Sheet 1 of 20

DONG Energy

Walney Extension
Export Cable Landfall
HDD Technical Assessment

B	**11-12-13**	**For information**	**R. Cooke**	**J. Stoelinga**	**J. Stoelinga**		
A	**10-12-13**	**For Information**	**R. Cooke**	**J. Stoelinga**	**J. Stoelinga**		
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Landfall HDD Technical
Assessment

ORIGINATOR

Visser & Smit Hanab

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REVISION CHANGE DETAILS		
Revision	Location of change	Brief description of change
0	All of document	First Issue
A	All of document	Amended to reflect Client's comments & additional requirements
B	Throughout document	Amended to reflect Client's comments

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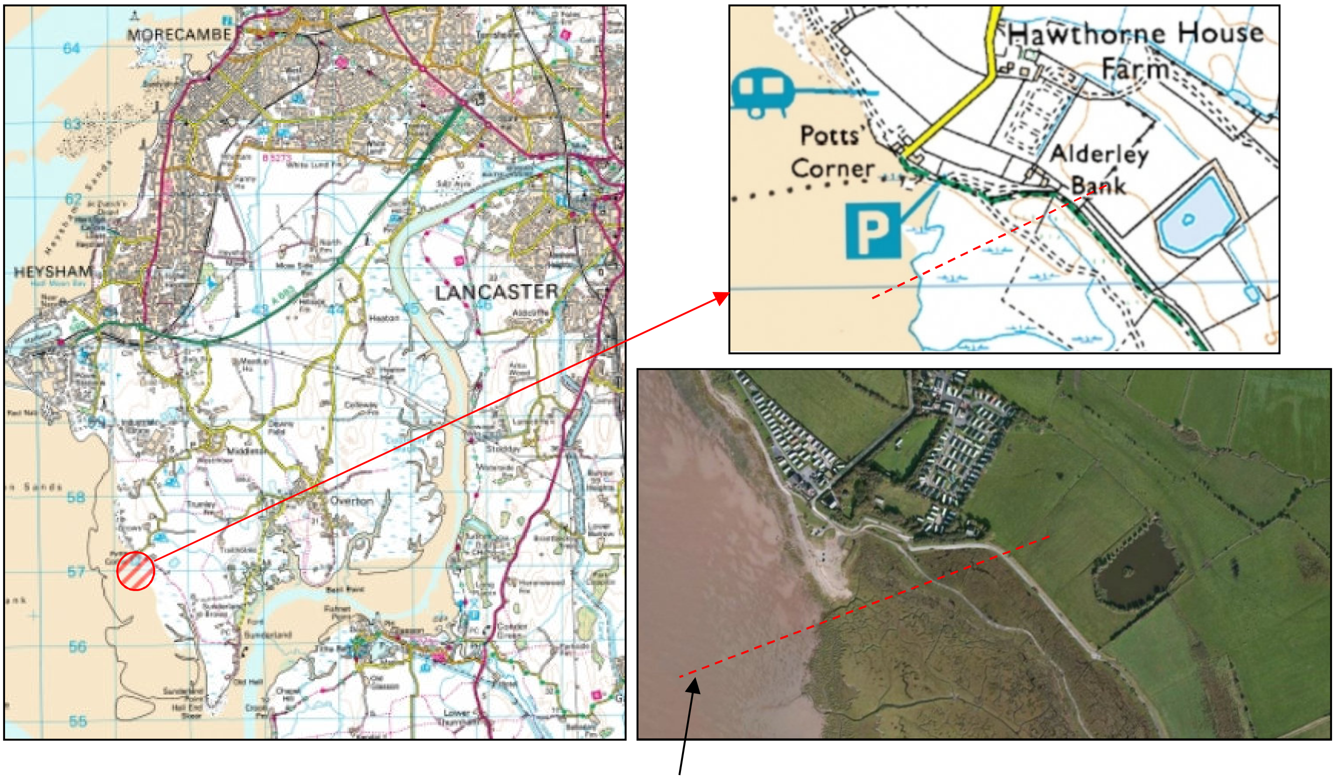
1. INTRODUCTION

Visser & Smit Hanab (VSH) have been appointed by DONG energy (DE) to provide a high level assessment of the export cable landfall(s) associated with the extension to the existing Walney Extension Offshore Windfarm. The project involves the landing of 220kV export cable systems. It is intended that the cable connections shall be installed by means of Horizontal Directional Drill (HDD), exiting onto the beach within the intertidal zone, beyond which the cable will be buried beneath the sea bed out to the Offshore Windfarm. The HDD option is driven by the sensitive salt marshes at the landfall location and the need to cross the sea defence structure.

The preferred landfall location, south of Heysham, Lancashire, has been identified by DONG energy and is shown below;



Indicative location of HDD Landfall (N.T.S)

This report is intended to provide a high level overview of the viability of installing the landfalls by means of HDD at the above location. The study will take into account the design of the HDD profiles, soil conditions, site constraints and set up and pipe stringing locations, based on the available data.

A site visit was attended by Bryan Lynch of DE, Jorn Stoelinga and Rebecca Cooke of Visser & Smit Hanab on 14th November 2013. Access and local conditions were evaluated at the site.

2. ENGINEERING

2.1 Design Considerations

The export cable to be installed within the HDD cable duct is a submarine cable with an OD of 270 mm. As a rule of thumb, this requires a duct with an ID of 1.5 x the OD of the cable, hence 405 mm. This would result in a 500 mm SDR 11 HDPE pipe. (OD 500 mm, ID 410 mm). Further assessment of the required pipe diameter must be made based on the detailed pull force and other installation calculations, in order to confirm the suitability of this pipe. It may be necessary to apply a higher grade (larger wall thickness) and thus larger OD pipe due to mechanical properties. The preparation of such calculations is currently outside the scope of this report.

The HDD installation must pass beneath the sea defence structure and sensitive salt marshes, thus the depth of installation will be determined to ensure there is no structural impact to the structure.

Issues associated with utility service crossings, environmental requirements, consents, archaeological value, contaminated land and land owner requirements which may influence the final HDD profiles have not been addressed as part of this high level study and are currently outside the scope of Visser & Smit Hanabs remit.

Photo 1.0:- View across Salt Marshes

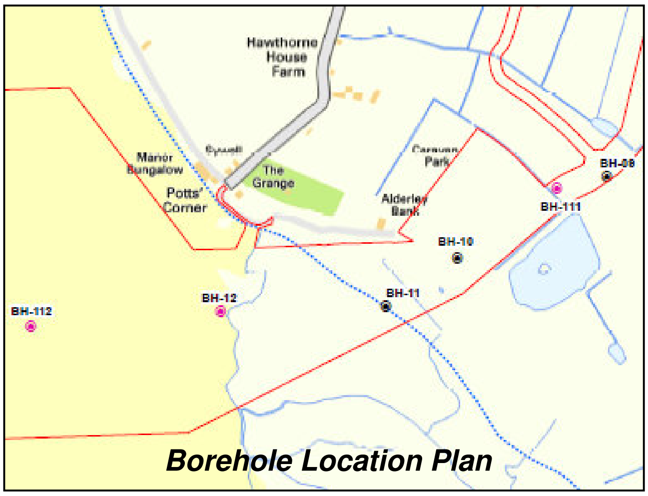
Photo 2.0:- Car Remnants on the Beach

The beach area has been regularly used by the local community and in particular, beach car racing. The remnants of sunken cars can be seen at low tide.

In addition, it is understood that the area has been used for Army Practice and also, anti-landing obstacles were installed during World War II, the remains of which are thought to be buried below the beach. Before commencing HDD works, it is critical that a thorough archaeological survey to include UXO, will need to be carried out within the affected area.

2.2 Soil Evaluation

The substrata is an important factor in Horizontal Directional Drilling. It determines the tools, equipment and drilling fluids that are required, as well as the time it takes to drill the hole. A dedicated soil investigation has been carried out by others for the entire cable route, including the land section and the landfall. Boreholes were sunk using a shell and auger rig, relatively shallow.



For the landfall, Boreholes 10, 11 and 12 are relevant (refer to the adjacent plan). These were sunk to 15, 10.50 and 10.50 metres depth respectively. The commentary provided regarding borehole 11 states that it was terminated due to the presence of dense cobbles. Boreholes 10 and 11 show the same layering of soft silty clay and sand, overlaying approximately 3m of red gravelly clay, with possible cobbles. Borehole 12 indicates looser sand in the top 3m, followed by sandy clay. Towards the end of the borehole, very stiff reddish gravelly clay was encountered. (Refer to the attachments for the full logs of the Boreholes).

Photo 3.0:-Millstone Grit

The boreholes reflect the general geology which can be expected in this area. The underlying bed rock is a very layered and fractured sandstone, referred to as Millstone Grit. This is a highly abrasive material. It is likely that on top of the bed rock a layer of cobbles and boulders is encountered. The thickness of this layer can vary dramatically. The bedrock and layer above are unsuitable for the HDD technique.

The adjacent photograph shows the Millstone Rock outcrops visible at nearby Heysham.

The top 9 m (approximately) of sediments is composed of soft silty clay and sand, overlaying red gravelly clay which is suitable for HDD, the bedrock encountered at around 9 m is unsuitable due to its instability and fractured nature, and drilling is not proposed within the bedrock layer. Based on the available evidence, it is considered with a high degree of certainty that HDD is feasible within a depth range of 6 – 8 m deep.

At the detailed design stage, it will be necessary to obtain further information on the thickness of the layer of sand and clay and the transition zone thereof to the bedrock and the intermediate layer, in order to further refine the likely depth of the HDD profile. This could be done by performing a non-intrusive geophysical investigation in further engineering stages, e.g. Seismic refraction, geared towards investigation of the interface overburden / bed rock. The drilling of additional boreholes is not required.

2.3 Drilling Profile

HDD cross sectional profiles and alignments of the crossings specified in the Introduction have been developed based on the information provided, including Google Earth and Lidar data where available. The profiles take into account the depth of cover under the critical features and the limitations of the tooling, including bending radius. The current center line is designed at 2 m below OD, between 6 to 8 m deep, as shown in the profile drawing in the attachments.

The drilling operation will start onshore within farmland behind the sea defence structure and will exit on the beach. Drilling from onshore to offshore, provides the most feasible solution, limiting operations on the beach and the need for a considerable working platform within the intertidal area.. As stated in 2.2 above, the preference would be to ensure the drilling profile is above the bed rock and thus within the sandy clay located above. This would ensure the HDD operation is viable, however mud outbreaks could possibly occur as a result of the relatively unconsolidated nature of the top 9m of sediments.

Measures would be taken to reduce the chance of bentonite mud outbreaks on such an occurrence by adjusting the bit size and reducing flow rate as well as to limit the impact from such a breakout by means of physical containment and subsequent removal. The entry, exit and drilling lengths are determined based on a number of factors, including the topography and underlying soil conditions. The influence of the expected profile depth on the functionality of the installed cable must be further considered, however, the cable specification is currently unavailable.

The indicative drilling profile has been designed as a straight line between the exit and entry points (see drawing in the attachments).

2.4 Drilling Fluid

During the drilling process, a fluid (or mud) is used. The drilling mud used in the drilling process may rise to surface at either the entry or the exit point. The recycling equipment and high pressure pump are installed at the entry point. The drilling mud that surfaces at the exit location must be transported to the entry location. This is best done by laying a return line on the beach towards the car park, parallel to the sea defence to the entry site. This mud return line must be secured against the tidal effects.

The drilling fluid has several functions which include the following:

- Transportation of drilled solids and fluid out of the borehole
- Powering the mud motor if used
- Keeping the solids in suspension when circulation stops to prevent deposition of solids
- Stabilisation of borehole by static pressure against soil formation

- Creation of a filter cake to minimize the penetration and loss of drilling fluid into the formation and the flow of groundwater into the borehole
- Lubrication of the pipe during pull back, reducing the pull force on the pipe
- Cooling and lubrication of the drilling equipment, tools and drill pipe.

Additional requirements:
- Minimum impact on surrounding soil formations
- No harmful impact on environment and groundwater
- No harmful impact on drilling equipment and pipe.

The mud is mixed locally and contains around 95% water and 5% of a special clay called bentonite. Some additives may be used in small amounts to improve the properties of the fluid. All components have been tested and approved for their environmental impact. Given the probability of a mud breakout occurring, and hence the mixing of sea water with the mud, a salt water based drilling mud should be used.

3. ACCESS &SITE REQUIREMENTS

3.1 Access & Site Requirements

Existing access to the rig site located within farmland behind the sea defence structure is currently poor, with narrow lanes and tight bends. Although general access to the anticipated site entrance, off the public highway (Carr Lane) is considered poor, it is manageable. Traffic management will need to be established to facilitate the movement of heavy plant and vehicles into and out of the site entrance. There is also likely to be a requirement to temporarily remove hedgerows at the site entrance off the public highway. Carr Lane has previously been the main access route for heavy transport to the open-cut landfall associated with the West of Duddon Sands Project, in close proximity to this location.

Photo 4.0:-Existing Access off Carr Lane

Photo 5.0:-Farm track leading off Carr Lane

With regards to access from the site entrance on the public highway, via the farm track and into the field, re-inforcement will be required. The following requirements are standard and must be met as a minimum to enable the HDD operation to be achieved;

The access route to the rig site and the compound must be suitable for safe manoeuvrability of heavy goods vehicles. A suitable haul road would need to be created into the rig site with a hard standing/compound area. In addition, suitable access into the pipe welding area (pipe welding location yet to be determined) will need to be created.

The haul road (and compound) would need to accommodate 10 ton axle loads and would need to be in the region of 3.5/4 metres wide. A temporary hard standing area to be used as a compound shall need to be available and/or created for the duration of the works. The compound required for this operation is likely to be in the region of 50m by 50m as a general rule of thumb, to enable the accommodation of the drilling rig, ancillary plant and equipment and to enable the safe offloading of materials and safe manoeuvre of vehicles and pedestrians within the site. A typical site setup schematic is included within the drilling profile drawing within the Appendices. A turning area within the compound for HGV's shall be required. A number of options are present for the creation of the haul road and compound, namely the laying of steel

The following photographs taken from a previous project show a typical site haul road and compound hard standing, created using steel plates;

Photo 6.0

Photo 7.0

It is currently envisaged that a maxi type drilling rig is required for this operation similar to that shown in the following images.

The following photographs show the 100 Ton Drilling Rig;

Photo 8.0 & 9.0

The ground profile and gradient of the site should be considered. The site must be stable enough to accommodate the weight requirements of the necessary plant and equipment. The site layout together with any apparent obstructions/obstacles within the site should be considered, for example: mature tree's, overhead power lines, drainage channels etc. In addition, the presence of any utility services must be established, particularly in relation to the excavation of entry/exit pits.

An area equal to the drill length must be available with access to the sea, to enable the fabrication and laying out and subsequent float out of the pipe strings. It would be necessary to find a suitable location elsewhere along the coast to eliminate any interface with the sensitive salt marshes present at the landfall location. That said, it may be possible to prepare the pipe string within the car park close to the beach access, subject to agreement and pull the string in a northerly direction as it is being welded. The pipe would require anchoring down by tying it to small poles or sheet piles.

Alternatively, the pipe string(s) may be floated to the landfall location shortly prior to pull back, in a complete string either welded elsewhere or directly from a specialist factory where the pipe is produced in a single continuous length. The single length production would remove the requirement for on-site butt fusion welding. This option has the added advantage of eliminating the joints present in the butt fusion option and thus potential area of weakness, as the pipe is extruded in a complete string.

The following photograph shows the butt fusion operation to fabricate the pipe string from 12metre lengths. The pipe shown is a 560mm diameter PE pipe;

Photo 10.0

The following photograph shows a pipe being towed to the UK from Manufacturer's in Norway. The pipe shown is a 710mm diameter PE pipe and is over a kilometre in length;

Photo 11.0

During the HDD process, a reliable water source is required. The volume required would depend on the ground conditions encountered. As a rough indication, the volume of water used at each stage would be in the region of 30% pilot drilling, 60% reaming phase and 10% during pull back operations. It is currently envisaged that a salt water supply would be utilised for the drilling fluid. Water would need to be abstracted from the sea via a series of hoses with a pump submersed in the sea water or alternatively brought in by tanker from an alternative sea water abstraction point The abstraction of water would be subject to obtaining the necessary permissions and consent. The current estimated volume of water consumption, assuming there are no losses during the drilling process is in the region of 500m^3.

The site must be suitably secured, however, where necessary, this is usually established by the erection of Heras fencing and the use of site security.

The following shows a typical working area for the drilling operation. Note the pre-fabricated pipe strings behind, ready to be pulled out into position for the pull back operation. The field shown proved the most suitable location for welding and laying out of the pipe strings, with easy access to the sea. The pipe strings were manoeuvred onto the shore and pulled out by tug boat ready for the pull back operation.

Photo 12.0

Once the pilot hole has been drilled, the hole will need to be enlarged in the so called reaming process. To minimize the operations on the beach, this will be done by so called forward reaming instead of traditional back reaming.

The exit point can be reached over the beach, without impinging on the sensitive salt marshes. There is a beach access close to the exit point. At low tide the sand dries out hard and becomes firm enough to enable light construction equipment to pass over. At high tide equipment and materials must be transported back to the beach access point.

4. METHODOLOGY

The Horizontal Directional Drilling operation is essentially a three staged process, consisting of the pilot hole, reaming phases and finally the pull back of the product pipe.

4.1 Pilot Hole

The drilling rig will be setup and aligned along the project centre-line and elevated to the requisite entry angle in relation to the pre-surveyed entry point. The auxiliary equipment e.g. control cabin, hiab flat, recycling unit etc. will be placed in the vicinity of the drilling rig.

Typically a drilling rig in the region of 100 ton pulling capacity would be utilised, using a 9 5/8 drill bit on 4 ½ drill pipe. In order to reduce mud pressure in the pilot stage, it is recommended to use a larger bit, e.g. 12 ¼", thus creating a larger flow path in the annulus around the drill pipe, thus requiring less pressure for the mud to rise to surface. The pilot hole will commence along the designed profile. A bottom hole assembly (BHA) consisting of a 12 ¼" bit and steering housing will be pushed into the ground with the drill string. The use of a mud motor is currently not foreseen but could be required.

The following photographs show the rig setup and the commencement of the Pilot Hole;

Photo 13.0

Photo 14.0

Drilling mud, consisting of a mixture of water and bentonite will be pumped down the drill string through the bit. The hydraulic power of the mud through the nozzles in the bit will hydraulically cut the stratum in front of the bit. The drilling mud will bring the cuttings contained within the drilling fluid back to the entry point holding pit, excavated in front of the drilling rig. From this point the returning fluid will be pumped back to the mud mixing/recycling unit where the drilling fluid will be cleaned to remove the arisings from the borehole, before being pumped over to a mud holding tank. The fluid will then be fed from this tank to one of two high-pressure triplex mud pumps. From here it will be pumped up to the rear of the drilling rig rotary drive unit and pumped down the hole inside the drill string to the down hole BHA. The recycling unit can also be utilised as a mixing unit to introduce additional bentonite into the system as fluid levels reduce.

Directional control is accomplished by rotating the drill string to orient a bent sub between the bit and the steering tool thereby creating a steering bias in the direction and plane of the bent housing. If a change in direction is required, the drill string is rotated thereby changing the bent sub to the desired orientation.

The trajectory of the pilot hole is determined by taking periodic surface readings of the inclination and azimuth from the steering tool located behind the bent housing of the bottom hole assembly. These readings are transmitted as a signal to the surface computation unit, in conjunction with measurements of the distance drilled since the last survey, the Surveyor is able to calculate the horizontal and vertical co-ordinates of the bottom hole assembly relative to the entry point at the surface. Directional surveys are taken at least when a joint of drill pipe is added, or more often if required. Survey coordinates are plotted along the design plan and profile drawings to monitor the course of the drill bit. If unacceptable deviations occur, the drill string is withdrawn sufficiently to re-drill the pilot hole within acceptable limits. Deflections of the borehole path will be held to a tolerance equivalent to the minimum radius of curvature allowable for the pipeline to be installed.

The steering system for this operation can either be a gyro based system, or a system using the earth’s magnetic field. In the latter, a wire or grid must be laid out from the entry pit up to the salt marshes. If no pedestrian access is allowed on the marshes, a new grid can be laid out near the exit point. An electrical current is applied to the wire grid which generates another magnetic field of known strength and orientation. As this magnetic field is picked up by the sensors in the tool, it can be used to determine the tool’s position. The second system is an optical gyro, which cannot be affected by external sources. However, the gyro tool requires regular calibration during the drilling process. Further information with regards to the Optical Gyro is contained within the Appendices of this document.

4.2 Reaming

Once the hole has been drilled, it’s diameter is too small for the duct to be installed. The hole must thus be enlarged to ensure safe passage of the cable duct. This is done by the so called reaming process. The Bottom Hole Assembly (BHA) used for the pilot hole, will be removed. A special tool, called a fly cutter will be used.

In order to reduce the activities on the beach, and to make the HDD operations more independent from the tides, the pilot hole will not be completed. Shortly before exiting on the beach, the pilot hole drilling will be stopped and the drill bit retracted to the rig. The fly cutter will then be connected to the string at the rig and pushed along the hole, while rotating and pumping drilling mud into the bore preceded by a special sub guiding the reamer into the existing hole.

This process can be repeated until the final diameter of 28" (normally approximately 1.5 x the OD of the duct) is reached. One or two steps are normally sufficient to reach this diameter in this type of formation.

When the hole has been enlarged and has thus reached its final diameter, the final break through of the borehole to the beach will be made. This will require the same steps, pilot and reaming to be repeated over the last section of hole.

4.3 Pullback

Once the hole has been properly conditioned the duct can be pulled in. Immediately, before pull back the pre-fabricated pipe string is pulled out onto the beach/sea and aligned with the exit point. Furthermore, it is then pulled towards the exit point, with a short straight section immediately behind the exit point and in a curve back to the beach. Poles can be installed again to hold the pipe in place, where required, on the beach.

At the exit point a barrel type reamer will be connected to the drill string. To allow rotation of the drill pipes a swivel will be connected to the trailing end of this barrel thus preventing torsional stress from the drill pipes being transferred to the duct. The duct is then pulled into the hole in one continuous operation.

During this step, drilling mud will flow into the sea. The amount is difficult to predict but will be in the region of 30 m3.

5. IN THE EVENT OF A BENTONITE BREAKOUT ON THE SALT MARSHES

The drilling process will need to be adapted to reduce the risk of break outs of drilling mud to surface. This will be done by using a larger bit, thus enlarging the flow path around the drill pipe and hence reducing the pressure required for the mud to flow back through the hole to the entry point. However, taking into account the limited cover as a result of the bedrock being close to surface and unsuitable for HDD, the occurrence of a break out of bentonite to surface cannot be ruled out.

Therefore, a team should be on standby near the borders of the marshes, constantly looking for such an outbreak. In case this actually happens, the drilling operations would be interrupted and the break out contained by means of sand bags and or oil spill kit type material. Oil spill material is only suggested for its absorbing capacity. Drilling mud used in HDD;s does not contain any oil, only water and an inert clay material. Pumps must then be installed and hoses or pipes laid to shore, to enable the spillage of drilling fluid to be transferred back to the rig site for re-use in the process. The area affected by the spill would normally be limited to approximately 2 x 2 m.

6. CONCLUSIONS AND RECOMMENDATIONS

In general, it is concluded that an HDD solution is a viable option for this landfall, on the basis that the profile is designed above the bed rock in the soft material (6-8 m depth). Given the nature of this material and the mud pressures required to undertake the drilling operation, it is likely that drilling fluid will breakout to the surface. Possible measures during the drilling operation to limit the extent of the mud dispersal in this area include: the use of a larger bit to reduce the pressures in the borehole, and having a team ready near the salt marshes to look out for break outs, and when they occur to stop the drilling process and contain the flow of bentonite. Any identified mud breakout could either be contained by physical means to facilitate subsequent removal or alternatively, allowed to wash into the sea. The drilling fluid, is generally 95% water (sea water in this case) and 5% bentonite (an inert clay substance) thus its chemical composition is harmless to the marine environment.

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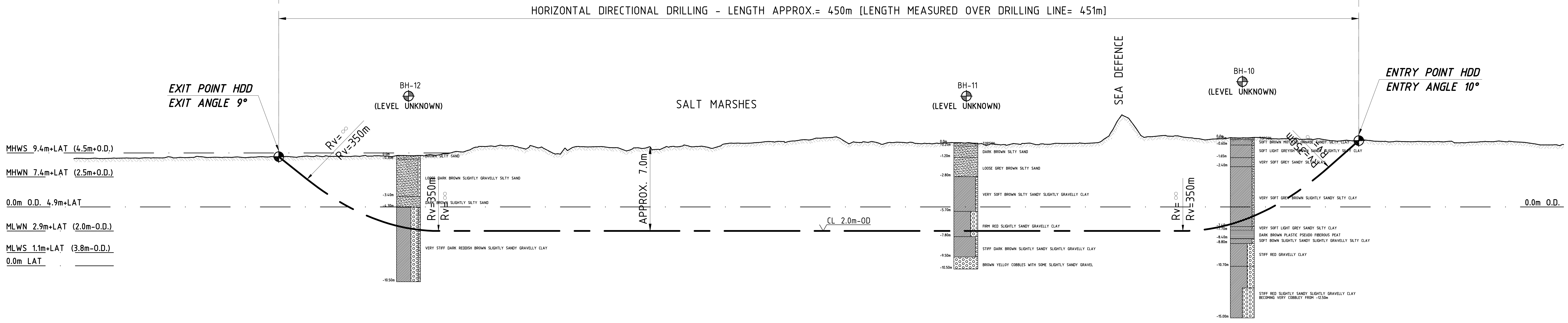
APPENDIX I

CROSS SECTIONAL HDD PROFILE & PLAN DRAWING

SITUATION

SCALE 1 : 1000

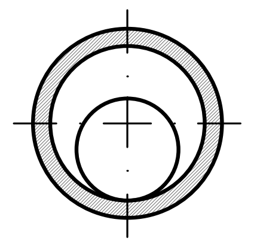


LONGITUDINAL PROFILE

SCALE H=1 : 1000

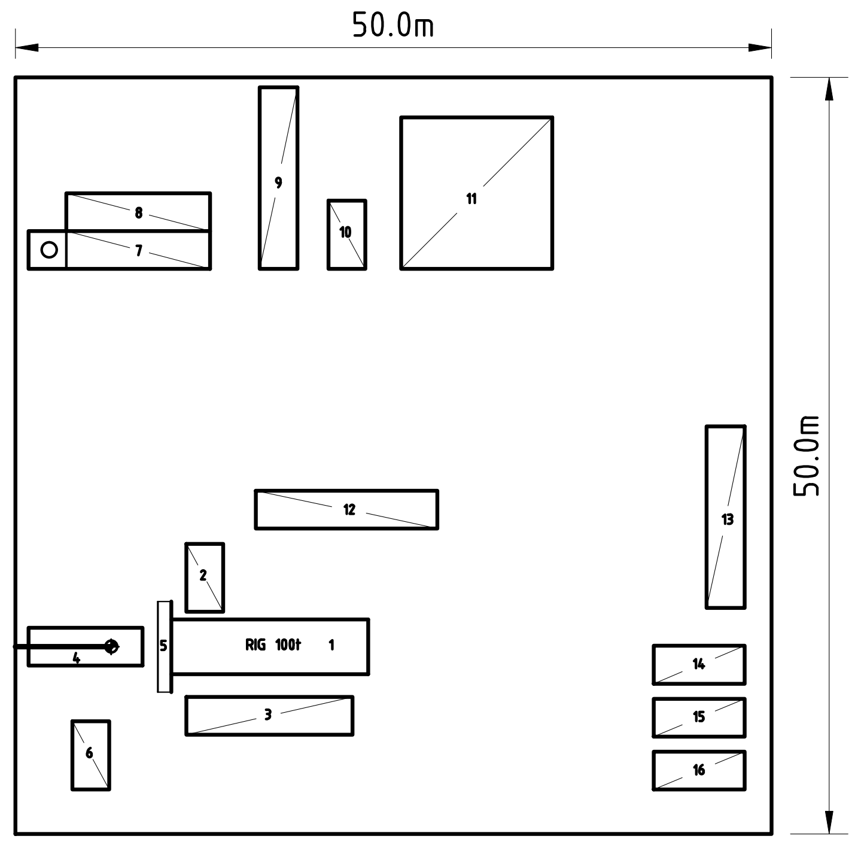
V=1 : 200

TO INSTALL
CASING PIPE
⌀500 PE100 SDR 11
WITH CABLE ⌀270



CROSS-SECTION

SCALE 1 : 20



LAY OUT WORKING AREA

SCALE 1 : 500

SITE LAYOUT 100 TONS RIG

1 DRILLRIG
2 OPERATING CABIN
3 FLATBED CONTAINER
4 MUD PIT
5 DEAD MAN
6 PUMP
7 RECYCLING UNIT
8 CUTTINGS
9 MUD IN STOCK
10 HIGH PRESSURE MUDPUMP
11 BENTONITE IN STOCK
12 PIPES IN STOCK
13 OFFICE V&SH
14 WORKSHOP
15 GENERATOR
16 STORAGE

REMARKS

- SITUATION FROM LIDAR DATA RECEIVED FROM DONG ENERGY AND GOOGLE MAPS IMAGE DATA
- COORDINATES IN BRITISH NATIONAL GRID (OSGB36 / O.D. NEWLYN)
- LONGITUDINAL PROFILE GENERATED FROM LIDAR DATA RECEIVED FROM DONG ENERGY
- SOIL INFORMATION TAKEN FROM DUNELM REPORT RECEIVED FROM DONG ENERGY (LEVELS OF BOREHOLES UNKNOWN)
- TIDAL LEVEL TAKEN FROM TIDAL PREDICTION SOFTWARE "TIDE PLOTTER" AT HEYSHAM

- **EXISTING PIPELINES AND CABLES TO BE LOCATED BEFORE THE START OF WORK**

PRELIMINARY

REV.	DATE	REVISION	DWN	CKD	STATUS
B	12-12-13	RETURN PIPELINE REMOVED	MHU	JRH	FOR TENDER
A	09-12-13	DRILLING LINE CHANGED	MHU	JRH	FOR TENDER
0	02-12-13	FIRST ISSUE	MHU	JRH	FOR TENDER

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CLIENT: DONG ENERGY

PROJECT: SUBMARINE CABLE LANDFALL

SUBJECT: GENERAL PLAN
HDD LANDFALL AT
MIDDLETON

SCALE	FORM.	PROJECT NO.	DRAWING NO.	SHEET:	OF:	REV.
1 : 1000	A1		TP13194-0-X-02	1	1	B

Date: 12-12-2013 / Time: 16:15 / Drawing: G:\OCT\2013\TP13194\Technologie\OUTFALL\STRUC\X-02.dwg

APPENDIX II

OPTICAL GYRO DETAIL

THE MOST ADVANCED STEERING TOOL IN THE WORLD

Drillguide GST

GYRO STEERING TOOL

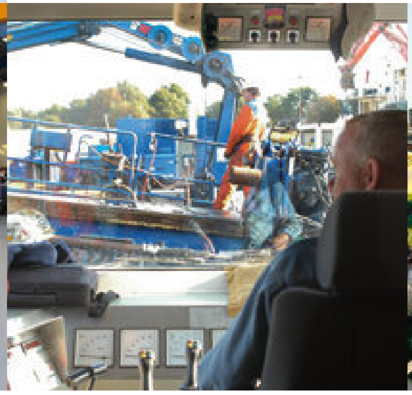
DON'T JUST GUESS, BE PRECISE !

Horizontal directional drilling is a specialized profession nowadays. The days when directional drilling was ruled by assumptions, are far behind us. Clients are more demanding, drillings get more and more complex and the underground infrastructure is more dense and complex. All these factors require a professional approach to complete a successful drilling project. Also the capital-intensive investment, related to the drilling project, requires a smooth completion, resulting in a positive revenue per project.

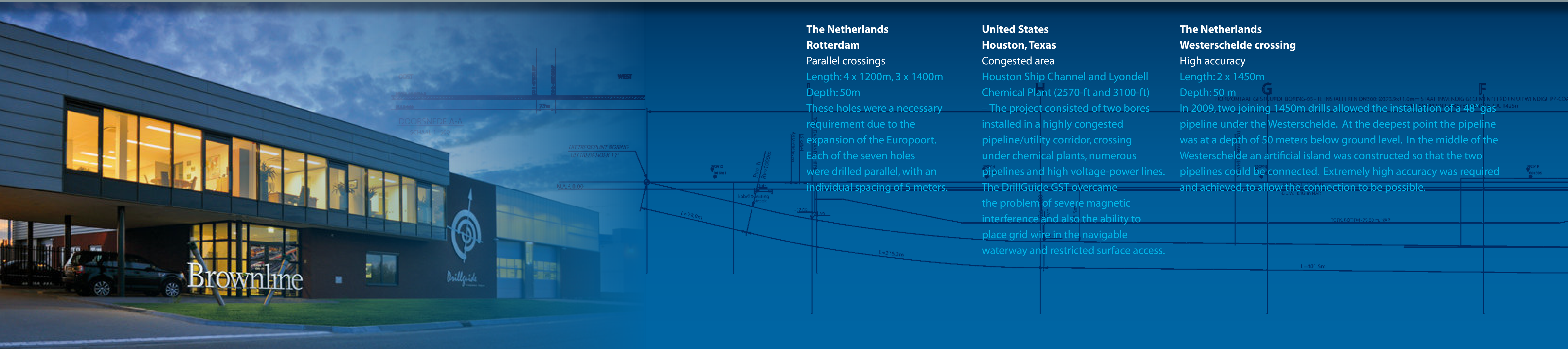
Magnetic steering tools were the standard guidance systems of drilling companies. But the drawbacks were numerous: disturbance, inaccessible areas above a drillpath and a huge tolerance of the actual drilling trajectory towards the desired trajectory.

The DrillGuide Gyro Steering Tool (GST) was developed to eliminate these problems and achieve greater accuracy. It was decided to combine new technologies, in which gyroscopes play an important role. This technique does not depend on the magnetic North and is insensitive to magnetic disturbances. The advantages of this approach translates into a reliable system, that is able to perform under virtually all conditions. The system is resilient to vibrations and practice shows that a pilot drilling, performed with a GST, is completed much sooner than with previous systems.

The DrillGuide GST is not effected by external disturbances, there is no involvement from external magnetic field interference. Railways, bridges, pipelines with or without cathodic protection and high voltage cables,



THE MOST ADVANCED STEERING TOOL IN THE WORLD



The Netherlands
Rotterdam
Parallel crossings
Length: 4 x 1200m, 3 x 1400m
Depth: 50m

These holes were a necessary requirement due to the expansion of the Europoort. Each of the seven holes were drilled parallel, with an individual spacing of 5 meters.

United States
Houston, Texas
Congested area
Houston Ship Channel and Lyondell Chemical Plant (2570-ft and 3100-ft)

– The project consisted of two bores installed in a highly congested pipeline/utility corridor, crossing under chemical plants, numerous pipelines and high voltage-power lines. The DrillGuide GST overcame the problem of severe magnetic interference and also the ability to place grid wire in the navigable waterway and restricted surface access.

The Netherlands
Westerschelde crossing
High accuracy
Length: 2 x 1450m
Depth: 50 m

In 2009, two joining 1450m drills allowed the installation of a 48" gas pipeline under the Westerschelde. At the deepest point the pipeline was at a depth of 50 meters below ground level. In the middle of the Westerschelde an artificial island was constructed so that the two pipelines could be connected. Extremely high accuracy was required and achieved, to allow the connection to be possible.

are no longer disruptive elements. Also moving traffic, whether it be on road, rail or river are no obstacle. Furthermore, there is no requirement to create a known magnetic field grid above the drill-path. This saves time, money and offers new drilling opportunities. Drillings under lakes, rivers, roads, or environmentally sensitive areas can be accurately and efficiently, performed.
Due to the DrillGuide GST being insensitive to magnetic disturbance (therefore not requiring to be housed in a non-magnetic environment), the need for expensive non-magnetic collars, is no longer present.

DRILLING IS NOW AN EXACT BUSINESS

Due to the advanced technology of the DrillGuide GST, it is continually known where the drill-head is located. Not only is the "seen" exit point exactly where it is expected, but also you have the assurance that the entire pilot hole route is being drilled as planned. This offers new opportunities in areas where the infrastructure under the ground calls for a specific route, for example to avoid other pipes, sewers, or foundations. In addition, this technique can also be applied to specific projects, ie. parallel-drills, with multiple parallel routes, where a fixed distance from each other, needs to be maintained.

The DrillGuide GST is accurate to four hundreth (0.04) of a degree on azimuth and to two hundreth (0.02) of a degree on pitch readings. This means precise localization and no guesswork. The permanent

THE MOST ADVA ED STEERING TOOL IN THE WORLD

Drillguide GST
GYRO STEERING TOOL

Denmark
Aero
Water crossing
Length: 730m
Depth: 35m
This crossing was conducted from beach to beach, beneath a 650m expanse of water.

Italy
Venice
Congested area
Length: 1250m
Depth: 50m
Combined 25 degree horizontal curve. The drill was undertaken in the port of Venice, within a vicinity of many industries, with a large volume of storage tanks and steel pilings. The object of the drill was to connect utilities to the two parts of the port.

Hungary
Baja
Downhole motor project
Length: 950m
Depth: 30m
Utilizing a downhole motor does not affect the stability, or accuracy of the DrillGuide tool. The drill was made under the River Danube.

Germany
Boxberg / Nuclear Reactor
High accuracy
Length: 1 x 740m, 1 x 796m
The two bores were drilled towards each other and at the point of intersect an excavation was made allowing the two drills to be connected.
The photo shows how close the bores are situated.

PUNCH OUT AT THE RIGHT SPOT

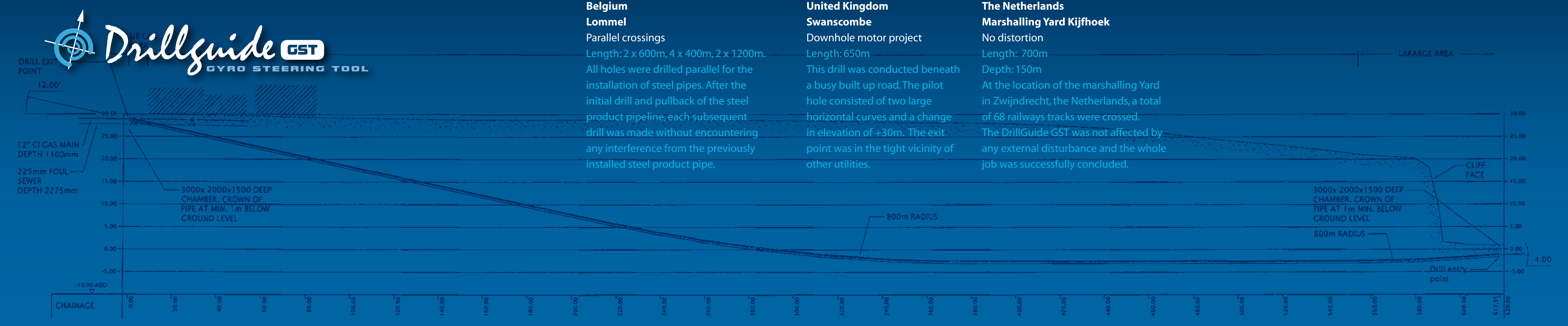
communication with the drillhead supplies continuous data, which provides accurate x, y and z coordinates of the drillhead. The DrillGuide GST has no restriction on drill-depth and works on the principle of CMWD (Continuous measurement while drilling). Measuring the location of the drillhead can also be achieved when the drillhead is rotating, as the DrillGuide GST does not require a stationary drillhead to take readings. During drilling all information is provided in realtime, so the driller promptly knows exactly what is required. There are no problems in obtaining correct measurement readings when drilling with a mudmotor.

Measuring the mud pressure in the borehole, is increasingly important, therefore, the DrillGuide GST is equipped with a mud pressure sensor. The mud is measured at two points, in the drillhead and in the borehole.

The startup time of a pilot hole, in which the DrillGuide GST is deployed, is significantly reduced due to the known magnetic field grid being redundant. For a drilling project the surveying engineer arrives with the DrillGuide GST assembly. He shoots in the tool, connects it to the drill pipe and is ready to go within approximately one hour from arrival. Drilling can then immediately begin, following the already digitized crossing profile.

THE MOST ADVANCED STEERING TOOL IN THE WORLD

Drillguide GST
GYRO STEERING TOOL



Belgium
Lommel
Parallel crossings
Length: 2 x 600m, 4 x 400m, 2 x 1200m.
All holes were drilled parallel for the installation of steel pipes. After the initial drill and pullback of the steel product pipeline, each subsequent drill was made without encountering any interference from the previously installed steel product pipe.

United Kingdom
Swanscombe
Downhole motor project
Length: 650m
This drill was conducted beneath a busy built up road. The pilot hole consisted of two large horizontal curves and a change in elevation of +30m. The exit point was in the tight vicinity of other utilities.

The Netherlands
Marshalling Yard Kijfhoek
No distortion
Length: 700m
Depth: 150m
At the location of the marshalling Yard in Zwijndrecht, the Netherlands, a total of 68 railways tracks were crossed. The DrillGuide GST was not affected by any external disturbance and the whole job was successfully concluded.

Drillguide
STEERING TOOLS

DRILLGUIDE IS A SMART SOLUTION OF BROWNLINE

Brownline

SLIMDRIL
INTERNATIONAL

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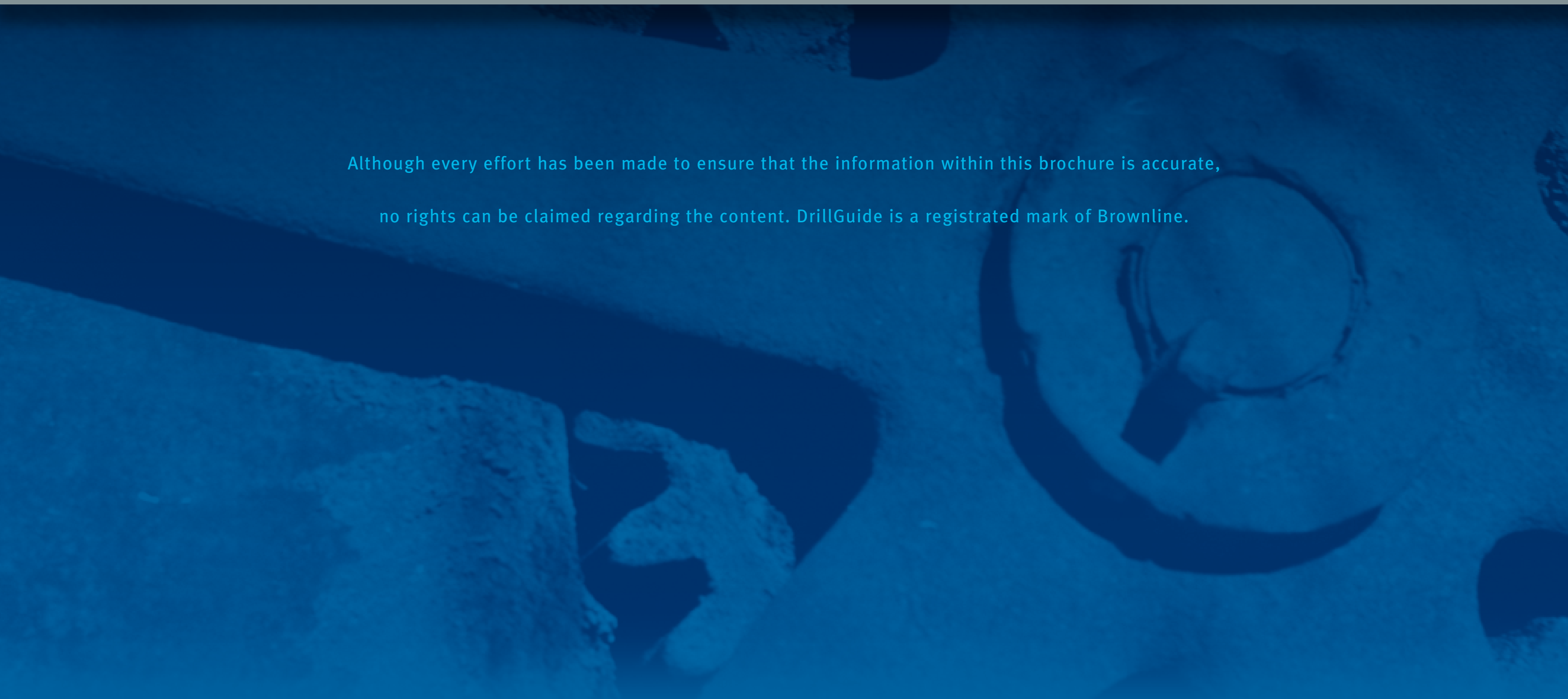
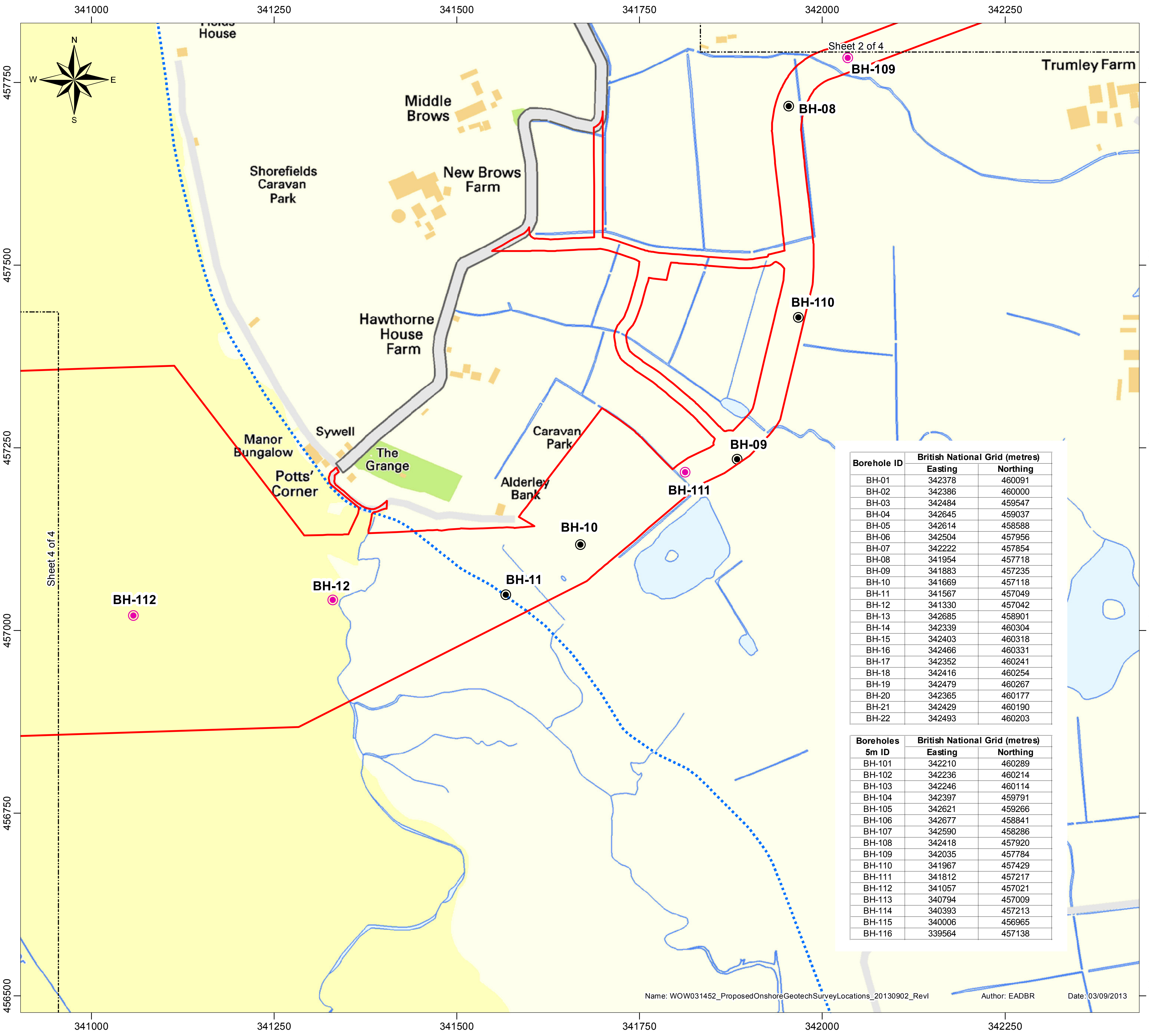


APPENDIX III

BOREHOLE LOGS BH 9, BH 10 AND BH 11



Borehole ID	British National Grid (metres)	
	Easting	Northing
BH-01	342378	460091
BH-02	342386	460000
BH-03	342484	459547
BH-04	342645	459037
BH-05	342614	458588
BH-06	342504	457956
BH-07	342222	457854
BH-08	341954	457718
BH-09	341883	457235
BH-10	341669	457118
BH-11	341567	457049
BH-12	341330	457042
BH-13	342685	458901
BH-14	342339	460304
BH-15	342403	460318
BH-16	342466	460331
BH-17	342352	460241
BH-18	342416	460254
BH-19	342479	460267
BH-20	342365	460177
BH-21	342429	460190
BH-22	342493	460203

Boreholes 5m ID	British National Grid (metres)	
	Easting	Northing
BH-101	342210	460289
BH-102	342236	460214
BH-103	342246	460114
BH-104	342397	459791
BH-105	342621	459266
BH-106	342677	458841
BH-107	342590	458286
BH-108	342418	457920
BH-109	342035	457784
BH-110	341967	457429
BH-111	341812	457217
BH-112	341057	457021
BH-113	340794	457009
BH-114	340393	457213
BH-115	340006	456965
BH-116	339564	457138

Name: WOW031452_ProposedOnshoreGeotechSurveyLocations_20130902_RevI
Author: EADBR
Date: 03/09/2013

Walney Extension offshore wind farm

Proposed onshore geotechnical survey locations

Sheet 3 of 4

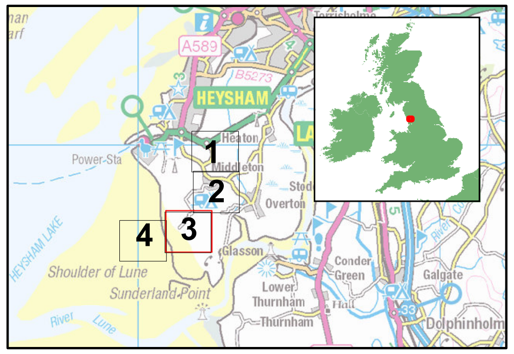
LEGEND

●	Proposed geotechnical survey locations
●	Optional additional geotechnical survey locations
⋯	Mean High Water Spring (MHWS)
▭	Walney Extension DCO Application - Order Limits

SOURCE:

Contains Ordnance Survey data © Crown copyright and database right 2012

Based on Pondus Doc. No. 1602093



Datum: OSGB 1936
Projected Coordinate System: British National Grid

Scale: 1:5000 @ A3

0 0.1 Miles

0 250 Metres

REV	REMARKS	DATE
G	BH-12 shifted approx. 50m to the west	29/08/2013
H	BH-113 relocated by 12m	30/08/2013
I	BH-05 relocated Northeast by 32m	02/09/2013

Project:	Walney Ext. Offshore Wind farm
Date:	02/09/2013
Created by:	EADBR
Accepted by:	KRIBE
Approved:	STEJA

Document nr.: WOW031452 Rev I

DONG energy

DUNELM GEOTECHNICAL & ENVIRONMENTAL

BOREHOLE RECORD

Borehole BH09

Contract No. D5113

Site: Walney HDD

GL (m AOD) -   **Scale** 1:50

Easting: -   **Northing:** -

Client: Dong Energy

Method: Cable Percussive Rig

Sheet: 1 of 2

Dates: 24/09/2013

Driller: SF

Logged By: BL

SAMPLE DETAILS

Type	Depth From - To(m)	N (cu)	Groundwater (Casing)
D J D B	0.05 0.20 0.30 - 1.00		
D U	1.10 1.20		
D B	1.70 1.70 - 2.15	N=1 (1,0,0,1,0,0)	1.20
U	2.20		
B	2.80		
D B	3.00 3.00 - 3.45	N=0 (1,0,0,0,0,0)	3.00
D	3.50 - 4.00		
U	4.00		
D	4.50 - 5.00		
U B	5.00 5.00 - 5.50		
D B	5.50 5.50 - 5.95	N=0 (1,0,0,0,0,0)	5.00
U B	6.00 6.00 - 6.50		
D	7.00 - 7.50		▽
U B	8.00 - 8.50		
D B	8.50 8.50 - 8.95	N=22 (2,3,5,5,5,7)	8.50
D	9.00 - 9.50		
B	9.50 - 10.00		

STRATA RECORD

Description	Depth (m)	Level (m AOD)
Dark brown sandy TOPSOIL. Sand is fine to coarse. Rootlets noted.	0.10	0
Reddish brown fine to coarse SAND. Roots noted.	1.00	1
Brown slightly silty SAND. Sand is fine to coarse.	2.70	3
Very soft brown slightly silty sandy CLAY. Sand is fine to coarse.	7.50	8
Stiff dark reddish brown slightly sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is subangular to subrounded fine to coarse of sandstone.		

Continued next sheet

Ground Water (m)

Depth Struck	7.40		
Casing Depth	7.00		
Water level after 20mins	7.40		
Water sealed at	7.40		

Chiselling/ Hard Strata

From (m)	To (m)	Time (hr)

Casing Depths

Diameter (mm)	Depth (m)
150	9.00

General Remarks

1. Hand dug pit for 1 hour.

DUNELM
GEOTECHNICAL & ENVIRONMENTAL

BOREHOLE RECORD

Borehole
BH09

Contract No. D5113

Site: Walney HDD

GL (m AOD) -

Scale 1:50

Easting: -

Northing: -

Client: Dong Energy

Method: Cable Percussive Rig

Sheet: 2 of 2

Dates: 24/09/2013

Driller: SF

Logged By: BL

SAMPLE DETAILS			Groundwater (Casing)	STRATA RECORD				
Type	Depth From - To(m)	N (cu)		Description	Depth (m)	Level (m AOD)	Legend	Well \Backfill
U	10.00		10	Stiff dark reddish brown slightly sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is subangular to subrounded fine to coarse of sandstone.	10.45	10		
				End of Borehole at 10.45 m				
			11					
			12					
			13					
			14					
			15					
			16					
			17					

Ground Water (m)

Depth Struck	7.40		
Casing Depth	7.00		
Water level after 20mins	7.40		
Water sealed at	7.40		

Chiselling/ Hard Strata

From (m)	To (m)	Time (hr)

Casing Depths

Diameter (mm)	Depth (m)
150	9.00

General Remarks

1. Hand dug pit for 1 hour.

DUNELM GEOTECHNICAL & ENVIRONMENTAL

BOREHOLE RECORD

Borehole BH10

Contract No. D5113	**Site:** Walney HDD	**GL (m AOD)** - **Scale 1:50** **Easting:** - **Northing:** -
Client: Dong Energy		Sheet: 1 of 2
Method: Cable Percussive Rig		Dates: 16/09/2013-18/09/2013
		Driller: SF
		Logged By: BL

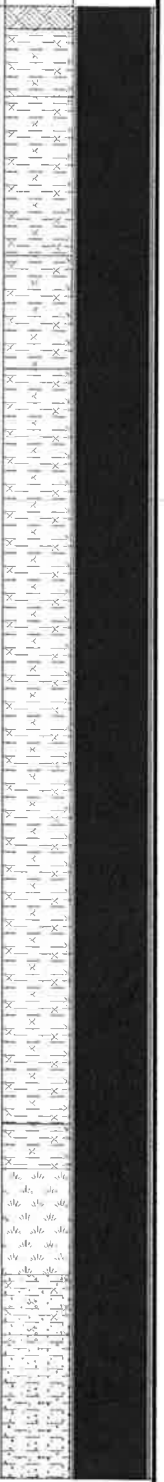
SAMPLE DETAILS

Type	Depth From - To(m)	N (cu)	Groundwater	(Casing)
D	0.10			
J				
D	0.30			
J	0.30 - 0.60			
B				
B	0.70 - 1.20			
D	0.70			
V	1.20			
D	1.70		1.70	
	1.70 - 2.15	N=0 (1,0,0,0,0 ,0)		
U	2.20			
B	2.70 - 3.00			
D	3.00		3.00	1.00
B	3.00 - 3.45	N=0 (2,1,0,0,0 ,0)		
D	3.50 - 4.00			
UF	4.00			
B	4.00 - 4.50			
D	4.50		4.50	3.50
B	4.50 - 4.95	N=0 (0,0,0,0,0 ,0)		
U	5.00			
D	5.50 - 6.00			
D	6.00		6.00	4.00
B	6.00 - 6.45	N=0 (1,0,0,0,0 ,0)		
D	6.50 - 7.00			
B	7.00 - 7.50			
U	7.50			
D	8.00			
B	8.20			
D	8.50 - 9.00			
U	9.00			
D	9.50 - 10.00			

STRATA RECORD

Description	Depth (m)	Level (m AOD)
Dark brown clayey slightly sandy TOPSOIL. Sand is fine to coarse. Rootlets noted.	0.15	0
Soft brown mottled orange sandy silty sandy CLAY. Sand is fine to coarse. Rootlets noted.	0.60	1
Soft light greyish brown very sandy slightly silty CLAY. Sand is fine to coarse.	1.65	2
Very soft grey sandy silty CLAY. Sand is fine to coarse.	2.40	2
Very soft grey brown slightly sandy silty CLAY. Sand is fine to coarse. Sand bands noted throughout.	7.40	7
Very soft light grey sandy silty CLAY. Sand is fine to coarse.	7.70	8
Dark brown plastic pseudo fiberous PEAT.	8.40	8
Soft brown slightly sandy slightly gravelly silty CLAY. Sand is fine to coarse. Gravel is subangular fine to coarse of sandstone.	8.80	9
Stiff red sandy gravelly CLAY. Sand is fine to coarse. Gravel is subangular to subrounded fine to coarse of sandstone.		

Legend | Well \Backfill



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Ground Water (m)

Depth Struck	2.40	13.85	
Casing Depth	1.70	12.00	
Water level after 20mins	1.70	13.00	
Water sealed at	-	-	

Chiselling/ Hard Strata | **Casing Depths**

From (m)	To (m)	Time (hr)	Diameter (mm)	Depth (m)
12.50	14.00	3	150	12.00

General Remarks

DUNELM GEOTECHNICAL & ENVIRONMENTAL

BOREHOLE RECORD

Borehole BH10

Contract No. D5113

Site: Walney HDD

GL (m AOD) -

Scale 1:50

Easting: -

Northing: -

Client: Dong Energy

Method: Cable Percussive Rig

Sheet: 2 of 2

Dates: 16/09/2013-18/09/2013

Driller: SF

Logged By: BL

SAMPLE DETAILS

Type	Depth From - To(m)	N (cu)
UF B	10.00 10.00 - 10.45	
B	11.00 - 11.40	
B	11.50 - 12.00	
B UF	12.00 - 12.80 12.00 - 12.45	
D	12.50 - 13.00	
B	13.00 - 13.50	
D	13.50 13.50 - 13.95	N=44 (9,8,7,7,8,22)

STRATA RECORD

Description	Depth (m)	Level (m AOD)
Stiff red sandy gravelly CLAY. Sand is fine to coarse. Gravel is subangular to subrounded fine to coarse of sandstone.	10.70	11
Stiff red slightly sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is subangular to subrounded fine to coarse of sandstone. Becoming very cobbley from 12.50m.	14.00	14
End of Borehole at 15.00 m		

Ground Water (m)

Depth Struck	2.40	13.85	
Casing Depth	1.70	12.00	
Water level after 20mins	1.70	13.00	
Water sealed at	-	-	

Chiselling/ Hard Strata

From (m)	To (m)	Time (hr)
12.50	14.00	3

Casing Depths

Diameter (mm)	Depth (m)
150	12.00

General Remarks

DUNELM GEOTECHNICAL & ENVIRONMENTAL

BOREHOLE RECORD

Borehole BH11

Contract No. D5113

Site: Walney HDD

GL (m AOD) -   **Scale 1:50**

Easting: -   **Northing:** -

Client: Dong Energy

Method: Cable Percussive Rig

Sheet: 1 of 2

Dates: 20/09/2013

Driller: SF

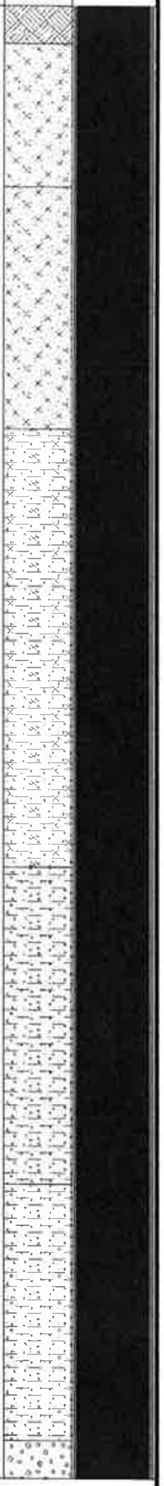
Logged By: BL

SAMPLE DETAILS

Type	Depth From - To(m)	N (cu)	Groundwater (Casing)
D	0.20		
J			
D	0.40		
B	0.40 - 1.20		
U	1.20		
D	1.70	N=8 (2,2,2,2,3,1)	1.20 Dry
	1.70 - 2.15		
U	2.00 - 2.45		
B			
D	2.50	N=8 (1,1,2,2,2,2)	2.50 2.00
	2.50 - 2.95		
D	3.00	N=11 (2,2,2,2,2,5)	3.00 1.00
B	3.00 - 3.45		
B	3.90 - 4.00		
U	4.00		
B	4.00 - 4.50		
D	4.50	N=0 (1,0,0,0,0,0)	4.50 2.00
B	4.50 - 4.95		
U	5.00		
B	5.00 - 5.50		
D	5.50 - 6.00		
D	6.00	N=17 (3,3,4,4,4,5)	6.00 2.80
B	6.00 - 6.45		
D	6.50 - 7.00		
B	7.00 - 7.50		
U	7.50		
B	7.50 - 8.00		
D	8.00	50/220mm (3,7,7,21,22)	
B	8.00 - 8.37		
	8.00 - 8.45		
D	8.50 - 9.00		
B	9.00 - 9.50		
B	9.60		
D	9.70 - 10.00		

STRATA RECORD

Description	Depth (m)	Level (m AOD)
Dark brown clayey slightly sandy TOPSOIL. Sand is fine to coarse. Gravel is subangular to rounded fine to coarse of sandstone. Rootlets noted.	0.25	0
Dark brown silty SAND. Sand is fine to coarse.	1.20	1
Loose grey brown silty SAND. Sand is fine to coarse, Occasional thin bands of silty clay. Shells noted.	2.80	3
Very soft brown silty sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is subangular to rounded fine to coarse of sandstone.	5.70	6
Firm red slightly sandy gravelly CLAY. Sand is fine to coarse. Gravel is subangular to subrounded fine to coarse of sandstone and mudstone.	7.80	8
Stiff dark brown slightly sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is angular to subrounded fine to coarse of sandstone and mudstone. Drillers notes cobbles throughout.	9.50	10



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Ground Water (m)

Depth Struck	1.40		
Casing Depth	-		
Water level after 20mins	1.00		
Water sealed at	-		

Chiselling/ Hard Strata

From (m)	To (m)	Time (hr)
7.50	9.50	3.5
9.50	10.50	3.5

Casing Depths

Diameter (mm)	Depth (m)
150	10.00

General Remarks

1. Unable to adavance borehole below 10.50m due to dense cobbles.

DUNELM GEOTECHNICAL & ENVIRONMENTAL

BOREHOLE RECORD

Borehole BH11

Contract No. D5113

Site: Walney HDD

GL (m AOD) -

Scale 1:50

Easting: -

Northing: -

Client: Dong Energy

Sheet: 2 of 2

Method: Cable Percussive Rig

Dates: 20/09/2013

Driller: SF

Logged By: BL

SAMPLE DETAILS				STRATA RECORD				
Type	Depth From - To(m)	N (cu)	Groundwater (Casing)	Description	Depth (m)	Level (m AOD)	Legend	Well \Backfill
D B	10.00 10.00 - 10.23 10.00 - 10.50	50/100mm (9,16,33,17)	10.00 2.00	Brown yellow COBBLES with some slightly sandy gravel. Sand is fine to coarse. Gravel is angular to rounded fine to coarse of sandstone.	10.50	11	▨	■
				End of Borehole at 10.50 m				

Ground Water (m)			
Depth Struck	1.40		
Casing Depth	-		
Water level after 20mins	1.00		
Water sealed at	-		
[redacted]			

Chiselling/ Hard Strata			Casing Depths	
From (m)	To (m)	Time (hr)	Diameter (mm)	Depth (m)
7.50	9.50	3.5	150	10.00
9.50	10.50	3.5		

General Remarks

1. Unable to adavance borehole below 10.50m due to dense cobbles.