Likelihood	Residual Likely Severity	Residual Risk Rating	Remaining Action Responsibility
Reference Drawings:	**16435-100-WIE-ZZ-XX-DR-C-90003-P01 & 16435-100-WIE-ZZ-XX-DR-C-90004-P01**										
						and covering cuts etc.					

Quantification

Likelihood	*1 = Highly Unlikely*	*2 = Unlikely*	*3 = Likely*	*4 = Highly Likely*	*5 = Certainty*
Severity	*1 = Property Damage*	*2 = Minor Injury (medical assistance required)*	*3 = Short Term Absence (< 3 days)*	*4 = Long Term Injury (> 3 days)*	*5 = Fatality*

Risk Rating *(Severity x Likelihood)*	1–4 = Acceptable	5–9 = Low	10–14 = Medium	15–19 = High	20–25 = Unacceptable

G. Calculations

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman		WIE16435	
	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall)	**Prepared**	**Date**
		LP	30-Jan-20
		Checked	**Date**
		RB	31-Jan-20

This spreadsheet makes extensive use of named cells and custom functions. This enables the calculation cells to be displayed as equations with meaningful variable names rather than the normal Excel cell references. Also, the values that have been used in the calculation are shown above the result.

In order to cope with the large number of named cells, the naming convention is of necessity fairly cryptic - but there is some method to it. This particularly applies to the repetitive calculations relating to each section of the pipe.

Thus for section specific variables the the section name is added as a suffix - eg **Lc**, **Lf** are the **L**engths of sections '**C**' and '**F**' respectively. And similarly **Hyc** and **Hyf** are the Hydrokinetic forces. Where there is a need to make a distinction between the **s**tart and **e**nd of a section then additional suffixes '**s**' and '**e**' are appended to the variable name. There are similar variations on this theme.

Input Data: Constants and Global Variables

Constants

Pi	π	3.142	
Gravity	g	9.81	m/s/s
Eulers Number	e	2.7182	
One metre Head of Water	Hw	0.009804	N/mm^2

Pipe Geometry

Pipe outside diameter	δ0	266	mm	**Do**	**0.266**	**m**
Pipe wall thickness	t =	133	mm			
Pipe inside diameter	δi =	δ0 - 2*t		**Di**	**0.000**	**m**
	=	266 - 2*133				
	=	0.00	mm			
Pipe X-sect (outer)	Ao =	INT(π * δ0^2 / 4)		**Aom**	**5.5571E-02**	**m^2**
	=	INT(3.142 * 266^2 / 4)				
	=	55571.0	mm^2			
Pipe X-sect (inner)	Ai =	INT(π * δi^2 / 4)		**Aim**	**0.0000E+00**	**m^2**
	=	INT(3.142 * 0^2 / 4)				
	=	0.0	mm^2			
Pipe wall X-sect area	Ap =	INT(π * (δ0^2 - δi^2) / 4)		**Apm**	**5.5571E-02**	**m^2**
	=	INT(3.142 * (266^2 - 0^2) / 4)				
	=	55571.0	mm^2			
Minimum radius of curvature	R =	836*δ0 / 1000				
	=	836*266 / 1000				
	=	**222 m**				

Modelling Soild Section

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman		WIE16435	
	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall)	**Prepared**	**Date**
		LP	30-Jan-20
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Densities

Density of fresh water	ρw	1000	kg/m^3
Density of sea water	ρsea	1025	kg/m^3
Density of drilling mud	ρm	1300	kg/m^3

Friction Factors

Between cable and soil — CFpr = 0.4 — ***Assumed value***

Buoyancy factors

Mass of cable — Mp= **139.0** **kg/m**

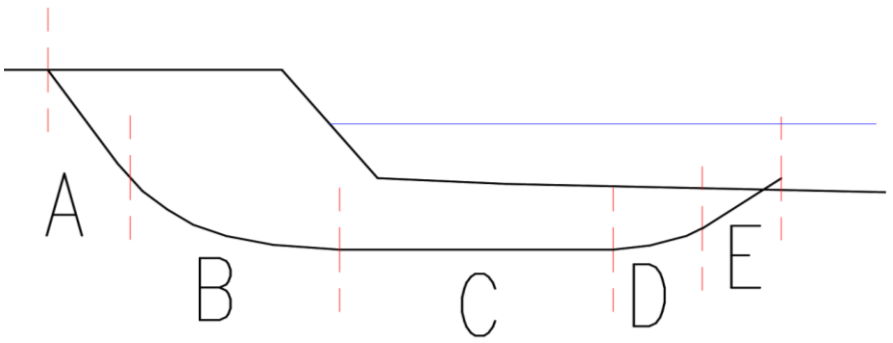
Mass of cable in air as specified by Nexans

waterman	***Spreadsheet Calcpad*** *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	**Project** WIE16435
	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall)	**Prepared** LP 30-Jan-20 **Checked** RB 31-Jan-20

Pipe Centre Line Profile

	A	A:B	B:C	C:D	D:E	E		
Ch	0.00	92.00	180.00	293.00	351.00	365.00		
mOD	14.53	-1.86	-10.43	-11.23	-8.45	-7.09		
Radius		500		500				
Slope	-10.32		-0.42		6.2			

Dimensions and levels are taken from CAD drawing



Summary Results

The general arrangement of the HDD borehole geometry is shown in the figure above. The analysis of the forces and combined stress during the cable pull will consider each section of the profile in order to identify the most critical portion. It is assumed that the maximum pulling force will be just as the cable reaches full insertion.

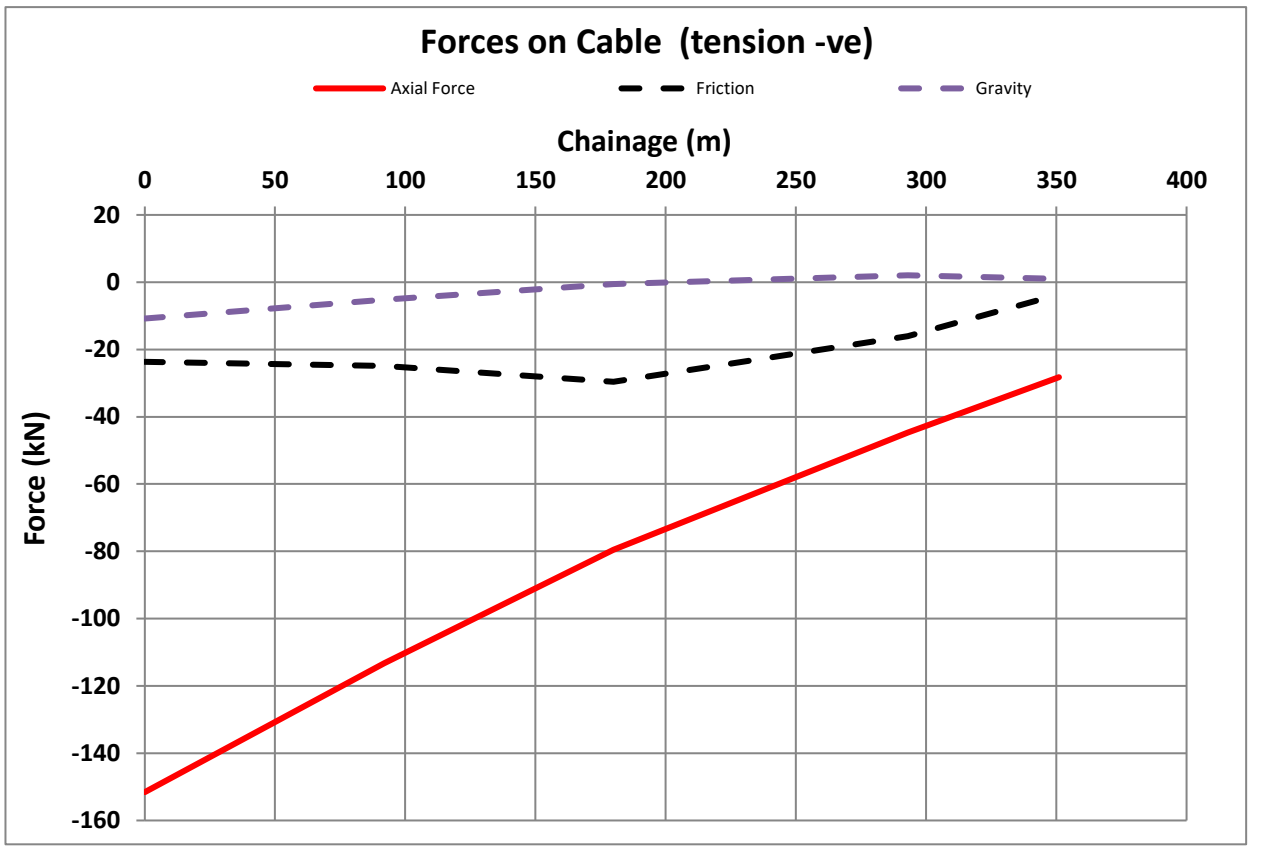
Sign Convention:

Axial Tensile Force: -ve	Axial Compressive Force: +ve
Tensile Stress -ve	Compressive Stress +ve
Weight (gravity) +ve	Buoyancy (uplift) -ve

waterman	***Spreadsheet Calcpad*** *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	**Project** WIE16435
	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall)	**Prepared** LP / **Date** 30-Jan-20 **Checked** RB / **Date** 31-Jan-20

Table of Cable Forces (kN)

Section	Length (m)	Chng (m)	Friction Comp	Hydro Comp	Gravity Comp	Axial Force
A	92	0.00	-23.71	-3.84	-10.79	-151.58
B	88	92.00	-24.87	-3.68	-5.18	-113.23
C	113	180.00	-29.60	-4.72	-0.54	-79.51
D	58	293.00	-16.03	-2.42	2.05	-44.64
E	14	351.00	-3.65	-0.58	0.99	-28.24



Section E - Straight Inclined

This is a straight section and the stresses in the pipe arise from tensile (pulling) forces and radial forces acting

Length of Section	Le	14.00	m	
Slope of Section	θe	6.2	deg	0.108 radian
Pipe CL datum (start)		-7.09	mOD	
Pipe CL datum (end)		-8.45	mOD	

Friction force (tensile)

Fre = -ABS(CFpr * Le * ((Mp+Mw-Mm) * COS(θe))) * g / 1000
= -ABS(0.4 * 365 * ((139+0-72.2) * COS(0))) * 9.81 / 1000
= **-3.65 kN**

Gravity component

Gre = (Le * (Mp + Mw - Mm) * SIN(θe)) * g /1000
= (365 * (139 + 0 - 72.2) * SIN(0)) * 9.81 /1000
= **0.99 kN**

Bouyancy is resisting by pushing back this section

Aggregate the axial forces local to this section at the start and end of the section

Axial force section start

Faes = **-25.00 kN**

Tethering force depends on sea conditions. Nominal value of 25kN assumed.

Increment for section

dFae = Fre + Hye + Gre
= -95.61 + -15.25 + 0
= **-3.24 kN**

Axial force section end

Faee = Faes + dFae
= -25 + -110.87
= **-28.24 kN**

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman		WIE16435	
	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall)	**Prepared**	**Date**
		LP	30-Jan-20
		Checked	**Date**
		RB	31-Jan-20

Section D - Vertical curve

This is a curved section as the pipe transitions from an incline to horizontal. This induces some forces that are additional to that of a straight section. These additional effects arise from the 'capstan' force required to move the pipe around a curve and the additional normal force and to bending the pipe.

Radius of curvature	Rdc	500.00	m	
Angle of curvature	θdc	6.2	deg	0.10821 radians
Length of Section	Ld	58.00	m	
Average Slope of Section	θd	3.1	deg	0.054 radians
Pipe CL datum (start)		-8.45	mOD	
Pipe CL datum (end)		-11.23	mOD	

Check on curve length

Ldc = ABS(Rdc * θdc)
= 54.11 m ***(Compared to profile figure of 58m)*** *Not used - check only*

Check change in elevation

Hdc = Rdc * (1 - COS(θdc))
= 0 * (1 - COS(0))
= 2.92 m ***(Compared to profile figure of 2.78m)*** *Not used - check only*

Capstan factor

CapFacd = EulerN^(CFpr *ABS(θdc))
= 2.7182^(0.4 *ABS(0))
= 1.044 ***(Increase the pipe pull by this factor)***

Check additional normal force of pipe against borehole due to bending. This will add to the calculation of the friction force. Conservative approach is to consider deflection then determine UDL loading necessary to cause that deflection. Consider both simply supported and fully fixed ends.

Assumed deflection at midpoint

Defdm = Rdc * (1 - COS(θdc / 2))
= 0 * (1 - COS(0 / 2))
= **0.73 m**

Total UDL equivalent Simply supported ends

Ndss = Defdm * (384 * Em * Im) * Ld / (5 * Ld^4) / 1000
= 0 * (384 * 800000000 * 0.00024575) * 0 / (5 * 0^4) / 1000
= **0.06 kN**

Pipe confined within the borehole so consider loading as UDL for SS and FF end cases.
Note the UDL is multiplied by length to give total load.

Total UDL equivalent Fully fixed ends

Ndfe = Defdm * (384 * Em * Im) * Ld / (Ld^4) / 1000
= 0 * (384 * 800000000 * 0.00024575) * 0 / (0^4) / 1000
= **0.28 kN**

Weighted UDL

Nd = (Ndss + Ndff) / 3 * 2
= (+) / 3 * 2
= **0.23 kN**

Friction forces (tensile) as if straight pipe

Frdl = -ABS(CFpr * (Ld * (Mp+Mw-Mm) * COS(θd)) * g/1000)
= -ABS(0.4 * (0 * (139+0-72.2) * COS(0)) * 9.81/1000)
= **-15.17 kN**

Friction forces (tensile) due to bending.

Frdc = -ABS(CFpr * 2 * Nd * COS(θd))
= -ABS(0.4 * 2 * 0.4 * COS(0))
= **-0.181 kN**

Note that in the above calculations the frictional force due to curvature is 1.19 percent of the linear friction force.

Determine the capstan effect force. It could be argued that considering additional normal force for friction and capstan force is double counting the effect of curvature, but probably not.

Capstan effect increased tension force

Cad = (CapFacd - 1) * (Frdl + Frdc)
(1 - 1) * (0 + 0)
-0.68 kN

Gravity component

Grd = (Ld * Mpb * SIN(θd)) * g /1000
= (0 * 66.76 * SIN(0)) * 9.81 /1000
= **2.05 kN**

Bouyancy is resisting by pushing back this section

Aggregate the axial forces local to this section at the start and end of the section. Note horizontal lay out length reduces as pipe pulled in.

Axial force section start

Fads = Faee
= -135.87
= **-28.24 kN**

Increment for section

dFad = Frdl + Frdc + Cad + Hyd + Grd
= 0 + 0 + 0 + 0 + 0
= **-16.40 kN**

Axial force section end

Fade = Fads + dFad
= -135.87 + -135.87
= **-44.64 kN**

Section C - Straight Inclinded

This is a straight section and the stresses in the pipe arise from pulling forces and radial forces acting on the circumfrence of the pipe. The borehole is filled with bentonite and the pipe may contain ballast water.

Length of Section	Lc	113.00	m	
Slope of Section	θc	-0.42	deg	-0.007 radian
Pipe CL datum (start)		-11.23	mOD	
Pipe CL datum (end)		-10.43	mOD	

Friction forces (tensile)

Frc = -ABS(CFpr * Lc * ((Mp+Mw-Mm) * COS(θc))) * g / 1000
= -ABS(0.4 * 0 * ((139+0-72.2) * COS(0))) * 9.81 / 1000
= **-29.60 kN**

Gravity component

Grc = (Lc * Mpb * SIN(θc)) * g /1000
= (0 * 66.76 * SIN(0)) * 9.81 /1000
= **-0.54 kN**

Aggregate the axial forces local to this section at the start and end of the section.

Axial force section start

Facs = Fade
=
-44.64 kN

Increment for section

dFac = Frc + Hyc + Grc
= 0 + 0 + 0
= **-34.86 kN**

Axial force section end

Face = Facs + dFac
= + 0
= **-79.51 kN**

Section B - Vertical curve

This is a curved section as the pipe transitions from an incline to horizontal. This induces some forces that are additional to that of a straight section. These additional effects arise from the 'capstan' force required to move the pipe around a curve and the additional normal force and to bending the pipe.

Radius of curvature	Rbc	500.00	m	
Angle of curvature	θbc	-10.32	deg	-0.180 radians
Length of Section	Lb	88.00	m	
Average Slope of Section	θb	-5.16	deg	-0.090 radians
Pipe CL datum (start)		-10.43	mOD	
Pipe CL datum (end)		-1.86	mOD	

Check on curve length

Lbc = ABS(Rbc * θbc)
= 90.06 m ***(Compared to profile figure of 88.00m)*** *Not used - check only*

Check change in elevation

Hbc = Rbc * (1 - COS(θbc))
= 0 * (1 - COS(0))
= 8.09 m ***(Compared to profile figure of -8.58m)*** *Not used - check only*

Capstan factor

CapFacb = EulerN^(CFpr *ABS(θbc))
= 2.7182^(0.4 *ABS(0))
= 1.075 ***(Increase the pipe pull by this factor)***

Check additional normal force of pipe against borehole due to bending. This will add to the calculation of the friction force. Conservative approach is to consider deflection then determine UDL loading necessary to cause that deflection. Consider both simply supported and fully fixed ends.

Assumed deflection at midpoint

Defbm = Rbc * (1 - COS(θbc / 2))
= 0 * (1 - COS(0 / 2))
= **2.03 m**

Total UDL equivalent Simply supported ends

Nbss = Defdm * (384 * Em * Im) * Ld / (5 * Ld^4) / 1000
= 0 * (384 * 800000000 * 0.00024575) * 0 / (5 * 0^4) / 1000
= **0.06 kN**

Total UDL equivalent Fully fixed ends

Nbff = Defdm * (384 * Em * Im) * Ld / (Ld^4) / 1000
= 0 * (384 * 800000000 * 0.00024575) * 0 / (0^4) / 1000
= **0.28 kN**

Weighted UDL

Nb = (Nbss + Nbff) / 3 * 2
= (+) / 3 * 2
= **0.23 kN**

Friction forces (tensile) as if straight pipe

Frbl = -ABS(CFpr * (Lb * (Mp+Mw-Mm) * COS(θb)) * g/1000)
= -ABS(0.4 * (0 * (139+0-72.2) * COS(0)) * 9.81/1000)
= **-22.96 kN**

Friction forces (tensile) due to bending.

Frbc = -ABS(CFpr * 2 * Nb * COS(θb))
= -ABS(0.4 * 2 * 0.4 * COS(0))
= **-0.18 kN**

Note that in the above calculations the frictional force due to curvature is 0.7 percent of the linear friction force.

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman		WIE16435	
	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall)	**Prepared**	**Date**
		LP	30-Jan-20
		Checked	**Date**
		RB	31-Jan-20

Determine the capstan effect force. It could be argued that considering additional normal force for friction and capstan force is double counting the effect of curvature, but probably not.

Capstan effect increased tension force

Cab = (CapFacb - 1) * (Frbl + Frbc)
(1 - 1) * (0 + 0)
-1.73 kN

Gravity component

Grb = (Lb * (Mp+Mw-Mm) * SIN(θb)) * g /1000
= (0 * (139+0-72.2) * SIN(0)) * 9.81 /1000
= **-5.18 kN**

Bouyancy is assisting by raising this section

Aggregate the axial forces local to this section at the start and end of the section. Note horizontal lay out length reduces as pipe pulled in.

Axial force section start

Fabs = Face
=
-79.51 kN

Increment for section

dFab = Frbl + Frbc + Cab + Hyb + Grb
= 0 + 0 + 0 + 0 + 0
= **-33.73 kN**

Axial force section end

Fabe = Fabs +dFab
= +
= **-113.23 kN**

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman		WIE16435	
	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall)	**Prepared**	**Date**
		LP	30-Jan-20
		Checked	**Date**
		RB	31-Jan-20

Section A - Straight Inclined

This is a straight section and the stresses in the pipe arise from tensile (pulling) forces and radial forces acting on the circumfrence of the pipe. Assume the bore hole is filled with bentonite.

Length of Section	La	92.00	m	
Slope of Section	θa	-10.32	deg	-0.180 radian
Pipe CL datum (start)		-1.86	mOD	
Pipe CL datum (end)		14.53	mOD	

Friction forces (tensile)

Fra = -ABS(CFpr * La * ((Mp+Mw-Mm) * COS(θa))) * g / 1000
= -ABS(0.4 * 0 * ((139+0-72.2) * COS(0))) * 9.81 / 1000
= **-23.71 kN**

Gravity component

Gra = (La * (Mp+Mw-Mm) * SIN(θa)) * g /1000
= (0 * (139+0-72.2) * SIN(0)) * 9.81 /1000
= **-10.79 kN**

Exit end of borehole lower than entry, so static mud level may not reach surface at 'A'. However, on pull back mud will be pushed ahead, so assume buoyant...

Aggregate the axial forces local to this section at the start and end of the section. Note horizontal lay out length reduces as pipe pulled in. (By end of this section the pipe is fully inserted.)

Axial force section start

Faas = Fabe
=
-113.23 kN

Increment for section

dFaa = Fra + Hya + Gra
= 0 + 0 + 0
= **-38.35 kN**

Axial force section end

Faae = Faas + dFaa
= + 0
= **-151.58 kN**

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman		WIE16435	
	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall, Option 2)	**Prepared**	**Date**
		LP	17-Mar-20
		Checked	**Date**
		CG	17-Mar-20

This spreadsheet makes extensive use of named cells and custom functions. This enables the calculation cells to be displayed as equations with meaningful variable names rather than the normal Excel cell references. Also, the values that have been used in the calculation are shown above the result.

In order to cope with the large number of named cells, the naming convention is of necessity fairly cryptic - but there is some method to it. This particularly applies to the repetitive calculations relating to each section of the pipe.

Thus for section specific variables the the section name is added as a suffix - eg **Lc**, **Lf** are the **L**engths of sections '**C**' and '**F**' respectively. And similarly **Hyc** and **Hyf** are the Hydrokinetic forces. Where there is a need to make a distinction between the **s**tart and **e**nd of a section then additional suffixes '**s**' and '**e**' are appended to the variable name. There are similar variations on this theme.

Input Data: Constants and Global Variables

Constants

Pi	π	3.142	
Gravity	g	9.81	m/s/s
Eulers Number	e	2.7182	
One metre Head of Water	Hw	0.009804	N/mm^2

Pipe Geometry

Pipe outside diameter	δ0	266	mm	**Do**	**0.266**	**m**
Pipe wall thickness	t =	133	mm			

Modelling Soild Section

Pipe inside diameter

δi = δ0 - 2*t
= 266 - 2*133
= 0.00 mm

Di **0.000** **m**

Pipe X-sect (outer)

Ao = INT(π * δ0^2 / 4)
= INT(3.142 * 266^2 / 4)
= 55571.0 mm^2

Aom **5.5571E-02** **m^2**

Pipe X-sect (inner)

Ai = INT(π * δi^2 / 4)
= INT(3.142 * 0^2 / 4)
= 0.0 mm^2

Aim **0.0000E+00** **m^2**

Pipe wall X-sect area

Ap = INT(π * (δ0^2 - δi^2) / 4)
= INT(3.142 * (266^2 - 0^2) / 4)
= 55571.0 mm^2

Apm **5.5571E-02** **m^2**

Minimum radius of curvature

R = 836*δ0 / 1000
= 836*266 / 1000
= **222 m**

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman		WIE16435	
	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall, Option 2)	**Prepared**	**Date**
		LP	17-Mar-20
		Checked	**Date**
		CG	17-Mar-20

Densities

Density of fresh water	ρw	1000	kg/m^3
Density of sea water	ρsea	1025	kg/m^3
Density of drilling mud	ρm	1300	kg/m^3

Friction Factors

Between cable and soil CFpr 0.4 ***Assumed value***

Buoyancy factors

Mass of cable Mp= **139.0** **kg/m**

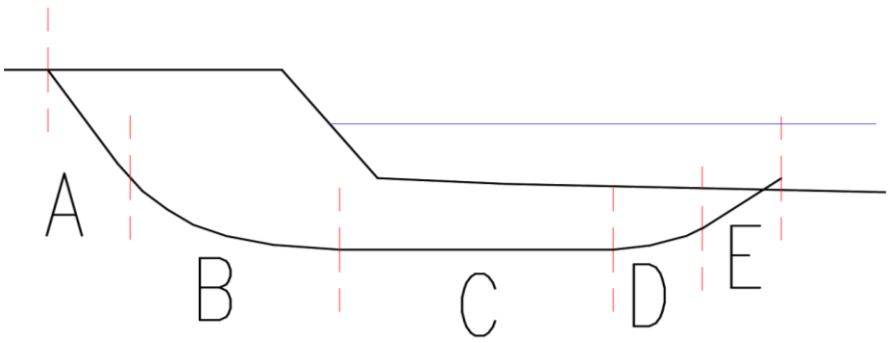
Mass of cable in air as specified by Nexans

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall, Option 2)	WIE16435	
		Prepared	**Date**
		LP	17-Mar-20
		Checked	**Date**
		CG	17-Mar-20

Pipe Centre Line Profile

	A	A:B	B:C	C:D	D:E	E		
Ch	0.00	86.00	149.00	378.00	439.00	462.00		
mOD	14.67	1.00	-4.30	-10.90	-9.00	-6.91		
Radius		500		500				
Slope	-8.76		-1.63		5.29			

Dimensions and levels are taken from CAD drawing



Summary Results

The general arrangement of the HDD borehole geometry is shown in the figure above. The analysis of the forces and combined stress during the cable pull will consider each section of the profile in order to identify the most critical portion. It is assumed that the maximum pulling force will be just as the cable reaches full insertion.

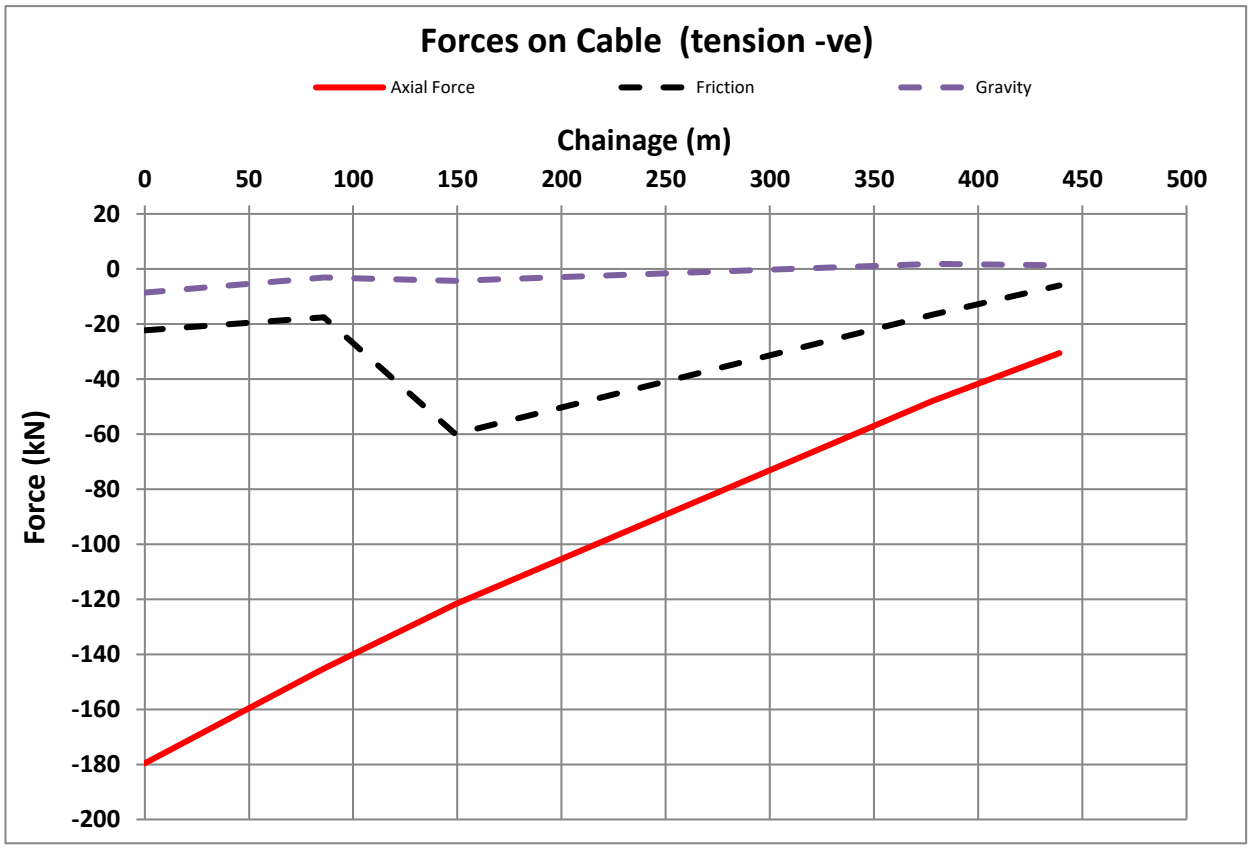
Sign Convention:

Axial Tensile Force: -ve	Axial Compressive Force: +ve
Tensile Stress -ve	Compressive Stress +ve
Weight (gravity) +ve	Buoyancy (uplift) -ve

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall, Option 2)	WIE16435	
		Prepared	**Date**
		LP	17-Mar-20
		Checked	**Date**
		CG	17-Mar-20

Table of Cable Forces (kN)

Section	Length (m)	Chng (m)	Friction Comp	Hydro Comp	Gravity Comp	Axial Force
A	86	0.00	-22.27	-3.59	-8.58	-179.59
B	63	86.00	-17.61	-2.63	-3.15	-145.15
C	229	149.00	-59.96	-9.57	-4.27	-121.76
D	61	378.00	-16.68	-2.55	1.84	-47.96
E	23	439.00	-6.00	-0.96	1.39	-30.57



Section E - Straight Inclined

This is a straight section and the stresses in the pipe arise from tensile (pulling) forces and radial forces acting

Length of Section	Le	23.00	m	
Slope of Section	θe	5.29	deg	0.092 radian
Pipe CL datum (start)		-6.91	mOD	
Pipe CL datum (end)		-9.00	mOD	

Friction force (tensile)

Fre = -ABS(CFpr * Le * ((Mp+Mw-Mm) * COS(θe))) * g / 1000
= -ABS(0.4 * 23 * ((139+0-72.2) * COS(0.092))) * 9.81 / 1000
= **-6.00 kN**

Gravity component

Gre = (Le * (Mp + Mw - Mm) * SIN(θe)) * g /1000
= (23 * (139 + 0 - 72.2) * SIN(0.092)) * 9.81 /1000
= **1.39 kN**

Bouyancy is resisting by pushing back this section

Aggregate the axial forces local to this section at the start and end of the section

Axial force section start

Faes = **-25.00 kN**

Tethering force depends on sea conditions. Nominal value of 25kN assumed.

Increment for section

dFae = Fre + Hye + Gre
= -6 + -0.96 + 1.39
= **-5.57 kN**

Axial force section end

Faee = Faes + dFae
= -25 + -5.57
= **-30.57 kN**

Section D - Vertical curve

This is a curved section as the pipe transitions from an incline to horizontal. This induces some forces that are additional to that of a straight section. These additional effects arise from the 'capstan' force required to move the pipe around a curve and the additional normal force and to bending the pipe.

Radius of curvature	Rdc	500.00	m	
Angle of curvature	θdc	5.29	deg	0.09233 radians
Length of Section	Ld	61.00	m	
Average Slope of Section	θd	2.645	deg	0.046 radians
Pipe CL datum (start)		-9.00	mOD	
Pipe CL datum (end)		-10.90	mOD	

Check on curve length

Ldc = ABS(Rdc * θdc)
= 46.16 m ***(Compared to profile figure of 61m)*** *Not used - check only*

Check change in elevation

Hdc = Rdc * (1 - COS(θdc))
= 500 * (1 - COS(0.09233))
= 2.13 m ***(Compared to profile figure of 1.90m)*** *Not used - check only*

Capstan factor

CapFacd = EulerN^(CFpr *ABS(θdc))
= 2.7182^(0.4 *ABS(0.09233))
= 1.038 ***(Increase the pipe pull by this factor)***

Check additional normal force of pipe against borehole due to bending. This will add to the calculation of the friction force. Conservative approach is to consider deflection then determine UDL loading necessary to cause that deflection. Consider both simply supported and fully fixed ends.

Assumed deflection at midpoint

Defdm = Rdc * (1 - COS(θdc / 2))
= 500 * (1 - COS(0.09233 / 2))
= **0.53 m**

Total UDL equivalent Simply supported ends

Ndss = Defdm * (384 * Em * Im) * Ld / (5 * Ld^4) / 1000
= 0.53 * (384 * 800000000 * 0.00024575) * 61 / (5 * 61^4) / 1000
= **0.04 kN**

Pipe confined within the borehole so consider loading as UDL for SS and FF end cases.
Note the UDL is multiplied by length to give total load.

Total UDL equivalent Fully fixed ends

Ndfe = Defdm * (384 * Em * Im) * Ld / (Ld^4) / 1000
= 0.53 * (384 * 800000000 * 0.00024575) * 61 / (61^4) / 1000
= **0.18 kN**

Weighted UDL

Nd = (Ndss + Ndff) / 3 * 2
= (0.04 + 0.18) / 3 * 2
= **0.14 kN**

Friction forces (tensile) as if straight pipe

Frdl = -ABS(CFpr * (Ld * (Mp+Mw-Mm) * COS(θd)) * g/1000)
= -ABS(0.4 * (61 * (139+0-72.2) * COS(0.046)) * 9.81/1000)
= **-15.96 kN**

Friction forces (tensile) due to bending.

Frdc = -ABS(CFpr * 2 * Nd * COS(θd))
= -ABS(0.4 * 2 * 0.14 * COS(0.046))
= **-0.113 kN**

Note that in the above calculations the frictional force due to curvature is 0.7 percent of the linear friction force.

Determine the capstan effect force. It could be argued that considering additional normal force for friction and capstan force is double counting the effect of curvature, but probably not.

Capstan effect increased tension force

Cad = (CapFacd - 1) * (Frdl + Frdc)
(1.038 - 1) * (-15.96 + -0.113)
-0.60 kN

Gravity component

Grd = (Ld * Mpb * SIN(θd)) * g /1000
= (61 * 66.76 * SIN(0.046)) * 9.81 /1000
= **1.84 kN**

Bouyancy is resisting by pushing back this section

Aggregate the axial forces local to this section at the start and end of the section. Note horizontal lay out length reduces as pipe pulled in.

Axial force section start

Fads = Faee
= -30.57
= **-30.57 kN**

Increment for section

dFad = Frdl + Frdc + Cad + Hyd + Grd
= -15.96 + -0.113 + -0.6 + -2.55 + 1.84
= **-17.39 kN**

Axial force section end

Fade = Fads + dFad
= -30.57 + -17.39
= **-47.96 kN**

Section C - Straight Inclinded

This is a straight section and the stresses in the pipe arise from pulling forces and radial forces acting on the circumfrence of the pipe. The borehole is filled with bentonite and the pipe may contain ballast water.

Length of Section	Lc	229.00	m	
Slope of Section	θc	-1.63	deg	-0.028 radian
Pipe CL datum (start)		-10.90	mOD	
Pipe CL datum (end)		-4.30	mOD	

Friction forces (tensile)

Frc = -ABS(CFpr * Lc * ((Mp+Mw-Mm) * COS(θc))) * g / 1000
= -ABS(0.4 * 229 * ((139+0-72.2) * COS(-0.028))) * 9.81 / 1000
= **-59.96 kN**

Gravity component

Grc = (Lc * Mpb * SIN(θc)) * g /1000
= (229 * 66.76 * SIN(-0.028)) * 9.81 /1000
= **-4.27 kN**

Aggregate the axial forces local to this section at the start and end of the section.

Axial force section start

Facs = Fade
= -47.96
-47.96 kN

Increment for section

dFac = Frc + Hyc + Grc
= -59.96 + -9.57 + -4.27
= **-73.80 kN**

Axial force section end

Face = Facs + dFac
= -47.96 + -73.8
= **-121.76 kN**

Section B - Vertical curve

This is a curved section as the pipe transitions from an incline to horizontal. This induces some forces that are additional to that of a straight section. These additional effects arise from the 'capstan' force required to move the pipe around a curve and the additional normal force and to bending the pipe.

Radius of curvature	Rbc	500.00	m	
Angle of curvature	θbc	-8.76	deg	-0.153 radians
Length of Section	Lb	63.00	m	
Average Slope of Section	θb	-4.38	deg	-0.076 radians
Pipe CL datum (start)		-4.30	mOD	
Pipe CL datum (end)		1.00	mOD	

Check on curve length

Lbc = ABS(Rbc * θbc)
= 76.45 m ***(Compared to profile figure of 63.00m)*** *Not used - check only*

Check change in elevation

Hbc = Rbc * (1 - COS(θbc))
= 500 * (1 - COS(-0.153))
= 5.83 m ***(Compared to profile figure of -5.30m)*** *Not used - check only*

Capstan factor

CapFacb = EulerN^(CFpr *ABS(θbc))
= 2.7182^(0.4 *ABS(-0.153))
= 1.063 ***(Increase the pipe pull by this factor)***

Check additional normal force of pipe against borehole due to bending. This will add to the calculation of the friction force. Conservative approach is to consider deflection then determine UDL loading necessary to cause that deflection. Consider both simply supported and fully fixed ends.

Assumed deflection at midpoint

Defbm = Rbc * (1 - COS(θbc / 2))
= 500 * (1 - COS(-0.153 / 2))
= **1.46 m**

Total UDL equivalent Simply supported ends

Nbss = Defdm * (384 * Em * Im) * Ld / (5 * Ld^4) / 1000
= 0.53 * (384 * 800000000 * 0.00024575) * 61 / (5 * 61^4) /
= **0.04 kN**

Total UDL equivalent Fully fixed ends

Nbff = Defdm * (384 * Em * Im) * Ld / (Ld^4) / 1000
= 0.53 * (384 * 800000000 * 0.00024575) * 61 / (61^4) / 1000
= **0.18 kN**

Weighted UDL

Nb = (Nbss + Nbff) / 3 * 2
= (0.04 + 0.18) / 3 * 2
= **0.14 kN**

Friction forces (tensile) as if straight pipe

Frbl = -ABS(CFpr * (Lb * (Mp+Mw-Mm) * COS(θb)) * g/1000)
= -ABS(0.4 * (63 * (139+0-72.2) * COS(-0.076)) * 9.81/1000)
= **-16.46 kN**

Friction forces (tensile) due to bending.

Frbc = -ABS(CFpr * 2 * Nb * COS(θb))
= -ABS(0.4 * 2 * 0.14 * COS(-0.076))
= **-0.11 kN**

Note that in the above calculations the frictional force due to curvature is 0.6 percent of the linear friction force.

Determine the capstan effect force. It could be argued that considering additional normal force for friction and capstan force is double counting the effect of curvature, but probably not.

Capstan effect increased tension force

Cab = (CapFacb - 1) * (Frbl + Frbc)
(1.063 - 1) * (-16.46 + -0.11)
-1.04 kN

Gravity component

Grb = (Lb * (Mp+Mw-Mm) * SIN(θb)) * g /1000
= (63 * (139+0-72.2) * SIN(-0.076)) * 9.81 /1000
= **-3.15 kN**

Bouyancy is assisting by raising this section

Aggregate the axial forces local to this section at the start and end of the section. Note horizontal lay out length reduces as pipe pulled in.

Axial force section start

Fabs = Face
= -121.76
-121.76 kN

Increment for section

dFab = Frbl + Frbc + Cab + Hyb + Grb
= -16.46 + -0.11 + -1.04 + -2.63 + -3.15
= **-23.40 kN**

Axial force section end

Fabe = Fabs +dFab
= -121.76 +-23.4
= **-145.15 kN**

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman		WIE16435	
	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall, Option 2)	**Prepared**	**Date**
		LP	17-Mar-20
		Checked	**Date**
		CG	17-Mar-20

Section A - Straight Inclined

This is a straight section and the stresses in the pipe arise from tensile (pulling) forces and radial forces acting on the circumfrence of the pipe. Assume the bore hole is filled with bentonite.

Length of Section	La	86.00	m	
Slope of Section	θa	-8.76	deg	-0.153 radian
Pipe CL datum (start)		1.00	mOD	
Pipe CL datum (end)		14.67	mOD	

Friction forces (tensile)

Fra = -ABS(CFpr * La * ((Mp+Mw-Mm) * COS(θa))) * g / 1000
= -ABS(0.4 * 86 * ((139+0-72.2) * COS(-0.153))) * 9.81 / 1000
= **-22.27 kN**

Gravity component

Gra = (La * (Mp+Mw-Mm) * SIN(θa)) * g /1000
= (86 * (139+0-72.2) * SIN(-0.153)) * 9.81 /1000
= **-8.58 kN**

Exit end of borehole lower than entry, so static mud level may not reach surface at 'A'. However, on pull back mud will be pushed ahead, so assume buoyant...

Aggregate the axial forces local to this section at the start and end of the section. Note horizontal lay out length reduces as pipe pulled in. (By end of this section the pipe is fully inserted.)

Axial force section start

Faas = Fabe
= -145.15
-145.15 kN

Increment for section

dFaa = Fra + Hya + Gra
= -22.27 + -3.59 + -8.58
= **-34.44 kN**

Axial force section end

Faae = Faas + dFaa
= -145.15 + -34.44
= **-179.59 kN**

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman		WIE16435	
	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall)	**Prepared**	**Date**
		LP	29-Jan-20
		Checked	**Date**
		RB	31-Jan-20

Hydrofracture - Longitudinal Profile Check

The model is based on axial symetry around the borehole and the following four conditions apply: Equilibrium, Hooke's Law of elastic deformation, Mohr-Coulomb's failure criterion and absence of isotropic deformation in the plastic zone. This gives rise to a fairly complex set of expressions as shown below.

$$Pmax = Pemax + U$$ *Eqn(1)*

$$Pemax = (Pf + c.cot\emptyset).\left\{\left(\frac{Ro}{Rpmax}\right)^2 + Q\right\}^{\frac{-sin\emptyset}{1+sin\emptyset}} - c.cot\emptyset$$ *Eqn(2)*

$$Q = \frac{(\sigma o.sin\emptyset + c.cos\emptyset)}{G}$$ *Eqn(3)*

$$Pf = \sigma o\,(1 + sin\emptyset) + c.cos\emptyset$$ *Eqn(4)*

$$G = \frac{E}{2}\,(1 + \vartheta)$$ *Eqn(5)*

Where:

Pmax	maximum allowable mud pressure
U	initial in-situ pore pressure
Pemax	maximum allowable effective mud pressure
σ_o	initial effective stress
ϕ	internal angle of friction
c	cohesion
Ro	internal radius of borehole
Rpmax	maximum allowable radius of plastic zone
G	shear modulus
E	elasticity modulus
N	Poisson's ratio

Only enter data into green highlight cells. Other cells may contain calculations and editing them will over-write the formula.

General variables

Gravity (m/s/s):	**g**	9.81		
Density of water (kg/m3):	**ɣw**	1000		
Density of drilling mud (kg/m3):	**ɣm**	1300		
Soil density (kg/m^3):	**ɣs**	2200		*Soil characteristic values are all assumed and should be confirmed by Intrusive Ground Investigation.*
Cohesion (kN/m^2):	**Coh**	50		
Friction angle (deg):	**Φ**	36	Radians Φr = 0.62832	
Poission's ratio :	**v**	0.35		
Elasticity modulus (kPa):	**Emod**	50000		
Shear modulus (kPa):	Gmod =	18519		
Product pipe OD (m):				
Drill bit diameter (inch):		44.00 inch	**Do** 1.118 m	
Drill pipe OD (inch):		11.00 inch	**Di** 0.279 m	
Initial radius of borehole (m):	**Ro**	0.559	*Equal half drill bit diameter*	*Rpmax usually assumed between 1/2 and 2/3 depth, assumed 1/2 as worst case scenario*
Allowable plastic radius factor	**Rpmax**	0.50		
Consider lateral soil pressure:	**No**		***Use drop-down to select Y/N***	
Passive coefficient **ko** =	IF(Y_N = "Yes", 1 - SIN(Φr), 0)			*Conservative to not consider lateral soil pressures*
=	IF(Y_N = "Yes", 1 - SIN(Φr), 0)			
=	**0**			

Annular pressure calculations

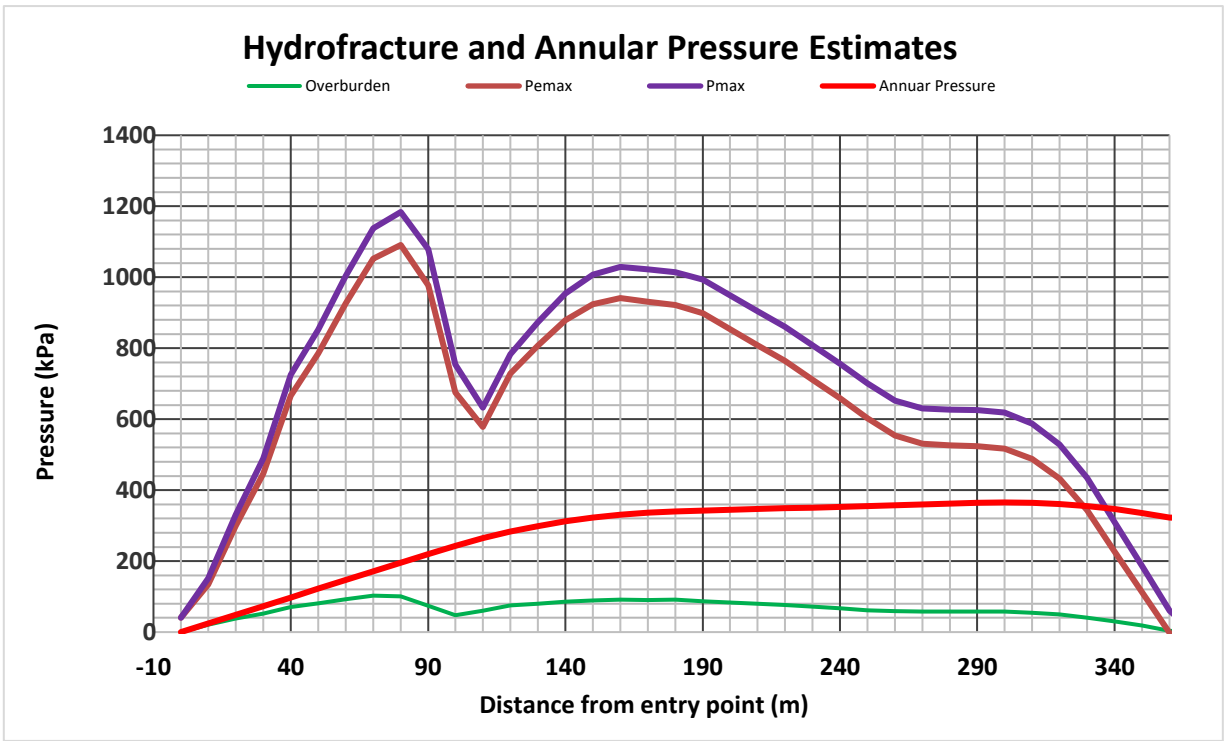
Darcy Weisbach equation for flow in an annulus is: H = f(L/Dh)(V^2/2g), where Dh is the hydraulic diameter, V the flow velocity, L flow pipe length and f is a friction factor. In the case of co-centered circular pipes Dh = Do - Di. The exact drilling operational parameters, such as flow rate are unknown, but some estimated values have been applied - but require verification. The total head is the flow head plus the static head.

Assumed flow velocity (m/s):	V	0.50
Assumed friction coefficient:	f	8.00

The calculations at each chainage location are performed in the fract-out table

Summary Figures

Elevation of entrance hole mOD =	**14.53 mOD**		
Elevation of exit hole mOD =	**-7.09 mOD**	***Diff =***	***21.62*** m
Maximum cover to HDD borehole =	**10.4 m**		
Maximum overburden pressure =	**102.7 kN/m^2**		***1.0 Bar***
Maximum safe effective stress **Pemax** =	**1091 kN/m^2**		***10.9 Bar***
Maximum safe stress **Pmax** =	**1184 kN/m^3**		***11.8 Bar***



Expressions used in hydrofracture calculations

In the tabulation below the following functions are applied

Saturated Layer **Sat'd**: IF (WTL<=HDD, Elevn-HDD, Max(Elevn-WTL, 0))

Bouyant Layer **Bou't**: IF (WTL<=HDD, 0, Min(WTL-HDD, Elevn-HDD))

σv = (ɣs*Satd+(ɣs-ɣw)*Bout)*g/1000

σo = SQRT((ɣs*Satd+(ɣs-ɣw)*Bout)^2 + (ko * (ɣs*Satd + (ɣs-ɣw)*Bout))^2))

Q = (σo*SIN(Φr) + Coh*COS(Φr)) / Gmod

Pf = (σo * (1+SIN(Φr))) + (Coh * COS(Φr))

Pemax = (Pf + Coh*COT(Φr)) * (((Ro/Rpmax)^2 + Q)^(-SIN(Φr)/(1+SIN(Φr)))) - Coh*COT(Φr)

Pelim = (Pf + Coh*COT(Φr)) * (Q^(-SIN(Φr)/(1+SIN(Φr)))) - Coh*COT(Φr)

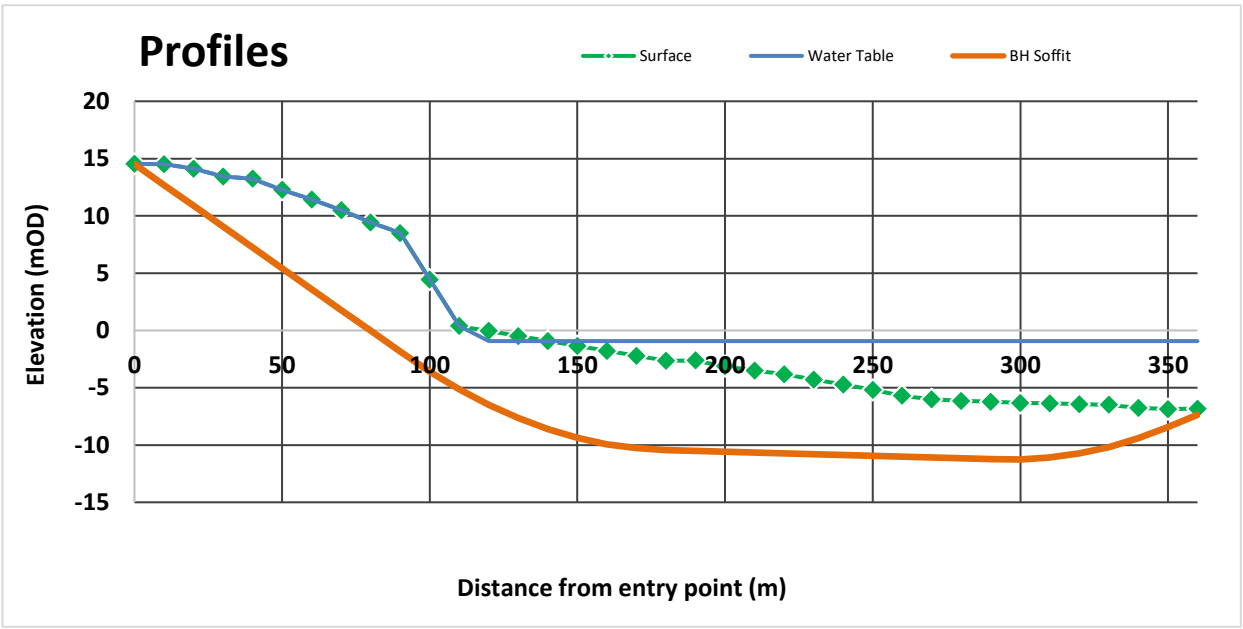
		LAT	
WT controls:	**0**	**-0.93**	

Dist (m)	Elev'n (mOD)	Loc'n	WTL (mOD)	C-Line (mOD)	Soffit (mOD)	Cover (m)	Sat'd (m)	Bou't (m)	U kN/m2	Hs kN/m3
0.00	14.53		14.53		14.53	0.00	0.00	0.00	***0***	***0***
10.00	14.51		14.51		12.71	1.80	0.00	1.80	***18***	***23***
20.00	14.11		14.11		10.89	3.23	0.00	3.23	***32***	***46***
30.00	13.45		13.45		9.07	4.38	0.00	4.38	***43***	***70***
40.00	13.24		13.24		7.24	6.00	0.00	6.00	***59***	***93***
50.00	12.27		12.27		5.42	6.85	0.00	6.85	***67***	***116***
60.00	11.44		11.44		3.60	7.84	0.00	7.84	***77***	***139***
70.00	10.51		10.51		1.78	8.72	0.00	8.72	***86***	***162***
80.00	9.44		9.44		-0.04	9.47	0.00	8.54	***93***	***186***
90.00	8.51		8.51		-1.86	10.36	0.00	6.31	***102***	***209***
100.00	4.46		4.46		-3.61	8.06	0.00	3.99	***79***	***231***
110.00	0.39		0.39		-5.16	5.54	0.00	5.11	***54***	***251***
120.00	-0.05	sea	-0.93		-6.51	6.47	0.45	5.58	***55***	***268***
130.00	-0.48	sea	-0.93		-7.67	7.19	0.02	6.74	***66***	***283***
140.00	-0.91	sea	-0.93		-8.62	7.71	0.00	7.28	***75***	***295***
150.00	-1.34	sea	-0.93		-9.37	8.03	0.00	7.60	***83***	***305***
160.00	-1.78	sea	-0.93		-9.92	8.15	0.00	7.72	***88***	***312***
170.00	-2.21	sea	-0.93		-10.28	8.07	0.00	7.64	***92***	***316***
180.00	-2.64	sea	-0.93		-10.43	7.79	0.00	7.81	***93***	***318***
190.00	-2.62	sea	-0.93		-10.50	7.88	0.00	7.38	***94***	***319***
200.00	-3.13	sea	-0.93		-10.58	7.45	0.00	7.09	***95***	***320***
210.00	-3.49	sea	-0.93		-10.65	7.16	0.00	6.83	***95***	***321***
220.00	-3.82	sea	-0.93		-10.72	6.90	0.00	6.45	***96***	***322***
230.00	-4.28	sea	-0.93		-10.80	6.52	0.00	6.07	***97***	***323***
240.00	-4.73	sea	-0.93		-10.87	6.14	0.00	5.69	***97***	***324***
250.00	-5.18	sea	-0.93		-10.94	5.76	0.00	5.24	***98***	***325***
260.00	-5.70	sea	-0.93		-11.01	5.31	0.00	5.00	***99***	***326***
270.00	-6.02	sea	-0.93		-11.09	5.07	0.00	4.94	***100***	***327***
280.00	-6.14	sea	-0.93		-11.16	5.02	0.00	4.93	***100***	***328***
290.00	-6.23	sea	-0.93		-11.23	5.00	0.00	4.91	***101***	***328***
300.00	-6.32	sea	-0.93		-11.26	4.94	0.00	4.88	***101***	***329***
310.00	-6.38	sea	-0.93		-11.10	4.72	0.00	4.66	***100***	***327***
320.00	-6.44	sea	-0.93		-10.74	4.30	0.00	4.25	***96***	***322***
330.00	-6.49	sea	-0.93		-10.18	3.68	0.00	3.41	***91***	***315***
340.00	-6.77	sea	-0.93		-9.41	2.65	0.00	2.55	***83***	***305***
350.00	-6.86	sea	-0.93		-8.45	1.59	0.00	1.62	***74***	***293***
360.00	-6.83	sea	-0.93		-7.37	0.54	0.00	0.28	***63***	***279***
370.00	-7.09	sea	-0.93		-7.09	0.00	0.00	0.00	***60***	***276***

This table defines the geometry of the surface and HDD bore levels. The water table level can also be defined. A sea level can be specified and elsewhere the water table is set at ground surface (worst-case scenario). This allows the borehole cover and saturated/ bouyant soil depths to be calculated.

U *is pressure at soffit level due to the water table elevation.*

Hs *is the static head in the borehole due to the drilling mud.*



HDD borehole profile graph based on the above table

Dist (m)	σv (kN/m²)	σh (kN/m²)	σo (kN/m²)	Pf (kN/m²)	Q	Rpmax (m)	Pemax (kN/m²)	Pmax (kN/m²)	Hf (kN/m²)	H (kN/m²)
0.0	0.0	0.0	0.0	40.5	0.00218	0.6	40	40	***0***	***0***
10.0	21.2	0.0	21.2	74.2	0.00286	0.9	134	152	***1***	***24***
20.0	38.0	0.0	38.0	100.8	0.00339	1.6	299	331	***2***	***49***
30.0	51.6	0.0	51.6	122.4	0.00382	2.2	446	489	***4***	***73***
40.0	70.6	0.0	70.6	152.5	0.00442	3.0	666	725	***5***	***98***
50.0	80.6	0.0	80.6	168.4	0.00474	3.4	786	853	***6***	***122***
60.0	92.3	0.0	92.3	187.0	0.00511	3.9	927	1004	***7***	***147***
70.0	102.7	0.0	102.7	203.5	0.00544	4.4	1053	1138	***9***	***171***
80.0	100.6	0.0	100.6	200.1	0.00538	4.7	1091	1184	***10***	***195***
90.0	74.3	0.0	74.3	158.4	0.00454	5.2	977	1079	***11***	***220***
100.0	47.0	0.0	47.0	115.0	0.00368	4.0	675	754	***12***	***243***
110.0	60.2	0.0	60.2	136.0	0.00409	2.8	578	633	***13***	***264***
120.0	75.4	0.0	75.4	160.2	0.00458	3.2	728	783	***15***	***283***
130.0	79.7	0.0	79.7	167.0	0.00471	3.6	807	873	***16***	***299***
140.0	85.6	0.0	85.6	176.4	0.00490	3.9	879	955	***17***	***312***
150.0	89.4	0.0	89.4	182.4	0.00502	4.0	924	1007	***18***	***323***
160.0	90.8	0.0	90.8	184.7	0.00507	4.1	942	1030	***19***	***331***
170.0	89.9	0.0	89.9	183.2	0.00504	4.0	930	1022	***21***	***337***
180.0	91.9	0.0	91.9	186.4	0.00510	3.9	921	1015	***22***	***340***
190.0	86.8	0.0	86.8	178.3	0.00494	3.9	899	993	***23***	***342***
210.0	80.4	0.0	80.4	168.1	0.00474	3.6	809	904	***26***	***347***
220.0	75.9	0.0	75.9	160.9	0.00459	3.5	764	860	***27***	***349***
230.0	71.5	0.0	71.5	153.9	0.00445	3.3	711	808	***28***	***351***
240.0	67.0	0.0	67.0	146.8	0.00431	3.1	659	756	***29***	***353***
250.0	61.7	0.0	61.7	138.4	0.00414	2.9	603	701	***30***	***355***
260.0	58.8	0.0	58.8	133.9	0.00405	2.7	554	652	***32***	***357***
270.0	58.2	0.0	58.2	132.8	0.00403	2.5	531	631	***33***	***359***
280.0	58.0	0.0	58.0	132.6	0.00403	2.5	526	626	***34***	***362***
290.0	57.8	0.0	57.8	132.3	0.00402	2.5	524	625	***35***	***364***
300.0	57.5	0.0	57.5	131.7	0.00401	2.5	517	619	***36***	***365***
310.0	54.8	0.0	54.8	127.5	0.00392	2.4	488	587	***38***	***364***
320.0	50.0	0.0	50.0	119.8	0.00377	2.1	432	528	***39***	***361***
330.0	40.1	0.0	40.1	104.2	0.00346	1.8	344	435	***40***	***355***
340.0	30.1	0.0	30.1	88.2	0.00314	1.3	227	310	***41***	***347***
350.0	19.1	0.0	19.1	70.7	0.00279	0.8	112	186	***43***	***336***
360.0	3.2	0.0	3.2	45.6	0.00229	0.3	-2	61	***44***	***323***
370.0	0.0	0.0	0.0	40.5	0.00218	0.0	-68	-8	***45***	***321***

*The pressure calculations are set out in this table. Note that **Rpmax** varies as it is set to be a proportion of the cover depth.*

Hf is a rough estimate of the drilling mud pressure in the return annular flow.

*The total head **H** is the static head **Hs** (table above) and **Hf**.*

Comments

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman		WIE16435	
	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall, Option 2)	**Prepared**	**Date**
		LP	17-Mar-20
		Checked	**Date**
		CG	17-Mar-20

Hydrofracture - Longitudinal Profile Check

The model is based on axial symetry around the borehole and the following four conditions apply: Equilibrium, Hooke's Law of elastic deformation, Mohr-Coulomb's failure criterion and absence of isotropic deformation in the plastic zone. This gives rise to a fairly complex set of expressions as shown below.

$$Pmax = Pemax + U$$ *Eqn(1)*

$$Pemax = (Pf + c.cot\emptyset).\left\{\left(\frac{Ro}{Rpmax}\right)^2 + Q\right\}^{\frac{-sin\emptyset}{1+sin\emptyset}} - c.cot\emptyset$$ *Eqn(2)*

$$Q = \frac{(\sigma o.sin\emptyset + c.cos\emptyset)}{G}$$ *Eqn(3)*

$$Pf = \sigma o\,(1 + sin\emptyset) + c.cos\emptyset$$ *Eqn(4)*

$$G = \frac{E}{2}\,(1 + \vartheta)$$ *Eqn(5)*

Where:

Pmax	maximum allowable mud pressure
U	initial in-situ pore pressure
Pemax	maximum allowable effective mud pressure
σ_o	initial effective stress
ϕ	internal angle of friction
c	cohesion
Ro	internal radius of borehole
Rpmax	maximum allowable radius of plastic zone
G	shear modulus
E	elasticity modulus
N	Poisson's ratio

Only enter data into green highlight cells. Other cells may contain calculations and editing them will over-write the formula.

General variables

Gravity (m/s/s):	**g**	9.81		
Density of water (kg/m3):	**ɣw**	1000		
Density of drilling mud (kg/m3):	**ɣm**	1300		
Soil density (kg/m^3):	**ɣs**	2200		
Cohesion (kN/m^2):	**Coh**	50		
Friction angle (deg):	**Φ**	36	Radians Φr =	0.62832
Poission's ratio :	**v**	0.35		
Elasticity modulus (kPa):	**Emod**	50000		
Shear modulus (kPa):	Gmod =	18519		

Soil characteristic values are all assumed and should be confirmed by Intrusive Ground Investigation.

Product pipe OD (m):					
Drill bit diameter (inch):		44.00 inch	**Do**	1.118	m
Drill pipe OD (inch):		11.00 inch	**Di**	0.279	m

Initial radius of borehole (m):	**Ro**	0.559	*Equal half drill bit diameter*
Allowable plastic radius factor	**Rpmax**	0.50	

Rpmax usually assumed between 1/2 and 2/3 depth, assumed 1/2 as worst case scenario

Consider lateral soil pressure: **No** ***Use drop-down to select Y/N***

Passive coefficient **ko** = IF(Y_N = "Yes", 1 - SIN(Φr), 0)
= IF(= "Yes", 1 - SIN(0.62832), 0)
= **0**

Conservative to not consider lateral soil pressures

Annular pressure calculations

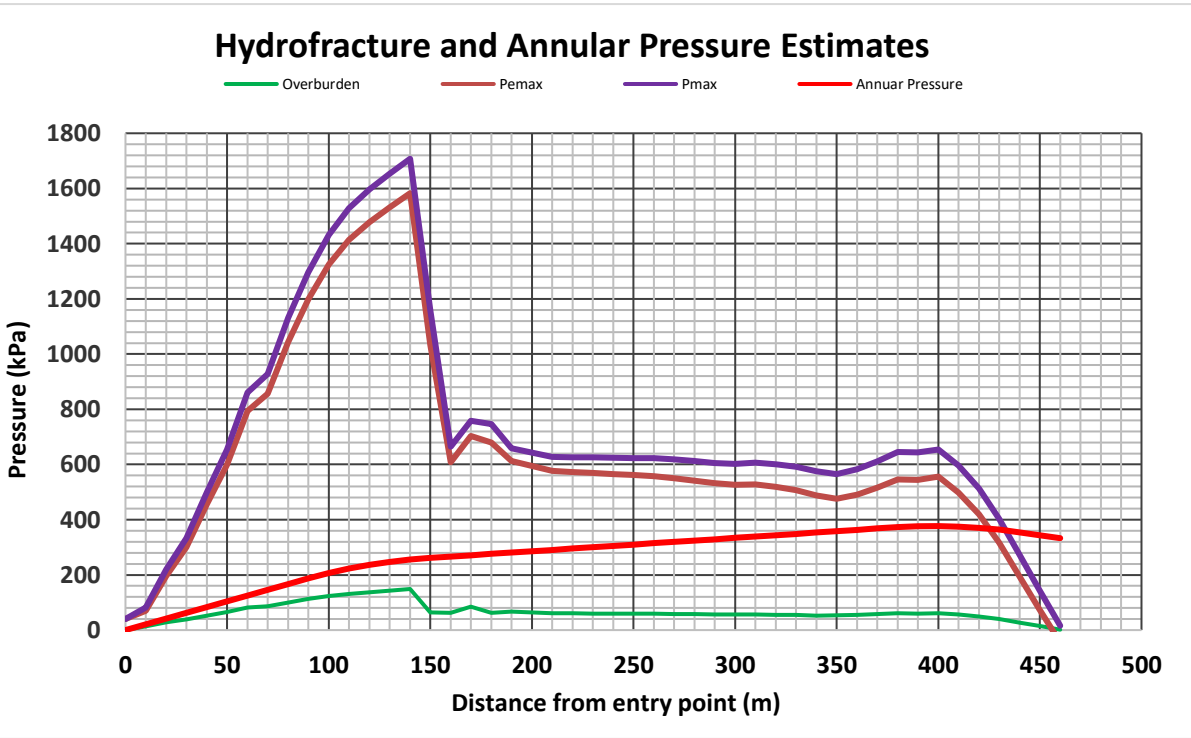
Darcy Weisbach equation for flow in an annulus is: H = f(L/Dh)(V^2/2g), where Dh is the hydraulic diameter, V the flow velocity, L flow pipe length and f is a friction factor. In the case of co-centered circular pipes Dh = Do - Di. The exact drilling operational parameters, such as flow rate are unknown, but some estimated values have been applied - but require verification. The total head is the flow head plus the static head.

Assumed flow velocity (m/s):	V	0.50
Assumed friction coefficient:	f	8.00

The calculations at each chainage location are performed in the fract-out table

Summary Figures

Elevation of entrance hole mOD =	**14.67**	**mOD**		
Elevation of exit hole mOD =	**-7.06**	**mOD**	***Diff =***	***21.72*** m
Maximum cover to HDD borehole =	**13.0**	**m**		
Maximum overburden pressure =	**148.9**	**kN/m^2**		***1.5 Bar***
Maximum safe effective stress **Pemax** =	**1583**	**kN/m^2**		***15.8 Bar***
Maximum safe stress **Pmax** =	**1708**	**kN/m^3**		***17.1 Bar***



Expressions used in hydrofracture calculations

In the tabulation below the following functions are applied

Saturated Layer **Sat'd**: IF (WTL<=HDD, Elevn-HDD, Max(Elevn-WTL, 0))

Bouyant Layer **Bou't**: IF (WTL<=HDD, 0, Min(WTL-HDD, Elevn-HDD))

σv = (ɣs*Satd+(ɣs-ɣw)*Bout)*g/1000

σo = SQRT((ɣs*Satd+(ɣs-ɣw)*Bout)^2 + (ko * (ɣs*Satd + (ɣs-ɣw)*Bout))^2))

Q = (σo*SIN(Φr) + Coh*COS(Φr)) / Gmod

Pf = (σo * (1+SIN(Φr))) + (Coh * COS(Φr))

Pemax = (Pf + Coh*COT(Φr)) * (((Ro/Rpmax)^2 + Q)^(-SIN(Φr)/(1+SIN(Φr)))) - Coh*COT(Φr)

Pelim = (Pf + Coh*COT(Φr)) * (Q^(-SIN(Φr)/(1+SIN(Φr)))) - Coh*COT(Φr)

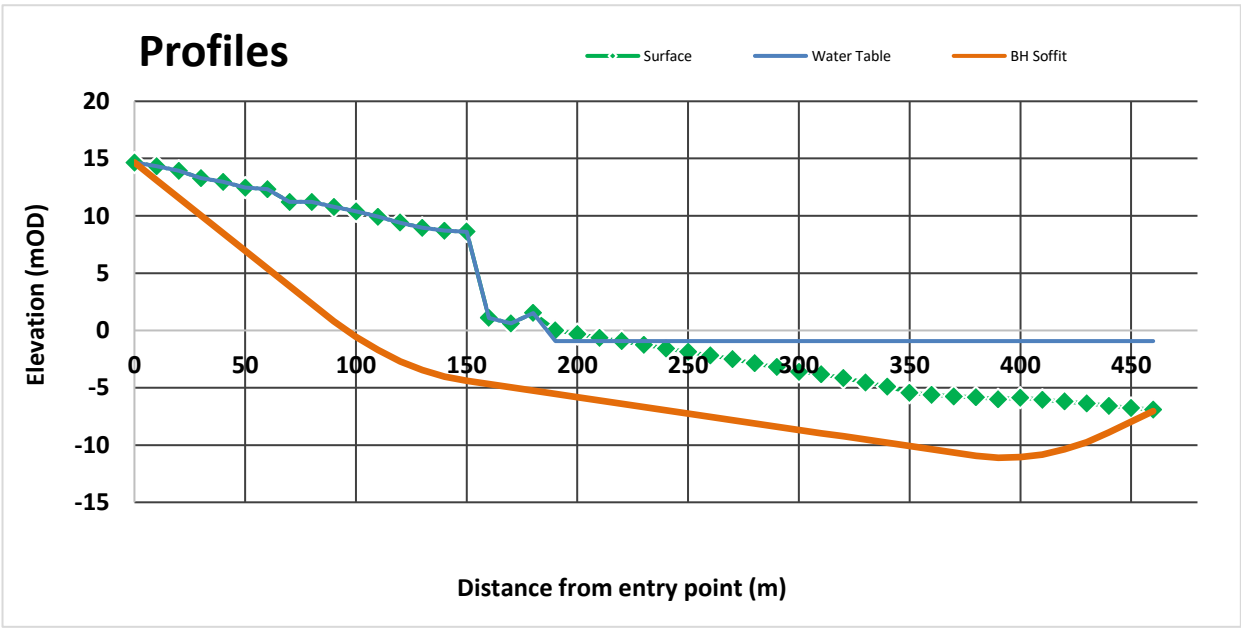
		LAT	
WT controls:	0	-0.93	

Dist (m)	Elev'n (mOD)	Loc'n	WTL (mOD)	C-Line (mOD)	Soffit (mOD)	Cover (m)	Sat'd (m)	Bou't (m)	U kN/m2	Hs kN/m3
0.00	14.67		14.67		14.67	0.00	0.00	0.00	*0*	*0*
10.00	14.33		14.33		13.13	1.21	0.00	1.21	*12*	*20*
20.00	13.95		13.95		11.59	2.36	0.00	2.36	*23*	*39*
30.00	13.29		13.29		10.04	3.24	0.00	3.24	*32*	*59*
40.00	12.97		12.97		8.50	4.46	0.00	4.46	*44*	*79*
50.00	12.48		12.48		6.96	5.52	0.00	5.52	*54*	*98*
60.00	12.33		12.33		5.42	6.90	0.00	6.90	*68*	*118*
70.00	11.22		11.22		3.88	7.34	0.00	7.34	*72*	*138*
80.00	11.23		11.23		2.34	8.89	0.00	8.44	*87*	*157*
90.00	10.78		10.78		0.81	9.97	0.00	9.57	*98*	*177*
100.00	10.39		10.39		-0.56	10.94	0.00	10.49	*107*	*194*
110.00	9.93		9.93		-1.72	11.65	0.00	11.14	*114*	*209*
120.00	9.41		9.41		-2.69	12.10	0.00	11.66	*119*	*221*
130.00	8.97		8.97		-3.46	12.43	0.00	12.16	*122*	*231*
140.00	8.70		8.70		-4.03	12.73	0.00	12.65	*125*	*238*
150.00	8.62		8.62		-4.40	13.01	0.00	5.49	*128*	*243*
160.00	1.10		1.10		-4.68	5.78	0.00	5.30	*57*	*247*
170.00	0.62		0.62		-4.97	5.59	0.91	5.59	*55*	*250*
180.00	1.53		1.53		-5.25	6.79	0.00	5.25	*67*	*254*
190.00	0.00	sea	-0.93		-5.54	5.54	0.62	4.61	*45*	*258*
200.00	-0.31	sea	-0.93		-5.82	5.51	0.31	4.89	*48*	*261*
210.00	-0.63	sea	-0.93		-6.11	5.48	0.00	5.17	*51*	*265*
220.00	-0.94	sea	-0.93		-6.39	5.45	0.00	5.14	*54*	*269*
230.00	-1.25	sea	-0.93		-6.68	5.43	0.00	5.11	*56*	*272*
240.00	-1.56	sea	-0.93		-6.96	5.40	0.00	5.09	*59*	*276*
250.00	-1.88	sea	-0.93		-7.25	5.37	0.00	5.06	*62*	*279*
260.00	-2.19	sea	-0.93		-7.53	5.34	0.00	5.03	*65*	*283*
270.00	-2.50	sea	-0.93		-7.82	5.32	0.00	4.94	*68*	*287*
280.00	-2.87	sea	-0.93		-8.10	5.23	0.00	4.91	*70*	*290*
290.00	-3.20	sea	-0.93		-8.39	5.19	0.00	4.79	*73*	*294*
300.00	-3.60	sea	-0.93		-8.67	5.07	0.00	4.85	*76*	*298*
310.00	-3.83	sea	-0.93		-8.96	5.13	0.00	4.80	*79*	*301*
320.00	-4.16	sea	-0.93		-9.24	5.09	0.00	4.70	*82*	*305*
330.00	-4.55	sea	-0.93		-9.53	4.98	0.00	4.63	*84*	*309*
340.00	-4.90	sea	-0.93		-9.81	4.91	0.00	4.38	*87*	*312*
350.00	-5.43	sea	-0.93		-10.10	4.67	0.00	4.50	*90*	*316*
360.00	-5.60	sea	-0.93		-10.38	4.78	0.00	4.62	*93*	*319*
370.00	-5.76	sea	-0.93		-10.67	4.91	0.00	4.91	*96*	*323*
380.00	-5.82	sea	-0.93		-10.95	5.13	0.00	5.13	*98*	*327*
390.00	-6.00	sea	-0.93		-11.11	5.11	0.00	5.11	*100*	*329*
400.00	-5.87	sea	-0.93		-11.07	5.20	0.00	5.20	*99*	*328*
410.00	-6.05	sea	-0.93		-10.83	4.78	0.00	4.78	*97*	*325*
420.00	-6.20	sea	-0.93		-10.39	4.18	0.00	4.18	*93*	*320*
430.00	-6.38	sea	-0.93		-9.75	3.37	0.00	3.37	*86*	*311*
440.00	-6.58	sea	-0.93		-8.91	2.33	0.00	2.33	*78*	*301*
450.00	-6.75	sea	-0.93		-7.98	1.23	0.00	1.23	*69*	*289*
460.00	-6.91	sea	-0.93		-7.06	0.14	0.00	0.14	*60*	*277*

This table defines the geometry of the surface and HDD bore levels. The water table level can also be defined. A sea level can be specified and elsewhere the water table is set at ground surface (worst-case scenario). This allows the borehole cover and saturated/ bouyant soil depths to be calculated.

U *is pressure at soffit level due to the water table elevation.*

Hs *is the static head in the borehole due to the drilling mud.*



HDD borehole profile graph based on the above table

Dist (m)	σv (kN/m²)	σh (kN/m²)	σo (kN/m²)	Pf (kN/m²)	Q	Rpmax (m)	Pemax (kN/m²)	Pmax (kN/m²)	Hf (kN/m²)	H (kN/m²)
0.0	0.0	0.0	0.0	40.5	0.00218	0.6	40	40	***0***	***0***
10.0	14.2	0.0	14.2	63.0	0.00263	0.6	70	82	***1***	***21***
20.0	27.8	0.0	27.8	84.6	0.00307	1.2	197	220	***2***	***42***
30.0	38.2	0.0	38.2	101.0	0.00340	1.6	301	333	***4***	***63***
40.0	52.5	0.0	52.5	123.9	0.00385	2.2	456	500	***5***	***83***
50.0	65.0	0.0	65.0	143.6	0.00425	2.8	599	653	***6***	***104***
60.0	81.3	0.0	81.3	169.5	0.00476	3.5	794	861	***7***	***125***
70.0	86.4	0.0	86.4	177.7	0.00493	3.7	856	928	***9***	***146***
80.0	99.4	0.0	99.4	198.2	0.00534	4.4	1044	1131	***10***	***167***
90.0	112.7	0.0	112.7	219.4	0.00576	5.0	1198	1296	***11***	***188***
100.0	123.4	0.0	123.4	236.4	0.00610	5.5	1325	1432	***12***	***206***
110.0	131.1	0.0	131.1	248.6	0.00634	5.8	1414	1528	***13***	***222***
120.0	137.2	0.0	137.2	258.4	0.00654	6.1	1477	1596	***15***	***236***
130.0	143.1	0.0	143.1	267.7	0.00673	6.2	1532	1654	***16***	***247***
140.0	148.9	0.0	148.9	276.8	0.00691	6.4	1583	1708	***17***	***255***
150.0	64.7	0.0	64.7	143.1	0.00424	6.5	1034	1162	***18***	***261***
160.0	62.4	0.0	62.4	139.6	0.00417	2.9	607	664	***19***	***266***
170.0	85.5	0.0	85.5	176.2	0.00490	2.8	704	759	***21***	***271***
180.0	61.8	0.0	61.8	138.6	0.00415	3.4	679	746	***22***	***276***
190.0	67.5	0.0	67.5	147.7	0.00433	2.8	613	658	***23***	***281***
210.0	60.8	0.0	60.8	137.1	0.00412	2.7	576	627	***26***	***290***
220.0	60.5	0.0	60.5	136.5	0.00411	2.7	573	626	***27***	***295***
230.0	60.2	0.0	60.2	136.0	0.00410	2.7	569	625	***28***	***300***
240.0	59.9	0.0	59.9	135.5	0.00408	2.7	565	625	***29***	***305***
250.0	59.6	0.0	59.6	135.0	0.00407	2.7	562	624	***30***	***310***
260.0	59.2	0.0	59.2	134.5	0.00406	2.7	558	623	***32***	***315***
270.0	58.2	0.0	58.2	132.8	0.00403	2.7	551	618	***33***	***320***
280.0	57.7	0.0	57.7	132.1	0.00402	2.6	542	612	***34***	***324***
290.0	56.4	0.0	56.4	129.9	0.00397	2.6	532	605	***35***	***329***
300.0	57.0	0.0	57.0	131.0	0.00399	2.5	526	602	***36***	***334***
310.0	56.5	0.0	56.5	130.2	0.00398	2.6	528	607	***38***	***339***
320.0	55.3	0.0	55.3	128.2	0.00394	2.5	519	600	***39***	***344***
330.0	54.4	0.0	54.4	126.9	0.00391	2.5	507	591	***40***	***349***
340.0	51.6	0.0	51.6	122.4	0.00382	2.5	488	575	***41***	***354***
350.0	53.0	0.0	53.0	124.5	0.00386	2.3	475	565	***43***	***358***
360.0	54.4	0.0	54.4	126.9	0.00391	2.4	491	584	***44***	***363***
370.0	57.8	0.0	57.8	132.2	0.00402	2.5	516	612	***45***	***368***
380.0	60.4	0.0	60.4	136.4	0.00410	2.6	546	645	***46***	***373***
390.0	60.2	0.0	60.2	136.0	0.00410	2.6	544	644	***47***	***376***
400.0	61.2	0.0	61.2	137.6	0.00413	2.6	555	655	***49***	***377***
410.0	56.2	0.0	56.2	129.8	0.00397	2.4	498	596	***50***	***375***
420.0	49.3	0.0	49.3	118.7	0.00375	2.1	420	513	***51***	***371***
430.0	39.7	0.0	39.7	103.4	0.00344	1.7	317	403	***52***	***364***
440.0	27.4	0.0	27.4	84.0	0.00305	1.2	193	271	***54***	***354***
450.0	14.5	0.0	14.5	63.4	0.00264	0.6	73	142	***55***	***344***
460.0	1.7	0.0	1.7	43.1	0.00224	0.1	-44	16	***56***	***333***

*The pressure calculations are set out in this table. Note that **Rpmax** varies as it is set to be a proportion of the cover depth.*

Hf is a rough estimate of the drilling mud pressure in the return annular flow.

*The total head **H** is the static head **Hs** (table above) and **Hf**.*

waterman	***Spreadsheet Calcpad*** *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	**Project**	WIE16435
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This spreadsheet makes extensive use of named cells and custom functions. This enables the calculation cells to be displayed as equations with meaningful variable names rather than the normal Excel cell references. Also, the values that have been used in the calculation are shown above the result.

In order to cope with the large number of named cells, the naming convention is of necessity fairly cryptic - but there is some method to it. This particularly applies to the repetitive calculations relating to each section of the pipe.

Thus for section specific variables the the section name is added as a suffix - eg **Lc**, **Lf** are the **L**engths of sections '**C**' and '**F**' respectively. And similarly **Hyc** and **Hyf** are the Hydrokinetic forces. Where there is a need to make a distinction between the **s**tart and **e**nd of a section then additional suffixes '**s**' and '**e**' are appended to the variable name. There are similar variations on this theme.

Input Data: Constants and Global Variables

Constants

Pi	π	3.142	
Gravity	g	9.81	m/s/s
Eulers Number	e	2.7182	
One metre Head of Water	Hw	0.009804	N/mm^2

Pipe Geometry

Pipe outside diameter	δ0	800	mm	**Do**	**0.800**	**m**
Pipe wall thickness	t =	38.09524	mm			
Pipe inside diameter	δi =	δ0 - 2*t		**Di**	**0.724**	**m**
	=	266 - 2*133				
	=	723.81 mm				
Pipe X-sect (outer)	Ao =	INT(π * δ0^2 / 4)		**Aom**	**5.0265E-01**	**m^2**
	=	INT(3.142 * 266^2 / 4)				
	=	502654.0	mm^2			
Pipe X-sect (inner)	Ai =	INT(π * δi^2 / 4)		**Aim**	**4.1147E-01**	**m^2**
	=	INT(3.142 * 0^2 / 4)				
	=	411470.0	mm^2			
Pipe wall X-sect area	Ap =	INT(π * (δ0^2 - δi^2) / 4)		**Apm**	**9.1184E-02**	**m^2**
	=	INT(3.142 * (266^2 - 0^2) / 4)				
	=	91184.0	mm^2			
Minimum radius of curvature	R =	836*δ0 / 1000				
	=	836*266 / 1000				
	=	**669 m**				

Note SDR21 assumed to determine wall thickness

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Pipe Material

Young's Modulus	Emm	8.00E+02	N/mm^2	***Units of force calculations***	*Generic values for HDPE material*
	Em	**8.00E+08**	N/m^2	***Units of stress calculations***	
Yield stress of pipe	YS	0	N/mm^2		

Densities

Density of fresh water	ρw	1000	kg/m^3		
Density of sea water	ρsea	1025	kg/m^3		
Density of drilling mud	ρm	1300	kg/m^3		
Density of pipe material	ρp	950	kg/m^3	***HDPE***	*Generic value*

Friction Factors

Between pipe and soil	CFpr	0.5		***Assumed value***	
Between pipe and bentonite	CFpb	50	N/m^2		

Pipe Ballast

Density of fluid in pipe	ρb	1000	kg/m^3	***Default, water 1000kg/m^3***	***Assumed filled***
Pressure of ballast fluid	Pb	0	bar	**Pb 0 N/mm^2**	***Assumed unpressurised***
Bentonite at surface	EBen	14.525	mOD	***To ordnance datum***	

Buoyancy factors

Mass of pipe

Mp = (Ap / 10^6) * ρp
= (55571 / 10^6) * 950
= **86.6 kg/m**

Mass of pipe in air

Mass of ballast in pipe

Mw = (Ai / 10^6) * ρb
= (0 / 10^6) * 1000
= **411.5 kg/m**

Mass of ballast water in air

Mass of drilling mud

Mm = (Ao / 10^6) * ρm
= (55571 / 10^6) * 1300
= **653.5 kg/m**

Mass of mud displaced by pipe

Buoyant mass of pipe

Mpb = (Mp + Mw) - Mm
= (139 + 0) - 72.2
= **-155.36 kg/m**

Result is -ve. Pipe floats so force up

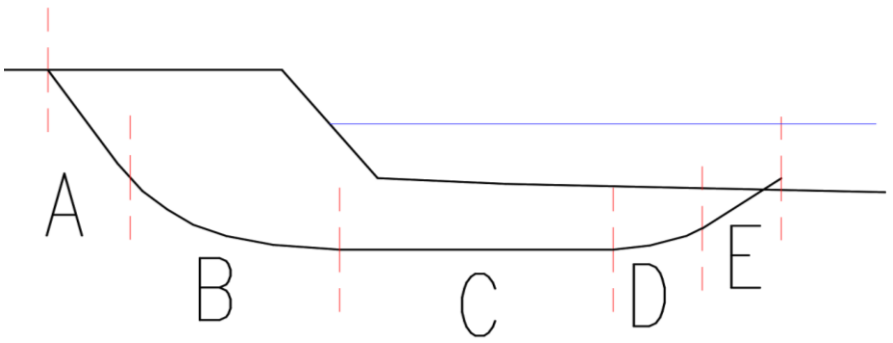
Mpb not used directly, but useful check on buoyancy

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
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Pipe Centre Line Profile

	A	A:B	B:C	C:D	D:E	E		
Ch	0.00	92.00	180.00	293.00	351.00	365.00		
mOD	14.53	-1.86	-10.43	-11.23	-8.45	-7.09		
Radius		500		500				
Slope	-10.32		-0.42		6.2			

Dimensions and levels are taken from CAD drawing



Summary Results

The general arrangement of the HDD borehole geometry is shown in the figure above. The analysis of the forces and combined stress during the pipe pull will consider each section of the profile in order to identify the most critical portion. It is assumed that the maximum pulling force will be just as the pipe reaches full insertion.

During pipe pulling the HDD borehole will be filled with bentonite and the pipe. Possibly the pipe will be flooded with ballast water and in some cases may be pressurised. Calculation of the friction forces and the pulling forces requires the buoyancy and pipe curvature to be taken into account.

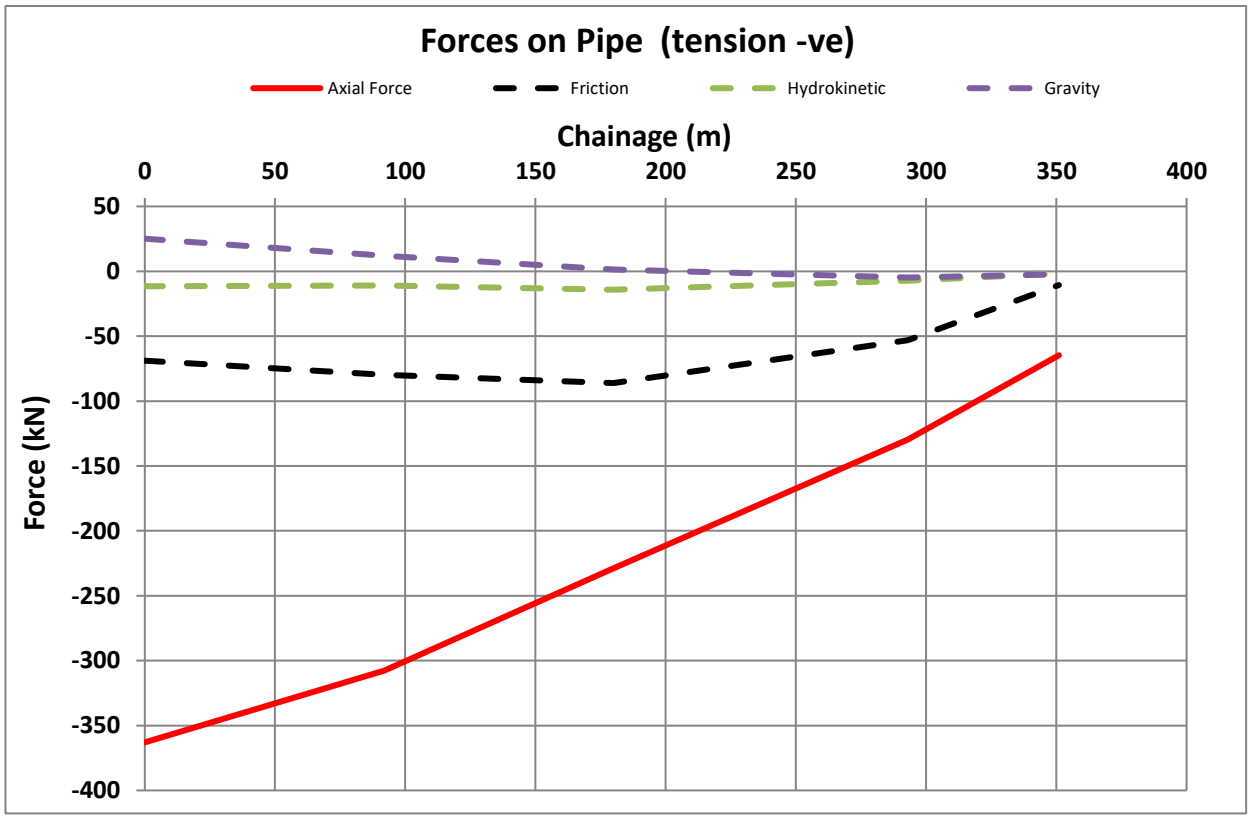
Sign Convention:

Axial Tensile Force: -ve	Axial Compressive Force: +ve
Tensile Stress -ve	Compressive Stress +ve
Weight (gravity) +ve	Buoyancy (uplift) -ve

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Table of Pipe Forces (kN)

Section	Length (m)	Chng (m)	Friction Comp	Hydro Comp	Gravity Comp	Axial Force
A	92	0.00	-68.97	-11.56	25.12	-362.96
B	88	92.00	-79.74	-11.06	12.06	-307.55
C	113	180.00	-86.11	-14.20	1.26	-228.81
D	58	293.00	-53.03	-7.29	-4.78	-129.77
E	14	351.00	-10.61	-1.76	-2.30	-64.67



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Section E - Straight Inclined

This is a straight section and the stresses in the pipe arise from tensile (pulling) forces and radial forces acting

Length of Section	Le	14.00	m	
Slope of Section	θe	6.2	deg	0.108 radian
Pipe CL datum (start)		-7.09	mOD	
Pipe CL datum (end)		-8.45	mOD	
Hydrotatic Head (start end)	Hhes	21.62	m	***(NB: This is bentonite head)***
Hydrostatic Head (end end)	Hhee	22.98	m	***(NB: This is bentonite head)***

Friction force (tensile)

Fre = -ABS(CFpr * Le * ((Mp+Mw-Mm) * COS(θe))) * g / 1000
= -ABS(0.4 * 14 * ((139+0-72.2) * COS(0.108))) * 9.81 / 1000
= **-10.61 kN**

Hydrokinetic force (tensile)

Hye = -(π * Do * Le * CFpb) / 1000
= -(3.142 * 0.266 * 14 * 50) / 1000
= **-1.76 kN**

Gravity component

Gre = (Le * (Mp + Mw - Mm) * SIN(θe)) * g /1000
= (14 * (139 + 0 - 72.2) * SIN(0.108)) * 9.81 /1000
= **-2.30 kN**

Bouyancy is resisting by pushing back this section

Aggregate the axial forces local to this section at the start and end of the section

Axial force section start

Faes = **-50.00 kN**

Pipe floating offshore. Tethering force depends on sea conditions. Nominal value of 50kN assumed.

Increment for section

dFae = Fre + Hye + Gre
= -3.65 + -0.58 + 0.99
= **-14.67 kN**

Axial force section end

Faee = Faes + dFae
= -25 + -3.24
= **-64.67 kN**

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Section D - Vertical curve

This is a curved section as the pipe transitions from an incline to horizontal. This induces some forces that are additional to that of a straight section. These additional effects arise from the 'capstan' force required to move the pipe around a curve and the additional normal force and to bending the pipe.

Radius of curvature	Rdc	500.00	m	
Angle of curvature	θdc	6.2	deg	0.10821 radians
Length of Section	Ld	58.00	m	
Average Slope of Section	θd	3.1	deg	0.054 radians
Pipe CL datum (start)		-8.45	mOD	
Pipe CL datum (end)		-11.23	mOD	
Hydrotatic Head (start end)	Hhds	22.98	m	***(NB: This is bentonite head)***
Hydrostatic Head (end end)	Hhde	25.76	m	***(NB: This is bentonite head)***

Check on curve length

Ldc = ABS(Rdc * θdc)
= 54.11 m ***(Compared to profile figure of 58m)*** *Not used - check only*

Check change in elevation

Hdc = Rdc * (1 - COS(θdc))
= 500 * (1 - COS(0.10821))
= 2.92 m ***(Compared to profile figure of 2.78m)*** *Not used - check only*

Capstan factor

CapFacd = EulerN^(CFpr *ABS(θdc))
= 2.7182^(0.4 *ABS(0.10821))
= 1.056 ***(Increase the pipe pull by this factor)***

Check additional normal force of pipe against borehole due to bending. This will add to the calculation of the friction force. Conservative approach is to consider deflection then determine UDL loading necessary to cause that deflection. Consider both simply supported and fully fixed ends.

Assumed deflection at midpoint

Defdm = Rdc * (1 - COS(θdc / 2))
= 500 * (1 - COS(0.10821 / 2))
= **0.73 m**

Total UDL equivalent Simply supported ends

Ndss = Defdm * (384 * Em * Im) * Ld / (5 * Ld^4) / 1000
= 0.73 * (384 * 800000000 * 0.00024575) * 58 / (5 * 58^4) / 1000
= **1.53 kN**

Pipe confined within the borehole so consider loading as UDL for SS and FF end cases.
Note the UDL is multiplied by length to give total load.

Total UDL equivalent Fully fixed ends

Ndfe = Defdm * (384 * Em * Im) * Ld / (Ld^4) / 1000
= 0.73 * (384 * 800000000 * 0.00024575) * 58 / (58^4) / 1000
= **7.64 kN**

Weighted UDL

Nd = (Ndss + Ndff) / 3 * 2
= (0.06 + 0.28) / 3 * 2
= **6.11 kN**

Friction forces (tensile) as if straight pipe

Frdl = -ABS(CFpr * (Ld * (Mp+Mw-Mm) * COS(θd)) * g/1000)
= -ABS(0.4 * (58 * (139+0-72.2) * COS(0.054)) * 9.81/1000)
= **-44.13 kN**

Friction forces (tensile) due to bending.

Frdc = -ABS(CFpr * 2 * Nd * COS(θd))
= -ABS(0.4 * 2 * 0.23 * COS(0.054))
= **-6.104 kN**

Note that in the above calculations the frictional force due to curvature is 13.83 percent of the linear friction force.

Determine the capstan effect force. It could be argued that considering additional normal force for friction and capstan force is double counting the effect of curvature, but probably not.

Capstan effect increased tension force

Cad = (CapFacd - 1) * (Frdl + Frdc)
(1.044 - 1) * (-15.17 + -0.181)
-2.79 kN

Hydrokinetic force (tensile)

Hyd = -(π * Do * Ld * CFpb) / 1000
= -(3.142 * 0.266 * 58 * 50) / 1000
= **-7.29 kN**

Gravity component

Grd = (Ld * Mpb * SIN(θd)) * g /1000
= (58 * 66.76 * SIN(0.054)) * 9.81 /1000
= **-4.78 kN**

Bouyancy is resisting by pushing back this section

Aggregate the axial forces local to this section at the start and end of the section. Note horizontal lay out length reduces as pipe pulled in.

Axial force section start

Fads = Faee
= -28.24
= **-64.67 kN**

Increment for section

dFad = Frdl + Frdc + Cad + Hyd + Grd
= -15.17 + -0.181 + -0.68 + -2.42 + 2.05
= **-65.10 kN**

Axial force section end

Fade = Fads + dFad
= -28.24 + -16.4
= **-129.77 kN**

Section C - Straight Inclinded

This is a straight section and the stresses in the pipe arise from pulling forces and radial forces acting on the circumfrence of the pipe. The borehole is filled with bentonite and the pipe may contain ballast water.

Length of Section	Lc	113.00	m	
Slope of Section	θc	-0.42	deg	-0.007 radian
Pipe CL datum (start)		-11.23	mOD	
Pipe CL datum (end)		-10.43	mOD	
Hydrotatic Head (start end)	Hhcs	25.76	m	***(NB: This is bentonite head)***
Hydrostatic Head (end end)	Hhce	24.96	m	***(NB: This is bentonite head)***

Friction forces (tensile)
Frc = -ABS(CFpr * Lc * ((Mp+Mw-Mm) * COS(θc))) * g / 1000
= -ABS(0.4 * 113 * ((139+0-72.2) * COS(-0.007))) * 9.81 / 1000
= **-86.11 kN**

Hydrokinetic force (tensile)
Hyc = -(π * Do * Lc * CFpb) / 1000
= -(3.142 * 0.266 * 113 * 50) / 1000
= **-14.20 kN**

Gravity component
Grc = (Lc * Mpb * SIN(θc)) * g /1000
= (113 * 66.76 * SIN(-0.007)) * 9.81 /1000
= **1.26 kN**

Aggregate the axial forces local to this section at the start and end of the section.

Axial force section start
Facs = Fade
= -44.64
-129.77 kN

Increment for section
dFac = Frc + Hyc + Grc
= -29.6 + -4.72 + -0.54
= **-99.04 kN**

Axial force section end
Face = Facs + dFac
= -44.64 + -34.86
= **-228.81 kN**

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Section B - Vertical curve

This is a curved section as the pipe transitions from an incline to horizontal. This induces some forces that are additional to that of a straight section. These additional effects arise from the 'capstan' force required to move the pipe around a curve and the additional normal force and to bending the pipe.

Radius of curvature	Rbc	500.00	m	
Angle of curvature	θbc	-10.32	deg	-0.180 radians
Length of Section	Lb	88.00	m	
Average Slope of Section	θb	-5.16	deg	-0.090 radians
Pipe CL datum (start)		-10.43	mOD	
Pipe CL datum (end)		-1.86	mOD	
Hydrotatic Head (start end)	Hhbs	24.96	m	***(NB: This is bentonite head)***
Hydrostatic Head (end end)	Hhbe	16.38	m	***(NB: This is bentonite head)***

Check on curve length
Lbc = ABS(Rbc * θbc)
= 90.06 m ***(Compared to profile figure of 88.00m)*** *Not used - check only*

Check change in elevation
Hbc = Rbc * (1 - COS(θbc))
= 500 * (1 - COS(-0.18))
= 8.09 m ***(Compared to profile figure of -8.58m)*** *Not used - check only*

Capstan factor
CapFacb = EulerN^(CFpr *ABS(θbc))
= 2.7182^(0.4 *ABS(-0.18))
= 1.094 ***(Increase the pipe pull by this factor)***

Check additional normal force of pipe against borehole due to bending. This will add to the calculation of the friction force. Conservative approach is to consider deflection then determine UDL loading necessary to cause that deflection. Consider both simply supported and fully fixed ends.

Assumed deflection at midpoint
Defbm = Rbc * (1 - COS(θbc / 2))
= 500 * (1 - COS(-0.18 / 2))
= **2.03 m**

Total UDL equivalent Simply supported ends
Nbss = Defdm * (384 * Em * Im) * Ld / (5 * Ld^4) / 1000
= 0.73 * (384 * 800000000 * 0.00024575) * 58 / (5 * 58^4) /
= **1.53 kN**

Total UDL equivalent Fully fixed ends
Nbff = Defdm * (384 * Em * Im) * Ld / (Ld^4) / 1000
= 0.73 * (384 * 800000000 * 0.00024575) * 58 / (58^4) / 1000
= **7.64 kN**

Weighted UDL
Nb = (Nbss + Nbff) / 3 * 2
= (0.06 + 0.28) / 3 * 2
= **6.11 kN**

Friction forces (tensile) as if straight pipe
Frbl = -ABS(CFpr * (Lb * (Mp+Mw-Mm) * COS(θb)) * g/1000)
= -ABS(0.4 * (88 * (139+0-72.2) * COS(-0.09)) * 9.81/1000)
= **-66.79 kN**

Friction forces (tensile) due to bending.
Frbc = -ABS(CFpr * 2 * Nb * COS(θb))
= -ABS(0.4 * 2 * 0.23 * COS(-0.09))
= **-6.09 kN**

Note that in the above calculations the frictional force due to curvature is 9.1 percent of the linear friction force.

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Determine the capstan effect force. It could be argued that considering additional normal force for friction and capstan force is double counting the effect of curvature, but probably not.

Capstan effect increased tension force

Cab = (CapFacb - 1) * (Frbl + Frbc)
(1.075 - 1) * (-22.96 + -0.18)
-6.87 kN

Hydrokinetic force (tensile)

Hyb = -(π * Do * Lb * CFpb) / 1000
= -(3.142 * 0.266 * 88 * 50) / 1000
= **-11.06 kN**

Gravity component

Grb = (Lb * (Mp+Mw-Mm) * SIN(θb)) * g /1000
= (88 * (139+0-72.2) * SIN(-0.09)) * 9.81 /1000
= **12.06 kN**

Bouyancy is assisting by raising this section

Aggregate the axial forces local to this section at the start and end of the section. Note horizontal lay out length reduces as pipe pulled in.

Axial force section start

Fabs = Face
= -79.51
-228.81 kN

Increment for section

dFab = Frbl + Frbc + Cab + Hyb + Grb
= -22.96 + -0.18 + -1.73 + -3.68 + -5.18
= **-78.74 kN**

Axial force section end

Fabe = Fabs +dFab
= -79.51 +-33.73
= **-307.55 kN**

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Section A - Straight Inclined

This is a straight section and the stresses in the pipe arise from tensile (pulling) forces and radial forces acting on the circumfrence of the pipe. Assume the bore hole is filled with bentonite.

Length of Section	La	92.00	m	
Slope of Section	θa	-10.32	deg	-0.180 radian
Pipe CL datum (start)		-1.86	mOD	
Pipe CL datum (end)		14.53	mOD	
Hydrotatic Head (start end)	Hhas	16.38	m	***(NB: This is bentonite head)***
Hydrostatic Head (end end)	Hhae	0.00	m	***(NB: This is bentonite head)***

Friction forces (tensile)

Fra = -ABS(CFpr * La * ((Mp+Mw-Mm) * COS(θa))) * g / 1000
= -ABS(0.4 * 92 * ((139+0-72.2) * COS(-0.18))) * 9.81 / 1000
= **-68.97 kN**

Hydrokinetic force (tensile)

Hya = -(π * Do * La * CFpb) / 1000
= -(3.142 * 0.266 * 92 * 50) / 1000
= **-11.56 kN**

Gravity component

Gra = (La * (Mp+Mw-Mm) * SIN(θa)) * g /1000
= (92 * (139+0-72.2) * SIN(-0.18)) * 9.81 /1000
= **25.12 kN**

Exit end of borehole lower than entry, so static mud level may not reach surface at 'A'. However, on pull back mud will be pushed ahead, so assume buoyant...

Aggregate the axial forces local to this section at the start and end of the section. Note horizontal lay out length reduces as pipe pulled in. (By end of this section the pipe is fully inserted.)

Axial force section start

Faas = Fabe
= -113.23
-307.55 kN

Increment for section

dFaa = Fra + Hya + Gra
= -23.71 + -3.84 + -10.79
= **-55.41 kN**

Axial force section end

Faae = Faas + dFaa
= -113.23 + -38.35
= **-362.96 kN**

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman		WIE16435	
	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall, Option 2)	**Prepared**	**Date**
		LP	17-Mar-20
		Checked	**Date**
		CG	17-Mar-20

This spreadsheet makes extensive use of named cells and custom functions. This enables the calculation cells to be displayed as equations with meaningful variable names rather than the normal Excel cell references. Also, the values that have been used in the calculation are shown above the result.

In order to cope with the large number of named cells, the naming convention is of necessity fairly cryptic - but there is some method to it. This particularly applies to the repetitive calculations relating to each section of the pipe.

Thus for section specific variables the the section name is added as a suffix - eg **Lc**, **Lf** are the **L**engths of sections '**C**' and '**F**' respectively. And similarly **Hyc** and **Hyf** are the Hydrokinetic forces. Where there is a need to make a distinction between the **s**tart and **e**nd of a section then additional suffixes '**s**' and '**e**' are appended to the variable name. There are similar variations on this theme.

Input Data: Constants and Global Variables

Constants

Pi	π	3.142	
Gravity	g	9.81	m/s/s
Eulers Number	e	2.7182	
One metre Head of Water	Hw	0.009804	N/mm^2

Pipe Geometry

Pipe outside diameter	δ0	800	mm	**Do**	**0.800**	**m**
Pipe wall thickness	t =	38.09524	mm			
Pipe inside diameter	δi =	δ0 - 2*t		**Di**	**0.724**	**m**
	=	δ0 - 2*t				
	=	723.81	mm			
Pipe X-sect (outer)	Ao =	INT(π * δ0^2 / 4)		**Aom**	**5.0265E-01**	**m^2**
	=	INT(π * δ0^2 / 4)				
	=	502654.0	mm^2			
Pipe X-sect (inner)	Ai =	INT(π * δi^2 / 4)		**Aim**	**4.1147E-01**	**m^2**
	=	INT(π * δi^2 / 4)				
	=	411470.0	mm^2			
Pipe wall X-sect area	Ap =	INT(π * (δ0^2 - δi^2) / 4)		**Apm**	**9.1184E-02**	**m^2**
	=	INT(π * (δ0^2 - δi^2) / 4)				
	=	91184.0	mm^2			
Minimum radius of curvature	R =	836*δ0 / 1000				
	=	836*δ0 / 1000				
	=	**669 m**				

Note SDR21 assumed to determine wall thickness

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
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Pipe Material

Young's Modulus	Emm	8.00E+02	N/mm^2	***Units of force calculations***	*Generic values for HDPE material*
	Em	**8.00E+08**	N/m^2	***Units of stress calculations***	
Yield stress of pipe	YS	0	N/mm^2		

Densities

Density of fresh water	ρw	1000	kg/m^3		
Density of sea water	ρsea	1025	kg/m^3		
Density of drilling mud	ρm	1300	kg/m^3		
Density of pipe material	ρp	950	kg/m^3	***HDPE***	*Generic value*

Friction Factors

Between pipe and soil	CFpr	0.5		***Assumed value***	
Between pipe and bentonite	CFpb	50	N/m^2		

Pipe Ballast

Density of fluid in pipe	ρb	1000	kg/m^3	***Default, water 1000kg/m^3***	***Assumed filled***
Pressure of ballast fluid	Pb	0	bar	**Pb 0 N/mm^2**	***Assumed unpressurised***
Bentonite at surface	EBen	14.525	mOD	***To ordnance datum***	

Buoyancy factors

Mass of pipe — *Mass of pipe in air*

Mp = (Ap / 10^6) * ρp
= (Ap / 10^6) * ρp
= **86.6 kg/m**

Mass of ballast in pipe — *Mass of ballast water in air*

Mw = (Ai / 10^6) * ρb
= (Ai / 10^6) * ρb
= **411.5 kg/m**

Mass of drilling mud — *Mass of mud displaced by pipe*

Mm = (Ao / 10^6) * ρm
= (Ao / 10^6) * ρm
= **653.5 kg/m**

Buoyant mass of pipe — **Mpb** not used directly, but useful check on buoyancy

Mpb = (Mp + Mw) - Mm
= (Mp + Mw) - Mm
= **-155.36 kg/m**

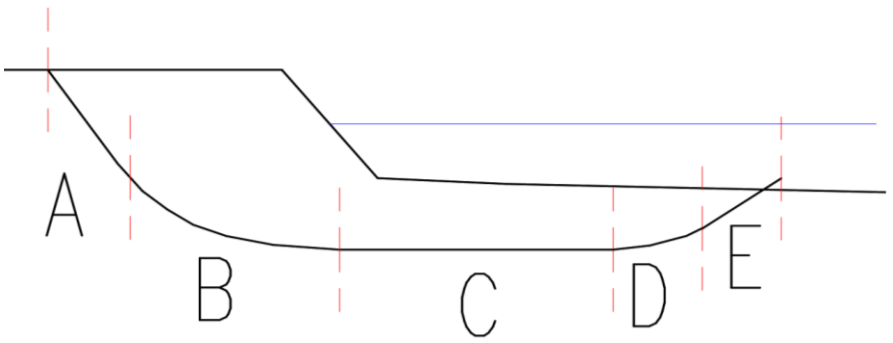
Result is -ve. Pipe floats so force up

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall, Option 2)	WIE16435	
		Prepared	**Date**
		LP	17-Mar-20
		Checked	**Date**
		CG	17-Mar-20

Pipe Centre Line Profile

	A	A:B	B:C	C:D	D:E	E		
Ch	0.00	86.00	149.00	378.00	439.00	462.00		
mOD	14.67	1.00	-4.30	-10.90	-9.00	-6.91		
Radius		500		500				
Slope	-8.76		-1.63		5.29			

Dimensions and levels are taken from CAD drawing



Summary Results

The general arrangement of the HDD borehole geometry is shown in the figure above. The analysis of the forces and combined stress during the pipe pull will consider each section of the profile in order to identify the most critical portion. It is assumed that the maximum pulling force will be just as the pipe reaches full insertion.

During pipe pulling the HDD borehole will be filled with bentonite and the pipe. Possibly the pipe will be flooded with ballast water and in some cases may be pressurised. Calculation of the friction forces and the pulling forces requires the buoyancy and pipe curvature to be taken into account.

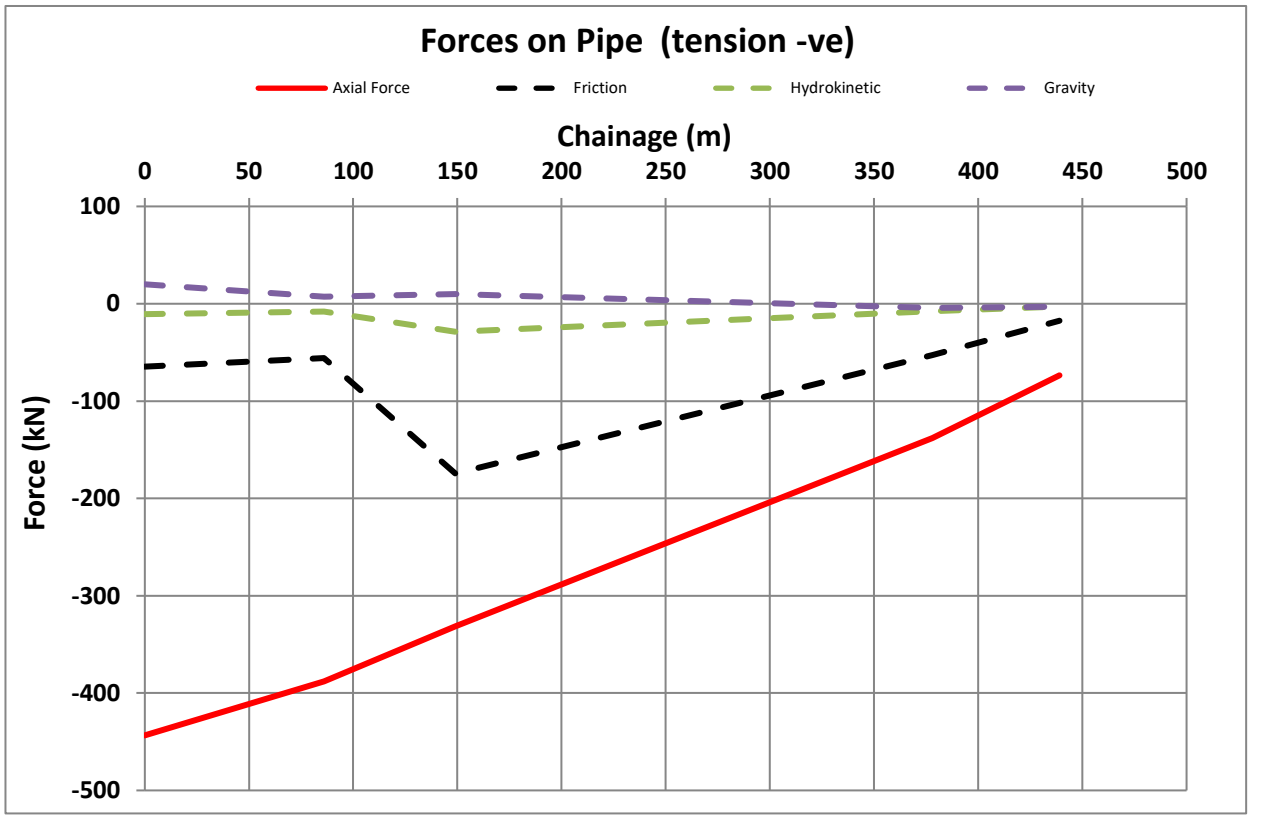
Sign Convention:

Axial Tensile Force: -ve	Axial Compressive Force: +ve
Tensile Stress -ve	Compressive Stress +ve
Weight (gravity) +ve	Buoyancy (uplift) -ve

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	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall, Option 2)	**Prepared**	**Date**
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Table of Pipe Forces (kN)

Section	Length (m)	Chng (m)	Friction Comp	Hydro Comp	Gravity Comp	Axial Force
A	86	0.00	-64.77	-10.81	19.96	-443.43
B	63	86.00	-55.79	-7.92	7.33	-387.81
C	229	149.00	-174.43	-28.78	9.93	-331.44
D	61	378.00	-52.63	-7.67	-4.29	-138.16
E	23	439.00	-17.45	-2.89	-3.23	-73.57



Section E - Straight Inclined

This is a straight section and the stresses in the pipe arise from tensile (pulling) forces and radial forces acting

Length of Section	Le	23.00	m	
Slope of Section	θe	5.29	deg	0.092 radian
Pipe CL datum (start)		-6.91	mOD	
Pipe CL datum (end)		-9.00	mOD	
Hydrotatic Head (start end)	Hhes	21.44	m	***(NB: This is bentonite head)***
Hydrostatic Head (end end)	Hhee	23.53	m	***(NB: This is bentonite head)***

Friction force (tensile)

Fre = -ABS(CFpr * Le * ((Mp+Mw-Mm) * COS(θe))) * g / 1000
= -ABS(CFpr * Le * ((Mp+Mw-Mm) * COS(θe))) * 9.81 / 1000
= **-17.45 kN**

Hydrokinetic force (tensile)

Hye = -(π * Do * Le * CFpb) / 1000
= -(π * 1.118 * Le * CFpb) / 1000
= **-2.89 kN**

Gravity component

Gre = (Le * (Mp + Mw - Mm) * SIN(θe)) * g /1000
= (Le * (Mp + Mw - Mm) * SIN(θe)) * 9.81 /1000
= **-3.23 kN**

Bouyancy is resisting by pushing back this section

Aggregate the axial forces local to this section at the start and end of the section

Axial force section start

Faes = **-50.00 kN**

Pipe floating offshore. Tethering force depends on sea conditions. Nominal value of 50kN assumed.

Increment for section

dFae = Fre + Hye + Gre
= Fre + Hye + Gre
= **-23.57 kN**

Axial force section end

Faee = Faes + dFae
= Faes + dFae
= **-73.57 kN**

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman		WIE16435	
	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall, Option 2)	**Prepared**	**Date**
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		CG	17-Mar-20

Section D - Vertical curve

This is a curved section as the pipe transitions from an incline to horizontal. This induces some forces that are additional to that of a straight section. These additional effects arise from the 'capstan' force required to move the pipe around a curve and the additional normal force and to bending the pipe.

Radius of curvature	Rdc	500.00 m		
Angle of curvature	θdc	5.29 deg	0.09233 radians	
Length of Section	Ld	61.00 m		
Average Slope of Section	θd	2.645 deg	0.046 radians	
Pipe CL datum (start)		-9.00 mOD		
Pipe CL datum (end)		-10.90 mOD		
Hydrotatic Head (start end)	Hhds	23.53 m	***(NB: This is bentonite head)***	
Hydrostatic Head (end end)	Hhde	25.43 m	***(NB: This is bentonite head)***	

Check on curve length	Ldc =	ABS(Rdc * θdc)		
	=	46.16 m	***(Compared to profile figure of 61m)***	*Not used - check only*

Check change in elevation	Hdc =	Rdc * (1 - COS(θdc))		
	=	Rdc * (1 - COS(θdc))		
	=	2.13 m	***(Compared to profile figure of 1.90m)***	*Not used - check only*

Capstan factor	CapFacd =	EulerN^(CFpr *ABS(θdc))	
	=	EulerN^(CFpr *ABS(θdc))	
	=	1.047	***(Increase the pipe pull by this factor)***

Check additional normal force of pipe against borehole due to bending. This will add to the calculation of the friction force. Conservative approach is to consider deflection then determine UDL loading necessary to cause that deflection. Consider both simply supported and fully fixed ends.

Assumed deflection at midpoint	Defdm =	Rdc * (1 - COS(θdc / 2))	
	=	Rdc * (1 - COS(θdc / 2))	
	=	**0.53 m**	

Total UDL equivalent Simply supported ends	Ndss =	Defdm * (384 * Em * Im) * Ld / (5 * Ld^4) / 1000	Pipe confined within the borehole so consider loading as UDL for SS and FF end cases. Note the UDL is multiplied by length to give total load.
	=	Defdm * (384 * Em * Im) * Ld / (5 * Ld^4) / 1000	
	=	**0.96 kN**	

Total UDL equivalent Fully fixed ends	Ndfe =	Defdm * (384 * Em * Im) * Ld / (Ld^4) / 1000	
	=	Defdm * (384 * Em * Im) * Ld / (Ld^4) / 1000	
	=	**4.78 kN**	

Weighted UDL	Nd =	(Ndss + Ndff) / 3 * 2	
	=	(Ndss + Ndff) / 3 * 2	
	=	**3.83 kN**	

Friction forces (tensile) as if straight pipe	Frdl =	-ABS(CFpr * (Ld * (Mp+Mw-Mm) * COS(θd)) * g/1000)	
	=	-ABS(CFpr * (Ld * (Mp+Mw-Mm) * COS(θd)) * 9.81/1000)	
	=	**-46.43 kN**	

Friction forces (tensile) due to bending.	Frdc =	-ABS(CFpr * 2 * Nd * COS(θd))	
	=	-ABS(CFpr * 2 * Nd * COS(θd))	
	=	**-3.822 kN**	

Note that in the above calculations the frictional force due to curvature is 8.23 percent of the linear friction force.

Determine the capstan effect force. It could be argued that considering additional normal force for friction and capstan force is double counting the effect of curvature, but probably not.

Capstan effect increased tension force

Cad = (CapFacd - 1) * (Frdl + Frdc)
(CapFacd - 1) * (Frdl + Frdc)
-2.37 kN

Hydrokinetic force (tensile)

Hyd = -(π * Do * Ld * CFpb) / 1000
= -(π * 1.118 * Ld * CFpb) / 1000
= **-7.67 kN**

Gravity component

Grd = (Ld * Mpb * SIN(θd)) * g /1000
= (Ld * Mpb * SIN(θd)) * 9.81 /1000
= **-4.29 kN**

Bouyancy is resisting by pushing back this section

Aggregate the axial forces local to this section at the start and end of the section. Note horizontal lay out length reduces as pipe pulled in.

Axial force section start

Fads = Faee
= Faee
= **-73.57 kN**

Increment for section

dFad = Frdl + Frdc + Cad + Hyd + Grd
= Frdl + Frdc + Cad + Hyd + Grd
= **-64.59 kN**

Axial force section end

Fade = Fads + dFad
= Fads + dFad
= **-138.16 kN**

Section C - Straight Inclinded

This is a straight section and the stresses in the pipe arise from pulling forces and radial forces acting on the circumfrence of the pipe. The borehole is filled with bentonite and the pipe may contain ballast water.

Length of Section	Lc	229.00	m	
Slope of Section	θc	-1.63	deg	-0.028 radian
Pipe CL datum (start)		-10.90	mOD	
Pipe CL datum (end)		-4.30	mOD	
Hydrotatic Head (start end)	Hhcs	25.43	m	***(NB: This is bentonite head)***
Hydrostatic Head (end end)	Hhce	18.83	m	***(NB: This is bentonite head)***

Friction forces (tensile)
Frc = -ABS(CFpr * Lc * ((Mp+Mw-Mm) * COS(θc))) * g / 1000
= -ABS(CFpr * Lc * ((Mp+Mw-Mm) * COS(θc))) * 9.81 / 1000
= **-174.43 kN**

Hydrokinetic force (tensile)
Hyc = -(π * Do * Lc * CFpb) / 1000
= -(π * 1.118 * Lc * CFpb) / 1000
= **-28.78 kN**

Gravity component
Grc = (Lc * Mpb * SIN(θc)) * g /1000
= (Lc * Mpb * SIN(θc)) * 9.81 /1000
= **9.93 kN**

Aggregate the axial forces local to this section at the start and end of the section.

Axial force section start
Facs = Fade
= Fade
-138.16 kN

Increment for section
dFac = Frc + Hyc + Grc
= Frc + Hyc + Grc
= **-193.28 kN**

Axial force section end
Face = Facs + dFac
= Facs + dFac
= **-331.44 kN**

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman		WIE16435	
	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall, Option 2)	**Prepared**	**Date**
		LP	17-Mar-20
		Checked	**Date**
		CG	17-Mar-20

Section B - Vertical curve

This is a curved section as the pipe transitions from an incline to horizontal. This induces some forces that are additional to that of a straight section. These additional effects arise from the 'capstan' force required to move the pipe around a curve and the additional normal force and to bending the pipe.

Radius of curvature	Rbc	500.00	m		
Angle of curvature	θbc	-8.76	deg	-0.153	radians
Length of Section	Lb	63.00	m		
Average Slope of Section	θb	-4.38	deg	-0.076	radians
Pipe CL datum (start)		-4.30	mOD		
Pipe CL datum (end)		1.00	mOD		
Hydrotatic Head (start end)	Hhbs	18.83	m	***(NB: This is bentonite head)***	
Hydrostatic Head (end end)	Hhbe	13.53	m	***(NB: This is bentonite head)***	

Check on curve length

Lbc = ABS(Rbc * θbc)
= 76.45 m ***(Compared to profile figure of 63.00m)*** *Not used - check only*

Check change in elevation

Hbc = Rbc * (1 - COS(θbc))
= Rbc * (1 - COS(θbc))
= 5.83 m ***(Compared to profile figure of -5.30m)*** *Not used - check only*

Capstan factor

CapFacb = EulerN^(CFpr *ABS(θbc))
= EulerN^(CFpr *ABS(θbc))
= 1.079 ***(Increase the pipe pull by this factor)***

Check additional normal force of pipe against borehole due to bending. This will add to the calculation of the friction force. Conservative approach is to consider deflection then determine UDL loading necessary to cause that deflection. Consider both simply supported and fully fixed ends.

Assumed deflection at midpoint

Defbm = Rbc * (1 - COS(θbc / 2))
= Rbc * (1 - COS(θbc / 2))
= **1.46 m**

Total UDL equivalent Simply supported ends

Nbss = Defdm * (384 * Em * Im) * Ld / (5 * Ld^4) / 1000
= Defdm * (384 * Em * Im) * Ld / (5 * Ld^4) / 1000
= **0.96 kN**

Total UDL equivalent Fully fixed ends

Nbff = Defdm * (384 * Em * Im) * Ld / (Ld^4) / 1000
= Defdm * (384 * Em * Im) * Ld / (Ld^4) / 1000
= **4.78 kN**

Weighted UDL

Nb = (Nbss + Nbff) / 3 * 2
= (Nbss + Nbff) / 3 * 2
= **3.83 kN**

Friction forces (tensile) as if straight pipe

Frbl = -ABS(CFpr * (Lb * (Mp+Mw-Mm) * COS(θb)) * g/1000)
= -ABS(CFpr * (0.00511 * (Mp+Mw-Mm) * COS(θb)) * 9.81/1000)
= **-47.87 kN**

Friction forces (tensile) due to bending.

Frbc = -ABS(CFpr * 2 * Nb * COS(θb))
= -ABS(CFpr * 2 * Nb * COS(θb))
= **-3.81 kN**

Note that in the above calculations the frictional force due to curvature is 7.9 percent of the linear friction force.

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman		WIE16435	
	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall, Option 2)	**Prepared**	**Date**
		LP	17-Mar-20
		Checked	**Date**
		CG	17-Mar-20

Determine the capstan effect force. It could be argued that considering additional normal force for friction and capstan force is double counting the effect of curvature, but probably not.

Capstan effect increased tension force

Cab = (CapFacb - 1) * (Frbl + Frbc)
(CapFacb - 1) * (Frbl + Frbc)
-4.11 kN

Hydrokinetic force (tensile)

Hyb = -(π * Do * Lb * CFpb) / 1000
= -(π * 1.118 * 0.00511 * CFpb) / 1000
= **-7.92 kN**

Gravity component

Grb = (Lb * (Mp+Mw-Mm) * SIN(θb)) * g /1000
= (0.00511 * (Mp+Mw-Mm) * SIN(θb)) * 9.81 /1000
= **7.33 kN**

Bouyancy is assisting by raising this section

Aggregate the axial forces local to this section at the start and end of the section. Note horizontal lay out length reduces as pipe pulled in.

Axial force section start

Fabs = Face
= Face
-331.44 kN

Increment for section

dFab = Frbl + Frbc + Cab + Hyb + Grb
= Frbl + Frbc + Cab + Hyb + Grb
= **-56.37 kN**

Axial force section end

Fabe = Fabs +dFab
= Fabs +dFab
= **-387.81 kN**

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman		WIE16435	
	WIE16435-100: Arklow Bank Wind Park, Phase 2 (Northern Landfall, Option 2)	**Prepared**	**Date**
		LP	17-Mar-20
		Checked	**Date**
		CG	17-Mar-20

Section A - Straight Inclined

This is a straight section and the stresses in the pipe arise from tensile (pulling) forces and radial forces acting on the circumfrence of the pipe. Assume the bore hole is filled with bentonite.

Length of Section	La	86.00	m	
Slope of Section	θa	-8.76	deg	-0.153 radian
Pipe CL datum (start)		1.00	mOD	
Pipe CL datum (end)		14.67	mOD	
Hydrotatic Head (start end)	Hhas	13.53	m	***(NB: This is bentonite head)***
Hydrostatic Head (end end)	Hhae	-0.14	m	***(NB: This is bentonite head)***

Friction forces (tensile)

Fra = -ABS(CFpr * La * ((Mp+Mw-Mm) * COS(θa))) * g / 1000
= -ABS(CFpr * La * ((Mp+Mw-Mm) * COS(θa))) * 9.81 / 1000
= **-64.77 kN**

Hydrokinetic force (tensile)

Hya = -(π * Do * La * CFpb) / 1000
= -(π * 1.118 * La * CFpb) / 1000
= **-10.81 kN**

Exit end of borehole lower than entry, so static mud level may not reach surface at 'A'. However, on pull back mud will be pushed ahead, so assume buoyant...

Gravity component

Gra = (La * (Mp+Mw-Mm) * SIN(θa)) * g /1000
= (La * (Mp+Mw-Mm) * SIN(θa)) * 9.81 /1000
= **19.96 kN**

Aggregate the axial forces local to this section at the start and end of the section. Note horizontal lay out length reduces as pipe pulled in. (By end of this section the pipe is fully inserted.)

Axial force section start

Faas = Fabe
= Fabe
-387.81 kN

Increment for section

dFaa = Fra + Hya + Gra
= Fra + Hya + Gra
= **-55.62 kN**

Axial force section end

Faae = Faas + dFaa
= Faas + dFaa
= **-443.43 kN**

waterman	***Spreadsheet Calcpad*** *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	**Project** WIE16435
	WIE16435 Arklow Bank Wind Park, Phase 2 (Southern Landfall)	**Prepared** LP 30-Jan-20 **Checked** RB 31-Jan-20

This spreadsheet makes extensive use of named cells and custom functions. This enables the calculation cells to be displayed as equations with meaningful variable names rather than the normal Excel cell references. Also, the values that have been used in the calculation are shown above the result.

In order to cope with the large number of named cells, the naming convention is of necessity fairly cryptic - but there is some method to it. This particularly applies to the repetitive calculations relating to each section of the pipe.

Thus for section specific variables the the section name is added as a suffix - eg **Lc**, **Lf** are the **L**engths of sections '**C**' and '**F**' respectively. And similarly **Hyc** and **Hyf** are the Hydrokinetic forces. Where there is a need to make a distinction between the **s**tart and **e**nd of a section then additional suffixes '**s**' and '**e**' are appended to the variable name. There are similar variations on this theme.

Input Data: Constants and Global Variables

Constants

Pi	π	3.142	
Gravity	g	9.81	m/s/s
Eulers Number	e	2.7182	
One metre Head of Water	Hw	0.009804	N/mm^2

Cable Geometry

Cable outside diameter	δ0	266	mm	**Do**	**0.266**	**m**
Cable wall thickness	t =	133	mm			
Cable inside diameter	δi =	δ0 - 2*t		**Di**	**0.000**	**m**
	=	266 - 2*133				
	=	0.00	mm			
Cable X-sect (outer)	Ao =	INT(π * δ0^2 / 4)		**Aom**	**5.5571E-02**	**m^2**
	=	INT(3.142 * 266^2 / 4)				
	=	55571.0	mm^2			
Cable X-sect (inner)	Ai =	INT(π * δi^2 / 4)		**Aim**	**0.0000E+00**	**m^2**
	=	INT(3.142 * 0^2 / 4)				
	=	0.0	mm^2			
Cable wall X-sect area	Ap =	INT(π * (δ0^2 - δi^2) / 4)		**Apm**	**5.5571E-02**	**m^2**
	=	INT(3.142 * (266^2 - 0^2) / 4)				
	=	55571.0	mm^2			
Second Moment of Area	I =	INT(π * (δ0^4 - δi^4) / 64)		**Im**	**2.4575E-04**	**m^4**
	=	INT(3.142 * (266^4 - 0^4) / 64)				
	=	245751651	mm^4			

Modelling Solid Section

Minimum radius of curvature R = 836*δ0 / 1000
= 836*266 / 1000
= **222 m**

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman		WIE16435	
	WIE16435 Arklow Bank Wind Park, Phase 2 (Southern Landfall)	**Prepared**	**Date**
		LP	30-Jan-20
		Checked	**Date**
		RB	31-Jan-20

Densities

Density of fresh water	ρw	1000	kg/m^3
Density of sea water	ρsea	1025	kg/m^3
Density of drilling mud	ρm	1300	kg/m^3

Friction Factors

Between cable and pipe CFpr 0.4 ***Assumed value***

Buoyancy factors

Mass of cable Mp = **139.0** kg/m

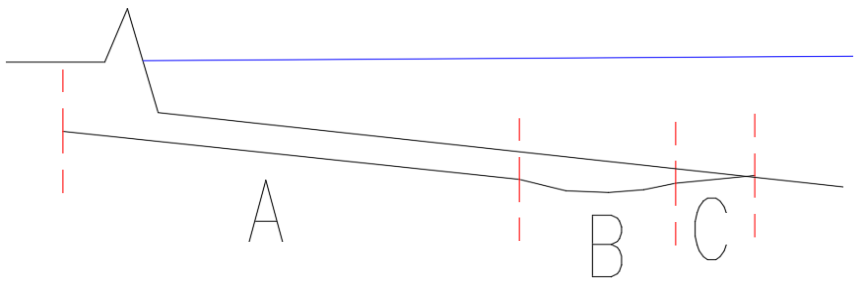
Mass of cable in air as specified by Nexans

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman	WIE16435 Arklow Bank Wind Park, Phase 2 (Southern Landfall)	WIE16435	
		Prepared	**Date**
		LP	30-Jan-20
		Checked	**Date**
		RB	31-Jan-20

Centre Line Profile

	A	A:B	B:C	C				
Ch	20.00	455.00	615.00	669.00				
mOD	-2.40	-11.44	-12.12	-11.50				
Radius		5000						
Slope	-1.19		0.66					

Dimensions and levels are taken from CAD drawing



Summary Results

The general arrangement of the HDD borehole geometry is shown in the figure above. The analysis of the forces and combined stress during the cable pull will consider each section of the profile in order to identify the most critical portion. It is assumed that the maximum pulling force will be just as the cable reaches full insertion.

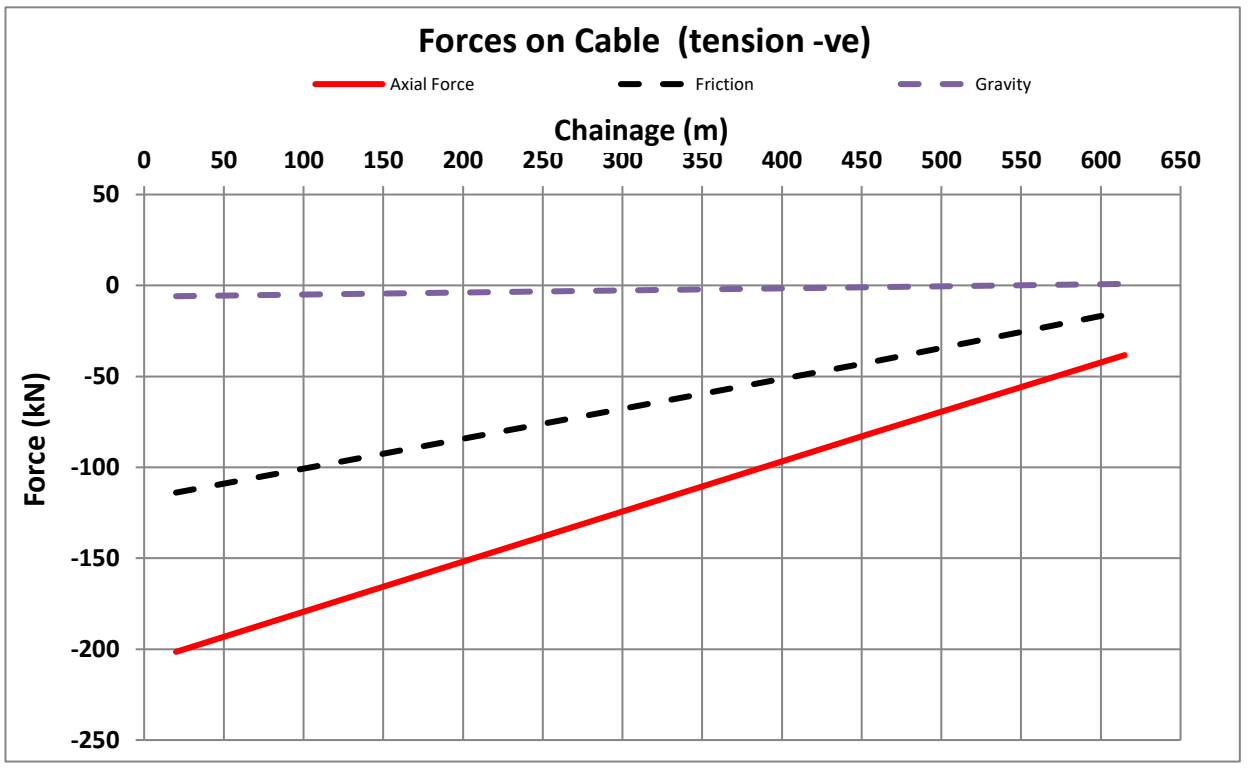
Sign Convention:

Axial Tensile Force: -ve	Axial Compressive Force: +ve
Tensile Stress -ve	Compressive Stress +ve
Weight (gravity) +ve	Buoyancy (uplift) -ve

waterman	***Spreadsheet Calcpad*** *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	**Project** WIE16435
	WIE16435 Arklow Bank Wind Park, Phase 2 (Southern Landfall)	**Prepared** LP / **Date** 30-Jan-20 **Checked** RB / **Date** 31-Jan-20

Table of Cable Forces (kN)

Section	Length (m)	Chng (m)	Friction Comp	Hydro Comp	Gravity Comp	Axial Force
A	435	20.00	-113.93	0.00	-5.92	-201.49
B	160	455.00	-42.26	0.00	-1.09	-81.65
C	54	615.00	-14.14	0.00	0.85	-38.30



Section C - Straight Inclined

This is a straight section and the stresses in the pipe arise from pulling forces and radial forces acting on the circumfrence of the pipe. The borehole is filled with bentonite and the pipe may contain ballast water.

Length of Section	Lc	54.00	m	
Slope of Section	θc	0.66	deg	0.012 radian
Pipe CL datum (start)		-11.50	mOD	
Pipe CL datum (end)		-12.12	mOD	

Friction forces (tensile)

Frc = -ABS(CFpr * Lc * ((Mp+Mw-Mm) * COS(θc))) * g / 1000
= -ABS(0.4 * 113 * ((139+0-72.2) * COS(-0.007))) * 9.81 / 1000
= **-14.14 kN**

Gravity component

Grc = (Lc * Mpb * SIN(θc)) * g /1000
= (113 * 66.76 * SIN(-0.007)) * 9.81 /1000
= **0.85 kN**

Aggregate the axial forces local to this section at the start and end of the section. Note horizontal lay out length reduces as pipe pulled in.

Axial force section start

Tethering Force depends on sea conditions. Nominal value of 25kN assumed.

Facs = **-25.00 kN**

Increment for section

dFac = Frc + Hyc + Grc
= -29.6 + -4.72 + -0.54
= **-13.30 kN**

Axial force section end

Face = Facs + dFac
= -44.64 + -34.86
= **-38.30 kN**

	Spreadsheet Calcpad *(Macros must be enabled. Ctrl+Alt+F9 recalculates.)*	Project	
waterman	WIE16435 Arklow Bank Wind Park, Phase 2 (Southern Landfall)	WIE16435	
		Prepared: LP	Date: 30-Jan-20
		Checked: RB	Date: 31-Jan-20

Section B - Vertical curve

This is a curved section as the pipe transitions from an incline to horizontal. This induces some forces that are additional to that of a straight section. These additional effects arise from the 'capstan' force required to move the pipe around a curve and the additional normal force and to bending the pipe.

Radius of curvature	Rbc	5000.00	m	
Angle of curvature	θbc	-1.19	deg	-0.021 radians
Length of Section	Lb	160.00	m	
Average Slope of Section	θb	-0.595	deg	-0.010 radians
Pipe CL datum (start)		-12.12	mOD	
Pipe CL datum (end)		-11.44	mOD	

Check on curve length

Lbc = ABS(Rbc * θbc)
= 103.85 m ***(Compared to profile figure of 160.00m)*** *Not used - check only*

Check change in elevation

Hbc = Rbc * (1 - COS(θbc))
= 500 * (1 - COS(-0.18))
= 1.08 m ***(Compared to profile figure of -0.68m)*** *Not used - check only*

Capstan factor

CapFacb = EulerN^(CFpr *ABS(θbc))
= 2.7182^(0.4 *ABS(-0.18))
= 1.008 ***(Increase the pipe pull by this factor)***

Check additional normal force of pipe against borehole due to bending. This will add to the calculation of the friction force. Conservative approach is to consider is to calculate deflection then determine UDL loading necessary to cause that deflection. Consider both simply supported and fully fixed ends.

Assumed deflection at midpoint

Defbm = Rbc * (1 - COS(θbc / 2))
= 500 * (1 - COS(-0.18 / 2))
= **0.27 m**

Total UDL equivalent Simply supported ends

Nbss = Defdm * (384 * Im) * Ld / (5 * Ld^4) / 1000
= 0 * (384 * 0.00024575) * -669 / (5 * -669^4) / 1000
= **0.00 kN**

Pipe confined within the borehole so consider loading as UDL for SS and FF end cases.
Note the UDL is multiplied by length to give total load.

Total UDL equivalent Fully fixed ends

Nbff = Defdm * (384 * Im) * Ld / (Ld^4) / 1000
= 0 * (384 * 0.00024575) * -669 / (-669^4) / 1000
= **0.00 kN**

Weighted UDL

Nb = (Nbss + Nbff) / 3 * 2
= (0 + 0) / 3 * 2
= **0.00 kN**

Friction forces (tensile) as if straight pipe

Frbl = -ABS(CFpr * (Lb * (Mp+Mw-Mm) * COS(θb)) * g/1000)
= -ABS(0.4 * (88 * (139+0-72.2) * COS(-0.09)) * 9.81/1000)
= **-41.91 kN**

Friction forces (tensile) due to bending.

Frbc = -ABS(CFpr * 2 * Nb * COS(θb))
= -ABS(0.4 * 2 * 0 * COS(-0.01))
= **0.00 kN**

Note that in the above calculations the frictional force due to curvature is 0 percent of the linear friction force.

Determine the capstan effect force. It could be argued that considering additional normal force for friction and capstan force is double counting the effect of curvature, but probably not.

Capstan effect increased tension force

Cab = (CapFacb - 1) * (Frbl + Frbc)
(1.008 - 1) * (-41.91 + 0)
-0.35 kN

Gravity component

Grb = (Lb * (Mp+Mw-Mm) * SIN(θb)) * g /1000
= (88 * (139+0-72.2) * SIN(-0.09)) * 9.81 /1000
= **-1.09 kN**

Aggregate the axial forces local to this section at the start and end of the section. Note horizontal lay out length reduces as pipe pulled in.

Axial force section start

Fabs = Face
= -79.51
-38.30 kN

Increment for section

dFab = Frbl + Frbc + Cab + Hyb + Grb
= -41.91 + 0 + -0.35 + 0 + -1.09
= **-43.35 kN**

Axial force section end

Fabe = Fabs +dFab
= -38.3 +-43.35
= **-81.65 kN**

Section A - Straight Inclined

This is a straight section and the stresses in the pipe arise from tensile (pulling) forces and radial forces acting on the circumfrence of the pipe. Assume the bore hole is filled with bentonite.

Length of Section	La	435.00	m	
Slope of Section	θa	-1.19	deg	-0.021 radian
Pipe CL datum (start)		-11.44	mOD	
Pipe CL datum (end)		-2.40	mOD	

Friction forces (tensile)

Fra = -ABS(CFpr * La * ((Mp+Mw-Mm) * COS(θa))) * g / 1000
= -ABS(0.4 * 92 * ((139+0-72.2) * COS(-0.18))) * 9.81 / 1000
= **-113.93 kN**

Gravity component

Gra = (La * (Mp+Mw-Mm) * SIN(θa)) * g /1000
= (92 * (139+0-72.2) * SIN(-0.18)) * 9.81 /1000
= **-5.92 kN**

Aggregate the axial forces local to this section at the start and end of the section. Note horizontal lay out length reduces as pipe pulled in. (By end of this section the pipe is fully inserted.)

Axial force section start

Faas = Fabe
= -81.65
-81.65 kN

Increment for section

dFaa = Fra + Hya + Gra
= -23.71 + -3.84 + -10.79
= **-119.84 kN**

Axial force section end

Faae = Faas + dFaa
= -81.65 + -119.84
= **-201.49 kN**

UK and Ireland Office Locations

