Environmental Impact Assessment Report - Volume 2C Addendum

Appendix 28-4:
Technical Note on Cable Construction at M1

ORIEL WINDFARM
OFFSHORE RENEWABLE ENERGY

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ORIEL WIND FARM PROJECT

Environmental Impact Assessment Report - Addendum
Appendix 28-4: Technical note on Cable Construction at M1

MDR1520C
EIAR – Appendix 28-4
A1 C01
December 2025

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Figures

Note: Figures 3 to 8 are included in Annex C

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Acronyms

Term	Meaning
c'	Effective cohesion
EIAR	Environmental Impact Assessment Report
GDS	Geo Drilling Solutions
HDD	Horizontal direction drilling
NIS	Natura Impact Statement
ODF	Over-design factor
OWL	Oriel Windfarm Ltd
PPP	Public Private Partnership
RAMS	Risk Assessment Method Statements
r_u	Pore water pressure ratio
TII	Transport Infrastructure Ireland
TN	Technical Note
ϕ'	Effective angle of internal friction

Units

Term	Meaning
m	Metre (distance)
mm	Millimetre (distance)
km	Kilometre (distance)
kN/m^3	Kilonewtons per metre cubed
kPa	Kilopascals

1 INTRODUCTION

1.1 Background

RPS was commissioned by Oriel Windfarm Ltd. (OWL), in November 2018 to provide Environmental and Planning Consultancy Services to compile a planning application for the proposed Oriel Wind Farm Project with an accompanying Environmental Impact Assessment Report (EIAR) for both the onshore and offshore elements of the project, including a Natura Impact Statement (NIS).

The proposed Oriel Wind Farm Project is located in the Irish Sea off the coast of County Louth, to the east of Dundalk Bay. As part of the proposed windfarm a 20.1 km onshore buried export cable (single circuit - 220kV) is proposed to connect with a substation at Ardee. The proposed onshore export cable route will comprise a number of crossings of rivers and infrastructure including a crossing under the Dublin-Belfast railway line and the M1 motorway located immediately to the north of the M1/N33 interchange (Figure 1).

The proposed crossing of the M1 and Dublin Belfast railway line will be by horizontal directional drilling (HDD) techniques.

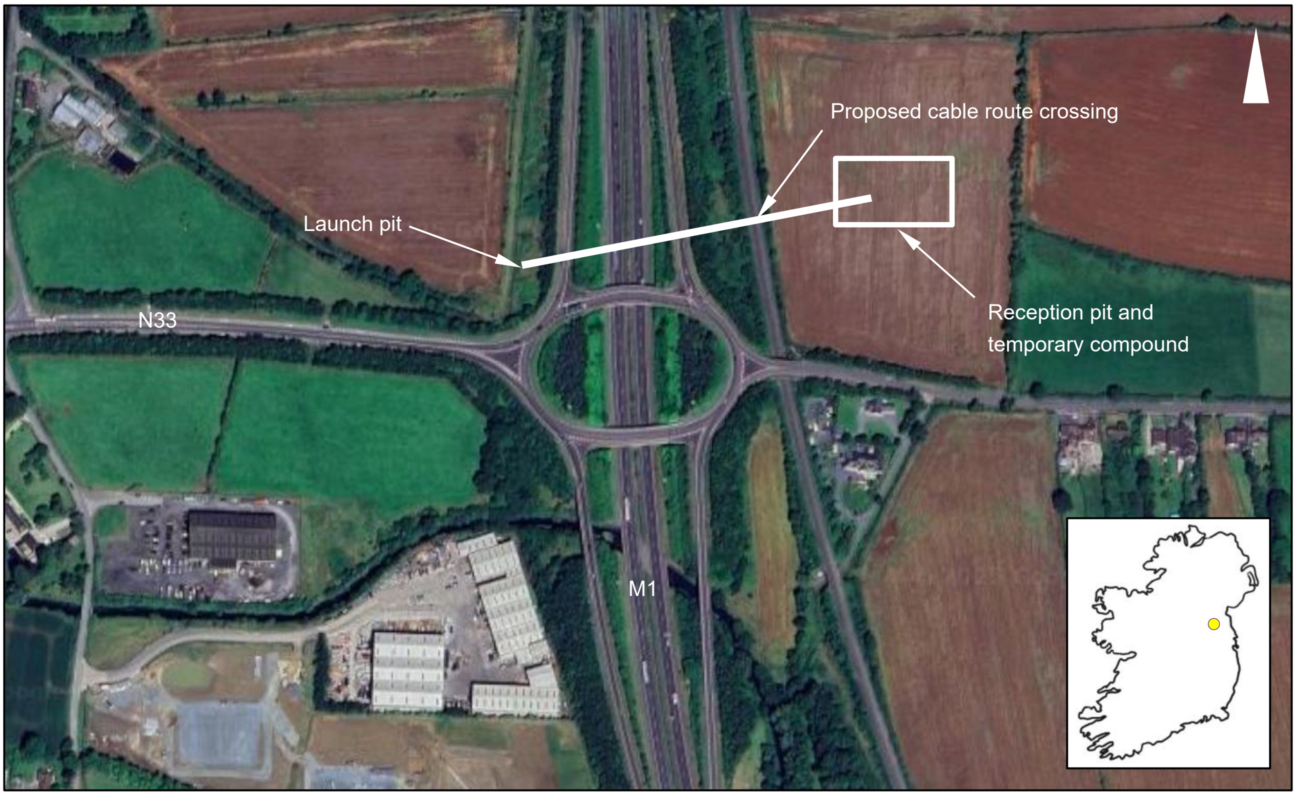

Figure 1 Location of the proposed M1 cable route crossing (shown approximately).

1.2 Scope

This Technical Note (TN) addresses comments received from TII on the cable route crossing under the M1 following consultation with TII post application. The pertinent comments received from TII that are addressed in this TN are summarised below:

(1) *The proposed pit to the west of the M1 is located very close to the embankment. There are concerns that the proposed pit and groundworks are in close proximity to the embankment. OWL/RPS to demonstrate the embankment will not be destabilised by the proposed pit and groundworks.*

(2) Provide vertical profile and further geotechnical details to show no risk to the embankment.

(3) Include further details on construction methodology for this location.

This TN covers item (1) and also provides additional information for item (2). The proposed construction methodology for the HDD and impacts from the sub-surface drilling on the existing infrastructure is provided in an accompanying report carried out by Geo Drilling Solutions (2025)[1], which covers item (2) and (3) of the scope (see Annex A: HDD Preliminary Design Report and Annex B which provides a HDD compound layout drawing).

The following items are included in this TN, namely:

(1) Site inspection. Carried out on 20 June 2025 with Geo Drilling Solutions (GDS) personnel.

(2) Site description. This includes topography and ground conditions. Review of particularly the western side of the M1 where the proposed works are close to the existing motorway embankment.

(3) Stability assessment. Assessment of the stability of the existing embankment on the western side of the M1 with and without the proposed works.

(4) HDD further details. Additional supporting information to show predicted settlement of the existing motorway from proposed HDD works.

(5) Findings.

[1] Geo Drilling Solutions (2025). Oriel Offshore Windfarm M1 Motorway & Dublin–Belfast Railway Crossing. HDD Preliminary Design Report. October 2025.

2 SITE INSPECTION

A site inspection was carried out on 20 June 2025 which included personnel from RPS and GDS. The inspection comprised a visual examination and measurement of salient features at the site.

The proposed crossing site is located about 120 m north of the centre of the M1/N33 interchange. The interchange comprises an elevated roundabout with on and off ramps to both the north and southbound carriageways of the M1. The crossing passes below the northbound on ramp, M1 carriageways, southbound off ramp and the Dublin-Belfast railway line. The M1 motorway in this area is operated by Celtic Roads Group on behalf of TII under a Public Private Partnership (PPP) contract.

The proposed HDD methodology presented by Geo Drilling Solutions (2025) is to carry out drilling works to the west of the M1, where the launch pit will be located, with the reception pit and associated temporary compound for stringing located to the east of the Dublin-Belfast railway line.

The proposed reception pit and associated groundworks will be located in an open field at a distance of about 90 m from the Dublin-Belfast railway line and 150 m from the M1 southbound off ramp. Given the significant distance of the reception pit and groundworks from the M1, and the Dublin-Belfast railway, there will be no impact on the infrastructure and as such this is not considered further.

The proposed launch pit on the western side of the M1 will be located on flat ground about 9 m from the toe of the northbound on ramp embankment slope. The launch pit will be about 5 to 6 m long, 1.2 m deep and about 2 to 3 m wide. Following drilling works, a transition chamber will be used to divert the cables from the HDD ducts into the trench ducts. The excavation for the transition chamber is about 1.9 m deep with plan size smaller than the launch pit.

The transition chamber comprises a pre-cast concrete box used in cable installation to manage the transition between the two different duct types, that is HDD ducts (SDR 11) and standard cable trench ducts (SDR 21). The transition chamber remains open during cable installation to allow the controlled transition between the two different duct types. Once cable installation is complete the transition chamber is buried and the ground above reinstated. Access to the chamber is not required during the operation of the cable circuit.

Inspection of the embankment slope shows no signs of instability. The slope is covered with semi-mature trees with a covering of grass. A shallow toe drain is located at the toe of the slope. Based on visual inspection of exposures, the embankment appears to be constructed of a cohesive fill, assumed locally won glacial till.

3 SITE DESCRIPTION

3.1 Topography

At the proposed crossing site the mainline of the M1 motorway is within shallow cutting with the on and off ramps on fill embankments as they meet the interchange.

On the western side of the M1 motorway at the site of the proposed launch pit the ground comprises flat agricultural land of arable fields and adjacent to the motorway a strip of land comprising grasses. The fill embankment at this location is typically 3 to 4 m high, extending up to about 5 m high. The embankment slope is inclined at 1V:2H (27 degrees). A ditch (less than 1m deep) is located at the toe of the embankment slope.

3.2 Ground conditions

Ground conditions at the site based on the Geological Survey Ireland (GSI)[2] shows superficial deposits comprising glacial till derived from limestones on the western side of the crossing and till derived from Paleozoic sandstones and shales on the eastern side of the crossing. Alluvial deposits associated with the nearby River Dee are mapped to the north and south of the crossing location.

As noted above, inspection of exposures of the fill embankment slope indicate the embankment is constructed of a cohesive fill, assumed locally won glacial till.

Bedrock in the area is considered to be at a notable depth, possibly 8 to 15 m deep based on existing borehole records from the GSI.

Groundwater was not evident during the inspection with ditches dry. Typically groundwater for stability analysis would be expected to be close to ground surface during wetter periods.

[2] GSI (2025). Geological Survey Ireland Spatial Resources. Web page: https://dcenr.maps.arcgis.com/apps/MapSeries/index.html?appid=a30af518e87a4c0ab2fbde2aaac3c228

4 STABILITY ASSESSMENT

4.1 General

As the proposed reception pit to the west of the M1 is located close to the embankment a stability analysis has been carried out to assess the impact of the proposed pit and groundworks on the nearby embankment.

The stability of the existing embankment with and without the proposed works has been carried out for the following cases:

Case (1) Existing stability. Realistic operating shear strengths for glacial till have been used together with groundwater at the surface and a r_u of 0.1 within the embankment fill (see below).

Case (2) Stability during drilling works with launch pit. Launch pit located at a distance of 9 m from the toe of the embankment slope. The launch pit is 6 m long and 1.2 m deep.

Case (3) Stability during use of the transition chamber. Excavation for chamber assumed to be also a distance of 9 m from the toe of the embankment slope. The transition chamber is 1.9 m deep with a plan area assumed similar to the launch pit.

The purpose of assessing the stability for the 3 cases is to check if there is any impact on the stability of the embankment slope with the launch pit and the transition chamber in place.

Stability was assessed using SLOPE/W limit equilibrium software and the Morgenstern-Price method of analysis. Partial factors from Eurocode 7[3] using Design Approach 1, Combination 1 (DA1C1) were applied to the characteristic loading conditions with partial factors using Design Approach 1, Combination 2 (DA1C2) applied to the characteristic ground material parameters used in the analysis. DA1C2 provides the critical condition, and as such these results are reported below.

The results of the stability analysis are provided as an over-design factor (ODF). An ODF of 1.0 or greater means the slope is acceptable. An ODF of less than 1.0 means an unacceptable slope.

4.2 Ground model

Based on GSI records and site inspection the ground model is as follows:

- Embankment 5 m high with slope face of 1V:2H constructed of engineered fill comprising cohesive glacial till; and
- Insitu ground below embankment and underlying the area comprising glacial till. Bedrock is assumed at notable depth and is therefore not included in the analysis.

Imposed load of 20kPa applied to northbound on ramp with 5kPa applied to verge. The loading from the drilling rig and any plant and compound area at the toe of the slope has been ignored as these loadings will provide a beneficial stability.

4.3 Design parameters – glacial till

As part of earthworks design for a number of motorways the shear strength of glacial till has been assessed based on extensive ground investigation and testing. From a review of the extensive ground investigation results, typical test results for glacial till show a range of ϕ' from 28 to 39 degrees and a range for c’ from 0 to

[3] NSAI (2013). I.S. EN 1997-1:2004+A1:2013. Eurocode 7: Geotechnical design - Part 1: General rules

10 kPa. Whilst a positive c' intercept can be interpreted from test results; design practice is to ignore cohesion. A cautious estimate for the glacial till of ϕ' of 37 degrees and c' = 0 kPa would be representative of glacial till found in the area of the M1 motorway. This design shear strength would be sufficient to construct slopes at 1V:2H as found on the M1 motorway.

As a comparison, based on an assessment of Irish Rail soil earthworks carried out in the Limerick Area the typical operational shear strength of the glacial till was estimated at ϕ' of 38° and c' of 1kPa (Jennings, 2003)[4], which is not dissimilar to that used in earthworks designs for highways above.

Design parameters for glacial till both insitu and within fill embankment is as follows:

ϕ' of 37 degrees, c' = 0 kPa and unit weight of 19kN/m^3

4.4 Groundwater

As a cautious estimate the groundwater is assumed at the existing ground surface and that there is some perched groundwater within the fill embankment, represented by a r_u of 0.1 (i.e. within any potential failure surface the groundwater represents 20 % of the depth of the failure surface).

4.5 Stability results

The results of the stability analysis for the three cases are given in Table 1. The results show that there is no impact on the stability of the embankment slope as a result of the presence of the launch pit or the transition chamber, that is the ODF value for the slope does not change between the existing slope and the slope when the launch pit or transition chamber are present.

The stability output showing the critical failure surfaces for each stability case are presented in Figure 3 to Figure 8 included in Annex C of this technical note.

Table 1 Stability results

Case	Description	ODF	Comment
1	Existing stability	1.20	Critical failure surface is a shallow failure on the slope face
2	Stability during drilling works with launch pit	1.20	Critical failure remains as above. The presence of the launch pit has no impact on the stability of the embankment slope
3	Stability during connection of cables within a transition chamber	1.20	Critical failure remains as above. The presence of the deeper transition chamber has no impact on the stability of the embankment slope

For case 3, it is assumed as a worst case that the excavation for the transition chamber is located at the same distance from the toe of the embankment slope as the launch pit. In practice, the transition chamber may be located at a greater distance from the embankment, particularly if the embankment was to be widened in the future. Should there be future widening of the embankment over the buried chamber then the chamber will be rated to withstand the likely imposed loading of any future embankment.

Notwithstanding the above, following cable installation the transition chamber is buried and the ground above reinstated and access to the chamber is no longer required during the operation of the cable circuit.

[4] Jennings, P. (2003). Performance of 150-year-old railway slopes in glacial till: case study from southwest Ireland. Prague: Proceedings XIIIth European Conference on Soil Mechanics and Geotechnical Engineering 2003, Vol. 2, Session 5, Vol. 2.

Prior to excavation works for the launch pit/transition chamber, topsoil and sub-soil will be stripped and stockpiled for use in reinstatement. Underling glacial soils will be excavated and also stockpiled separately. Similar stripping will be carried out below temporary works platforms located around the pit. Temporary works platforms will be removed on completion.

Reinstating of the launch pit and transition chamber excavations will comprise placing of recompacted suitable inert fill using either cohesive (Class 2) or granular fill (Class 1 or 6) as per TII Series 600 Specification for Road Works[5]. Ideally the excavated glacial soil will be used for reinstatement. Subsoil and topsoil will then be placed. The reinstated ground will be replanted with similar native grasses. The reinstated ground will have a similar bearing capacity as the surrounding ground.

Drainage on the western side of the motorway comprises a ditch located at the toe of the embankment slope. The ditch will be unaffected by the proposed works. In general, drainage of the works area is not anticipated. Where there is a need to limit say surface ponding at the proposed works area then a temporary shallow ditch may be formed to connect with the existing ditch. Any temporary ditch will be backfilled on completion. The proposed works will have no adverse effect on the existing drainage of the area during or following completion of the works.

[5] TII (2024). CC-SPW-00600 Earthworks Specification for National Roads. September 2024

5 HDD - FURTHER DETAILS

5.1 Findings from feasibility study

The proposed construction methodology for the HDD and impacts from the sub-surface drilling on the existing infrastructure is provided by the accompanying report by Geo Drilling Solutions (GDS). The purpose of the GDS report was to show the feasibility of the proposed HDD and to provide preliminary details.

The preliminary details included maximum settlement predictions below the M1 motorway and the Dublin-Belfast railway using available ground investigation information, see Table 2.

Table 2 Preliminary settlement predictions (Geo Drilling Solutions, 2025)

Location	Soil type	Depth to centre of pipe	Potential Settlement
M1 motorway	Stiff to hard sandy silty CLAY with cobbles and boulders (Glacial till)	8.3 m	5.6 mm
Railway line	Stiff to hard sandy silty CLAY with cobbles and boulders (Glacial till)	10.3 m	4.5 mm

With respect to the M1 motorway, the settlement predictions by GDS were based on conservative assumptions including keeping the HDD within the glacial till (soil) below the motorway. It is noted that the predicted maximum settlement exceeds 5 mm which is the upper acceptable limit for TII, refer section S3.7 of CC-PAV-04007 [6].

5.2 Further details

Based on discussions with TII the settlement as a result of the HDD below the motorway is required to be kept to a minimum. Further detailed assessment of the predicted settlement due to the HDD works has been carried out to determine the predicted maximum settlement where the HDD is taken to greater depth below the motorway.

Below the motorway the glacial till is estimated at about 14 m thick overlying bedrock. Where the HDD is within bedrock the settlement would effectively be zero or a nominal amount. The predicted maximum settlement with an increase in HDD depth below the motorway road surface is provided in Figure 2 with details of predicted settlement assessment included in Annex D.

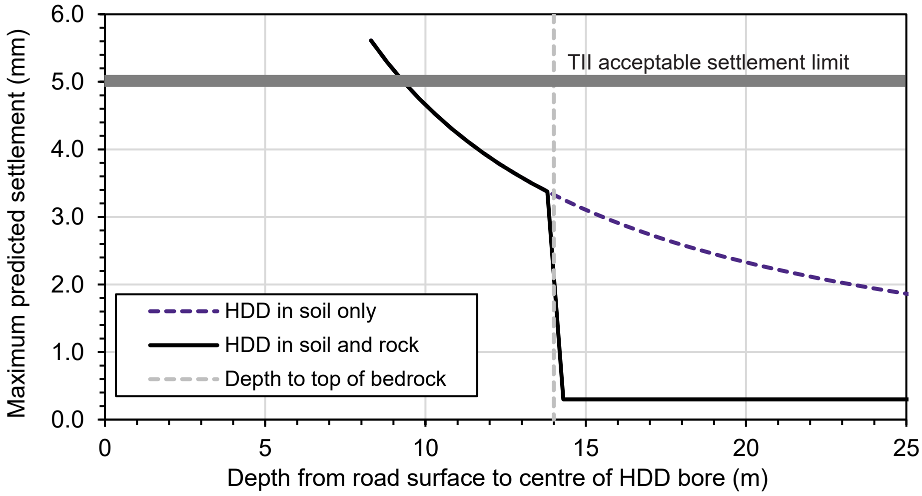

Figure 2 Predicted settlement with HDD depth below motorway road surface

[6] TII (2019). Requirements for the Reinstatement of Openings in National Roads. CC-PAV-04007. May 2019.

The results of the further detailed assessment of settlement show the following:

(1) To comply with the 5 mm acceptable settlement limit for TII the HDD bore depth needs to be a minimum depth of 9.3 m in glacial till. It is noted that TII require minimum settlement.

(2) Where the HDD bore is at a depth of 14 m below the motorway and is assumed to be in glacial till the maximum predicted settlement is 3 mm, which is below the 5 mm acceptable limit for TII.

(3) Where the HDD bore is taken into bedrock which is estimated to be at a depth of about 14 m or greater below the motorway, based on available ground investigation data, then settlement would effectively be zero or a nominal amount.

(4) To achieve a greater depth the HDD bore would need to have an angle of entry of about 20 degrees, which is achievable, assuming the launch pit was at the current location of about 9 m from the toe of the motorway embankment slope. Moving the launch pit further west would allow the entry angle to be reduced and still maintain a greater HDD bore depth.

6 FINDINGS

6.1 Stability assessment

The findings with respect to stability assessment are as follows:

(1) With respect to the cable route crossing of the M1 motorway and following a meeting between TII and OWL/RPS, concerns were expressed by TII that the proposed pit and groundworks on the western side of the M1 were in close proximity to the motorway embankment which could potentially destabilise the motorway embankment.

(2) In response to TII's concerns, OWL/RPS were requested to demonstrate the proposed works would not destabilise the motorway embankment.

(3) A stability analysis has been carried out to assess the impact of the proposed pit and groundworks on the western side of the motorway on the nearby embankment. The assessment comprised a stability analysis of the existing motorway embankment with and without the proposed works.

(4) The analysis included an assessment of the stability with the proposed launch pit and the deeper transition chamber in place. The results of the stability analysis show that there is no impact on the stability of the embankment as a result of the proposed works, see Table 1 and Figure 3 to Figure 8 in Annex C.

(4) There is no impact from the proposed works on the embankment slope chiefly due to the distance of the proposed works from the toe of the slope and generally the shallow nature of the excavation works associated with the works.

(5) Following completion of the works, the area will be reinstated with all excavation backfilled with engineered fill and compacted and tested as per TII Series 600 Specification for Road Works to match the existing ground condition. The proposed works will have no adverse effect on the existing drainage of the western area during or following completion of the works.

6.2 HDD further details

The findings with respect to the predicted maximum settlement below the motorway due to the proposed HDD works are as follows:

(1) Settlement assessment shows the following with respect to HDD bore depths below motorway:

  (a) HDD bore depth of 9.3 m in glacial till. Maximum predicted settlement is 5 mm which complies with TII's acceptable settlement limit of 5 mm, refer section S3.7 of CC-PAV-04007.

  (b) HDD bore depth of 14 m in glacial till. Maximum predicted settlement is 3 mm, which complies and is below TII's acceptable settlement limit of 5 mm.

  (c) HDD bore in bedrock, that is at a depth greater than 14 m. Maximum predicted settlement would effectively be zero or a nominal amount.

(2) Based on the above, increasing the HDD bore depth to greater than 9.3 m in glacial till (soil) or within rock will comply with TII's acceptable settlement limit. The selected HDD bore depth and corresponding maximum predicted settlement will need to be agreed with TII prior to any works together with surveying and monitoring requirements. TII's preference is to minimise settlement to as low as is practical.

(3) TII surveying and monitoring requirements for HDD works are included in section S3.7.1 in CC-PAV-04007, which are reproduced in italics as follows:

1. *An accurate pre-works level survey shall be completed and submitted to the authority in advance of the works as detailed hereunder;*
    - *The survey shall be carried out along the line of the proposed crossing as well as at 2m, 5m, 10m, 15m & 20m offsets either side of the proposed crossing line*
    - *As a minimum, the following locations shall be surveyed along the line of the proposed crossing and at all the required offsets:*
        - *edge of carriageway, edge of hard-shoulder, lane lines, median line, edges of footpaths, footways, cycle paths (as applicable for each specific location);*
    - *Additional survey points may be specified by the authority on a site-specific basis.*
2. *Monitoring shall be carried out during the works to ensure there is no excessive movement caused by the trenchless construction technique.*
3. *Two further surveys at the same locations as for the pre-works survey shall be completed and submitted to the authority:*
    - *immediately post works and*
    - *approximately 3 weeks post works.*
4. *Where deflection of the surface ≥5mm is observed) the authority shall be notified immediately, and the required remediation shall be carried out by the Licence Holder as soon as practically possible.*

(4) In addition to the above TII surveying and monitoring requirements, as a minimum the HDD works contractor will be required to include the following surveying and monitoring requirements within their Risk Assessment Method Statements (RAMS):

(a) Measures to be implemented on site to monitor drilling fluid pressures downhole, monitor the surface for inadvertent returns of drilling fluid, and include measures to contain and remove any drilling fluid from affected areas should the situation arise.

(b) Minor escape of drilling fluid to the surface may be expected for the first and final 20m of the alignment where cover is low and mitigation measures should be outlined in the RAMS. These may include foot patrols to watch for signs of drilling fluid escape and the development of clean-up plans.

(c) All control measures shall be included in the HDD contractor’s RAMS and agreed with TII.

(d) Ground settlement points shall be established as per section S3.7.1 in CC-PAV-04007 and any additional points required by the HDD contractor. The frequency and method of monitoring during the works shall be agreed with TII taking into account safe access.

(e) Critical trigger levels (ground settlement) shall be set by the HDD contractor taking into account S3.7.1 in CC-PAV-04007 and agreed with TII and included in the RAMS. A hierarchy of trigger levels shall be included in the RAMS and shall be based on increasing stages of criticality using a colour sequence of green, amber, red and black, or similar agreed. Trigger values shall relate to typically:

a. Verification of the HDD Contractor’s design.

b. TII asset protection (refer to S3.7.1 in CC-PAV-04007).

c. Construction process control.

d. Maintaining a safe system of work.

(f) Contractor within the RAMS shall prepare action plans for responses to breaches for each trigger level (green, amber, red and black) and clearly identify the line of communication and responsible individual personnel within the Contractor’s team.

Annex A

HDD Preliminary Design Report

ORIEL OFFSHORE WINDFARM M1 MOTORWAY & DUBLIN–BELFAST RAILWAY CROSSING

HDD Preliminary Design Report

Document:	03117-GDS-ZZ-XX-RP-C-00001 M1 & Dublin-Belfast Rail HDD Preliminary Design Report					
Status	**Revision**	**Reason for Revision**	**Prepared by**		**Reviewed by**	
			Initials	**Date**	**Initials**	**Date**
S3	**P01**	Initial Release for Information and Review	NM & CR	Sept 2025	NM	Sept 2025
S3	**P02**	Updated in response to client comments	NM & CR	Oct 2025	NM	Oct 2025
A1	**C01**	Entry side compound changed	NM & CR	Oct 2025	NM	Oct 2025

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TABLE OF FIGURES

NOMENCLATURE

BGL	=	Below Ground Level
BH	=	Borehole
BHA	=	Bottom Hole Assembly
CP	=	Cable Percussion
DTH	=	Down the Hole
ESB	=	Electricity Supply Board
GDS	=	Geo Drilling Solutions
GPR	=	Ground Penetrating Radar
GSI	=	Geological Survey Ireland
GWL	=	Ground Water Level
HDD	=	Horizontal Directional Drilling
ID	=	Internal Diameter
MTBM	=	Microtunnel Boring Machine
OD	=	Outside Diameter
PAC	=	PolyAnionic Cellulose (polymer)
PE	=	Polyethylene
RAMS	=	Risk Assessment Method Statement
RC	=	Rotary Core
ROP	=	Rate of Progress
SPT	=	Standard Penetration Test
TD	=	Total Depth
TII	=	Transport Infrastructure Ireland

Section 1 | INTRODUCTION

1.1 Overview

Geo Drilling Solutions (GDS) has been requested by Oriel Windfarm Limited to review the use of Horizontal Directional Drilling (HDD) techniques to install a bundle of 3 nr 225mm & 2 nr 125mm SDR11 PE100 ducts under the M1 Motorway & Dublin-Belfast railway line at Junction 14 in County Louth. The approximate HDD alignment is shown in Figure 1.

This report assess the use of HDD for the crossing by reviewing available local and regional information on ground conditions, assessing any site constraints, and examining the project requirements. Of particular concern is the potential impact on the M1 with respect to the proximity of the proposed cables alignment to the M1 infrastructure. The activities undertaken to support the study include a site visit, a desk study, and the preparation of drawings and this report.

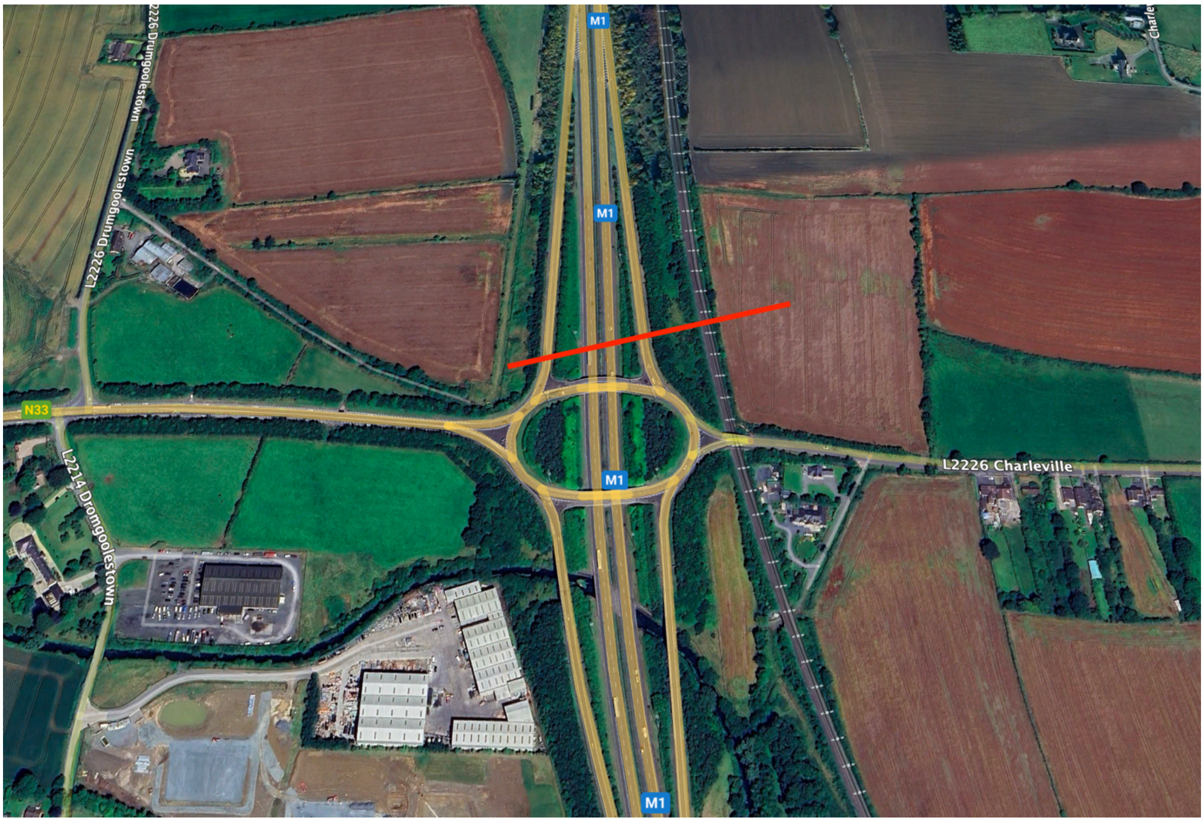

Figure 1 – Site location –approximate HDD alignment shown in red

1.2 Scope Of Works For The Feasibility Assessment

Geo Drilling Solutions' scope of works for the feasibility assessment included:

1. Visit site.
2. Assess the feasibility of completing the crossings using HDD techniques.
3. Review the geotechnical investigations.
4. Complete a ground risk assessment.
5. Draft and review profile and section drawings.
6. Complete a hydrofracture analysis.
7. Complete a preliminary settlement analysis.

Section 2 | SITE VISIT

Site location: ITM coordinates X: 703317, Y: 791190.

GDS engineers visited the location along with a RPS representative on 20th June 2025 to review the access and pipe stringing arrangements, the proposed entry and exit pit locations, and generally assess the scope of works. Photographs taken are presented in Figure 2 and Figure 3. A summary of the observations made is as follows:

1. Access to the entry side is along the cable route with site access from the N33 national road, where we assume traffic management shall be in place to enable safe access for the HDD equipment and operatives.
2. The proposed entry side offers generous space to set up equipment.
3. No evidence of existing surfaces buried or overhead along the proposed alignment of the HDD.
4. A water supply to facilitate the mixing of drilling fluids will be required on the entry side as there is no evidence of a hydrant.
5. Good access into the field off the L2226 Charleville Road on the exit side of the crossing.
6. A temporary road will be required to travel across the field to the exit location, and a hard standing created.
7. Subject to wayleaves there is ample room to weld and string out pipe.

For the purposes of this report it is assumed that the entry side is to the west of the M1. Where the entry is on the east side of the M1, then the same commentary given in this report will apply.

Figure 2 - View of the entry side looking towards the roundabout at Junction 14 on the M1

Figure 3 – Access off the L2226 Charleville Road through double gates looking towards the exit pit in the middle of the field.

Section 3 | GEOTECHNICAL FACTORS

3.1 Geotechnical Desk Study

Publicly available mapping from Geological Survey Ireland (GSI) shows the Quaternary geology (i.e. the top 1.0m of the overburden) as Glacial Till (Boulder Clay), being Till derived from limestones on the western side of the crossing and Till derived from Paleozoic sandstones and shales on the eastern side of the crossing. Alluvial deposits associated with the nearby River Dee are mapped to the north and south of the crossing location. Bedrock is indicated as the Salterstown Formation of calcareous greywacke & banded mudstone.

Groundwater vulnerability is indicated as “low” suggesting that there is a thick covering of overburden over the bedrock aquifer. The bedrock aquifer is indicated as a Poor Aquifer - Bedrock which is Generally Unproductive.

The following documents were provided by our Client and reviewed as part of the desk study:

- Dunleer-Dundalk Motorway Project Ground Investigation Contract Factual Report - Volume 4. Ref. DWB/IR-SI/04.
- Dunleer-Dundalk Motorway Project Contract 3 Horiz & Vert Alignment Ch. 2160 - Ch. 2880 Showing Site Investigation (Sheet 5 of 25 No.). Drawing No. DDM/SI-18. Rev C.
- Dunleer-Dundalk Motorway Project Contract 3 Horiz & Vert Alignment Ch. 28800 - Ch. 3600 Showing Site Investigation (Sheet 6 of 25 No.). Drawing No. DDM/SI-19. Rev C.

There are 9 historic borehole locations along the proposed alignment, with records for 8 available via the documents referenced earlier and Geological Survey Ireland datasets, all part of the Dunleer-Dundalk Motorway Project Ground Investigation:

- BH E7
- BH E8
- BH E9
- BH E15
- BH M24
- BH M25/ M25A / M25B
- BH M26 / M26A / M26B
- BH M27A

One other relevant borehole log (E19) was not available. The relevant borehole logs are shown in Appendix A. The locations are shown in the drawing 03117-GDS-ZZ-XX-DR-C-0001 attached as Appendix B.

The SPN N values recorded during the Dunleer-Dundalk Motorway Project Ground Investigation plotted against elevation (mOD) are presented in Figure 4. In cases where the N-value recorded is greater than 100 or when no value was recorded because progress was so slow, the N-value is shown as “100”.

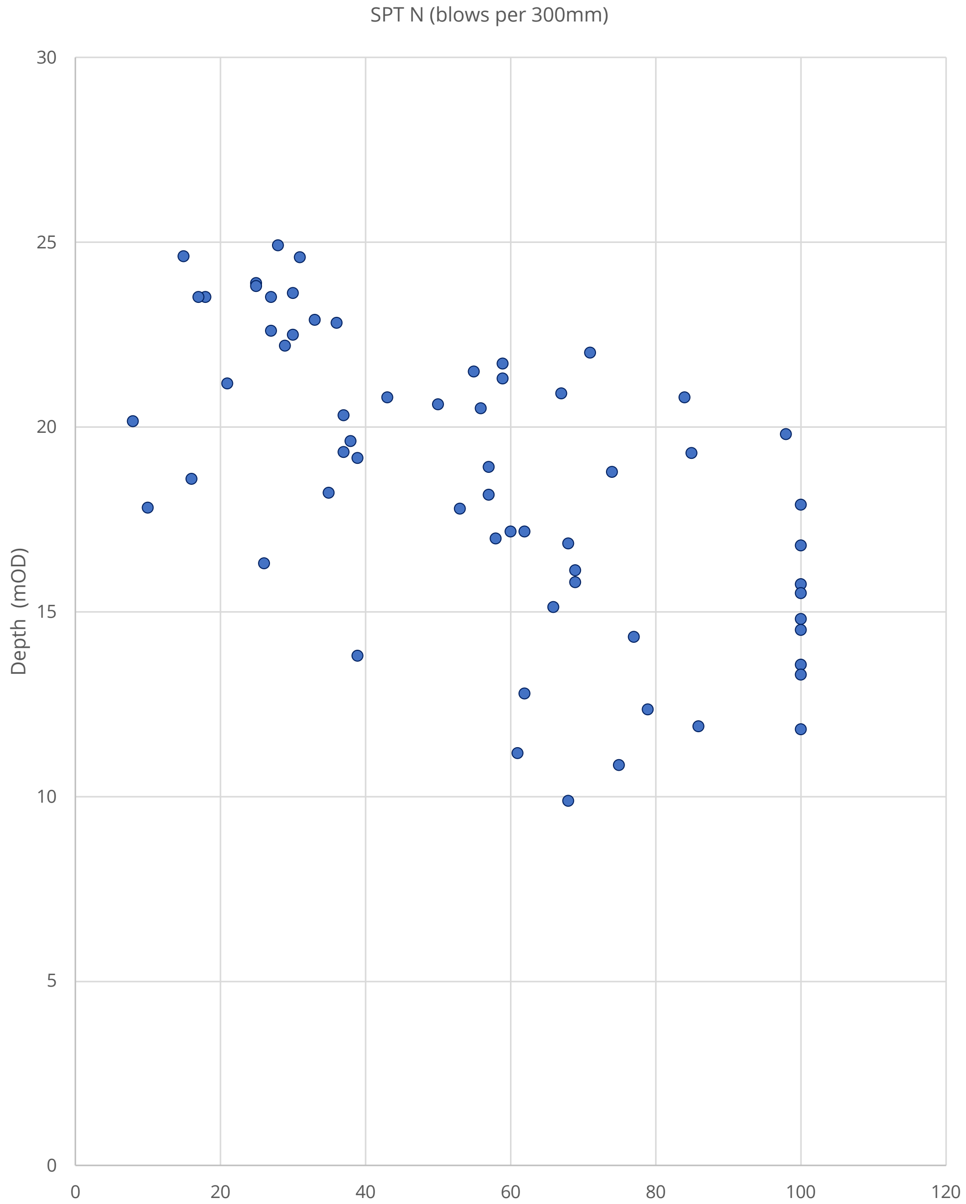

Figure 4 - SPT N plot from desk study information – where N values over 100 recorded, these are plotted as 100

A preliminary ground model is developed based on the desk study information as follows:

25.5 to 22/19mOD	Stiff sandy silty CLAY with cobbles and boulders
22/19 to 12/10mOD	Stiff to hard sandy silty CLAY with cobbles and boulders
12/10mOD & deeper	Moderately strong to strong LIMESTONE

3.2 Intrusive Ground Investigation

No site specific ground investigation has been carried out to date. This report will make recommendations for same and we would be happy to assist in specifying, procuring, and monitoring same on site.

3.3 Geophysical Investigation

None to date.

3.4 Contamination of groundwater sources

Groundwater vulnerability is indicated as "low" suggesting that there is a thick covering of overburden over the bedrock aquifer. The bedrock aquifer is indicated as a generally unproductive Poor Aquifer. Three domestic and agricultural wells are mapped in the locality, with the nearest being 290m from the proposed crossing. There are classed as "poor" to "moderate" yield.

Given usual precautions and good practice during design and construction, it is not anticipated that any unusual or exceptional risk of the contamination of groundwater sources exists at this site.

3.5 Obstructions to drilling

A review of the historical ground investigation available indicates a risk of the presence of cobbles and large boulders within a the Boulder Clay matrix. Site-specific ground investigation is required to quantify the risk of obstruction from cobbles and boulders and will enable appropriate selection of drilling methodologies.

3.6 Damage to geological heritage

The nearest known site of geological heritage is County Geological Site LH010 "Castlebellingham Morainic Complex", which includes a large accumulation of sands and gravels deposited at the edge of the northward-retreating ice margin at the end of the last Ice Age. The morainic complex includes a distinctive hummocky topography just south of Castlebellingham where the land surface is formed of many small hummocks and marked hollows. The proposed crossing site is at least 700m away from the mapped and audited boundary of the County Geological Site and will not have any adverse impact on the site.

3.7 Geotechnical summary

No site specific ground investigation has been carried out. Based on publicly-available and historic information, a preliminary ground model has been developed as follows:

25.5 to 22/19mOD	Stiff sandy silty CLAY with cobbles and boulders
22/19 to 12/10mOD	Stiff to hard sandy silty CLAY with cobbles and boulders
12/10mOD & deeper	Moderately strong to strong LIMESTONE

It is expected that there is 300mm of TOPSOIL on average at the entry and exit pit locations; TOPSOIL shall be stripped and stored carefully in low-height stockpiles for reinstatement on completion of the crossing.

Site-specific ground investigation is recommended and should consist of at least three boreholes to at least 5m below the proposed alignment and at least 20m on plan away from the alignment. Boreholes should be backfilled with bentonite.

Section 4 | ANTHROPOGENIC FACTORS

4.1 Land use

The main land use impact of the proposed crossing shall be the entry and exit pits and associated working areas and pipe stringing area. A recent earlier photograph showing the land usage is presented in Figure 5.

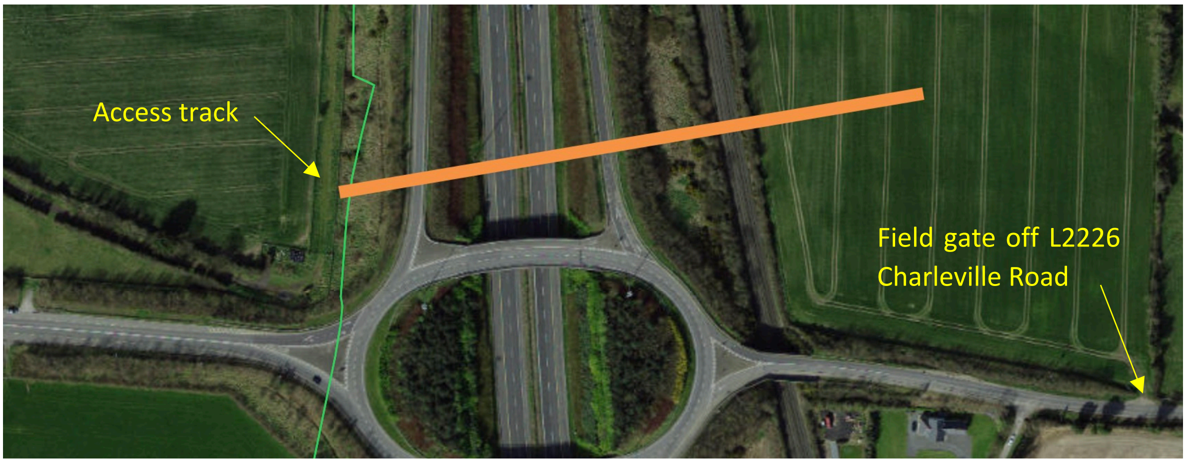

Figure 5 - Land use (entry pit on left, exit pit on right, crossing is orange line)

On the western side of the crossing, the proposed entry pit is located along a low-traffic agricultural access road, which provides good access to the more intense entry side of the works and is unlikely to significantly impact the public. Local arrangements will need to be made with landowners affected.

On the eastern side of the crossing, the proposed exit pit and pipe stringing area is in an agricultural field, which has been used for arable agriculture since at least 1995. Here, it is likely that the works would have a significant impact on the land owner and early consultation should take place to identify constraints and potentially optimum times of year to undertake the works.

4.2 Dublin-Belfast Railway Line

The Dublin-Belfast Railway Line has been in existence since the 1850s as the Dublin and Belfast Junction Railway. The railway line is owned and operated by Iarnród Éireann / Irish Rail and as part of the licensing requirement for any crossing, a number of requirements must be met, to include providing a minimum depth of cover to the proposed crossings, showing that predicted settlements are below required limits, and showing that the proposed installation will be strong enough to resist any loading it may be subjected to.

4.3 M1 Motorway

The proposed HDD will pass beneath the mainline and northbound and southbound slip roads of the M1 Motorway. This section of the motorway was opened in 2001. At the proposed crossing site the mainline of the motorway is within shallow cutting with approach slip roads to the junction on fill embankments. The motorway is operated by Celtic Roads Group on behalf of Transport Infrastructure Ireland (TII) under a Public Private Partnership (PPP) contract.and Transport Infrastructure Ireland. Typically motorway operators will require a geotechnical engineering assessment to include settlement and hydrofracture calculations to verify that the road surface will not be adversely affected by the proposed works.

Section 5 | ASSESSMENT OF TRENCHLESS OPTIONS

5.1 Listing of Options Considered

Based on the site visit and preliminary design work, taking into account the geometry of the site, only horizontal directional drilling (HDD) is being considered as a trenchless methodology.

5.2 Horizontal directional drilling (HDD).

Horizontal directional drilling (HDD) is a surface-launched trenchless technology for the installation of pipes, conduits, and cables. HDD creates a pilot bore along the design pathway and reams the pilot bore in one or more passes to a diameter suitable for the product, which is pulled into the prepared bore in the final step of the process.

1.1. <u>Positives:</u>

- Subject to ground conditions and technique drilling can progress quickly, rate of progress (ROP) whilst drilling a pilot bore in overburden would **average** 6 m in 15 minutes, and bedrock 6 m in one hour.
- Drilling overburden can achieve radii of < 100 m.
- Rock drilling can follow a radius as tight as 250 m.
- Drilling rigs are typically track mounted with the drilling fluid mixing/recycling systems installed in a truck or on a skid.
- The total length of the crossings can be installed in a single pipe section.
- A wide range of tooling options are available, ranging from aggressive jetting assemblies, dual wall drill pipe technology, down the hole (DTH) hammers and mud motors.
- Locating and tracking the drill head is completed using either a radio detection or wireline systems. The location of the drill head can be monitored in real time and plotted in three dimensions. There are now radio detections systems capable of locating a beacon mounted in the drill head 110m from the receiver.
- Ideal methodology for installing the multiple ducts.
- The use of bentonite, polymers, including polyanionic cellulose polymers (PACs), and lubricants aid to support the borehole, cool the drill head and remove the cuttings.
- Ducting can be installed without the need of a carrier duct/sleeve.
- The drilling equipment remains at surface which avoids the need for deep shafts.

1.2. <u>Negatives:</u>

- Intersecting a boulder or the transition zone into the bedrock can deviate the pilot bore, making it difficult to maintain the radius of curvature.
- If SPT values are >40 steering with a regular jetting assembly can be challenging.
- For drilling rock or very stiff boulder clays traditional HDD rigs require mud motors which use high volumes of drilling fluid that are typically recycled.
- Drilling fluid losses into broken formations or along a path of weakness can occur resulting in frac out (the condition where drilling fluid escapes through fractures) to surface or a water body along the profile.

- Drilling fluids have their limitations so collapsing formations can be an issue, using conductor casings can mitigate this situation if the problem is close to surface.
- Pipe scouring against angular material.
- An oversized borehole due to washout or key holing leading to subsidence in superficial deposits.

5.3 Recommendations

HDD is ideally suited to installing the ducts as a low disruption, quick, and accurate trenchless methodology and is considered the optimal approach for this crossing given the information to hand.

Section 6 | TRENCHLESS PROFILE REVIEW

6.1 HDD profile

It is proposed to install the required ducting in a single bore. The plan and profile drawing produced as a result of this feasibility assessment is provided in Appendix B, ref: 03117-GDS-ZZ-XX-DR-C-0001 Oriel Windfarm - M1 & Rail Crossing.

The information available for the design of the crossing is:

- Topographical detail.
- Exit and Entry locations.
- Utility detail.
- Historical geotechnical boreholes.

6.1.1 Profile Summary

The indicative profile of the installation bore is shown on drawing provided in Appendix B. A summary of the profile is given below:

- Distance from the entry to exit pit will be approximately 265m.
- An entry and exit angle of 15 degrees is proposed to facilitate the rig being set up either side of the crossing.
- The ground level at the entry pit is approximately 25.5 mOD.
- At entry the vertical curve of the section drawing begins straight through the boulder clay, bending commencing in the boulder clay 11.5 m from entry at a radius of 150 m until the radius flattens out, continuing beneath the motorway and railway until approximately 50m from the exit where the pilot hole will rise at a 150m radius to surface until a 15 degree angle is achieved and finishes on a straight line to exit.
- The deepest point of the HDD profile is 13 mOD.
- The motorway level is ~21.8 mOD.
- The track level is ~24.1 mOD.
- The GL at the exit pit in the field to the east of the railway is 23.0 mOD.

6.1.2 Observations

The profile involves drilling through Boulder Clay. Multiple challenges exist in the upper formations ranging from poor steering, collapse, deviation, and drilling fluid losses, until more competent Boulder Clay is intersected. All these factors may present difficulties in stabilising and removing the cuttings from the borehole, therefore it is imperative that a competent and experienced HDD contractor is selected and that the correct equipment, tooling, tracking system and drilling fluids are used.

The N-values across a large proportion of the profile would suggest all-terrain drilling techniques are required as the formation is too stiff for a jetting assembly. In all-terrain (Dual Wall Drill Pipe) drilling. the drill bit is turned using inner drilling rods whilst separate outer rods orientate the drill head.

6.1.3 Borehole Cross Section

The proposed borehole cross section is shown in Figure 6. This will be subject to detailed design.

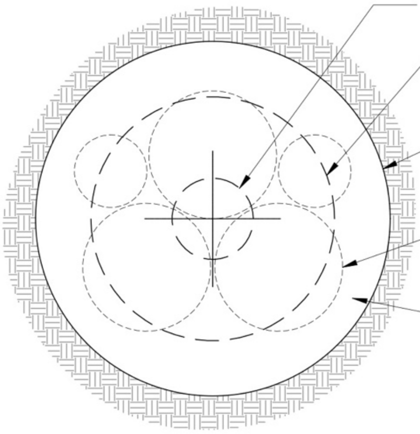

Figure 6 - Configuration of the ducts and bores for the proposed HDD crossing

Configuration: Based on the requirements of the client, the installation will consist of a bundle of 3 no. 225mm and 2 no. 125mm SDR11 PE100 ducts.

6.1.4 Transition Chamber

A precast concrete transition chamber in accordance with Eirgrid standard drawing “OFD-SSS-524 Transition Chamber” will be installed on the entry side, as per the drawing in Appendix B.

Section 7 | GEOTECHNICAL RISK ASSESSMENT

Risk	Mitigation undertaken by GDS	Residual risk / actions
Variability in ground conditions leads to difficulties drilling.	Historical ground investigation & public mapping reviewed. Preliminary ground model developed.	Site specific ground investigation is recommended, this should consist of at least 3 boreholes to at least 5m below the proposed alignment and at least 20m on plan away from the alignment. Boreholes should be backfilled with bentonite.
Unforeseen ground conditions.	Historical ground investigation & public mapping reviewed.	Site specific ground investigation is recommended.
UXO.	No design mitigation possible in this region as no mapping available.	Risk considered “low”.
Historical land use – contamination & obstructions.	Historical & present day OSi & satellite mapping reviewed. Site walkover undertaken.	Although no likely sources of contamination or obstruction related to historical ground use were identified, site-specific ground investigation is recommended.
Hydraulic fracture.	Frac out calculations carried out for crossing beneath M1 Motorway and Dublin-Belfast railway line.	Works to progress with appropriate drilling fluids & a high degree of control over operations to ensure trigger levels of downhole pressure not breached. Mitigation measures to be developed in RAMS to deal with possible loss of drilling fluid.
Adverse settlements.	Preliminary settlement calculations carried out; found settlements likely within tolerable limits.	Establish stakeholder requirements & complete detailed design settlement assessments. Settlement monitoring to be agreed with stakeholders.
Hitting buried services – gas & electricity.	We have not reviewed services records except those shown on ESB drawing PE605-D027-026-002-006 DRAFT.	Sufficient cover to M1 motorway and Dublin-Belfast railway has been provided to prevent contact with services buried at typical depths. Utility surveys to be carried out at detailed design stage.
Loss of flush through existing boreholes.	Alignment is at least 20m away from known locations of existing boreholes.	There may be other decommissioned geotechnical borings which are not recorded or visible.
Steering accuracy.	Given the constraints on access to the M1 motorway & Dublin-Belfast railway line, walkover locator systems will not be feasible.	Competent steering engineer to be employed; gyro guidance required.

Section 8 | ASSESSMENT OF DRILLING FLUID HYDROFRACTURE RISK FOR HDD

Drilling fluid hydrofracture occurs when the drilling fluid downhole pressure exceeds the strength and confining stress of the soil layers above the HDD bore. Drilling fluid downhole pressure is typically highest during the latter stages of the pilot hole drilling operation and, therefore, drilling fluid downhole pressure is monitored closely during this stage of operations and maintained at the minimum required level to ensure the drilling fluid maintains returns from the HDD bore to remove excavated spoil. Inadvertent drilling fluid returns to the surface can also occur where desiccation cracks and fissures/fractures exist in the soil layers.

The escape of drilling fluid occurs when drilling fluid pressures exceed the maximum allowable pressure (p_{max}) of the surrounding soil and localised plastic yielding or hydrofracture of the soil surrounding the annulus occurs (Bennett, 2008). A localised zone of soil yields around the bore. The limiting radius of yielding occurs at the point where the pressure is equal to p_{max}, the pressure required to cause plastic yielding. Beyond this zone, the pressure is less than the pressure required to cause plastic yielding, and hydrofracture does not occur.

In order to calculate the critical fluid pressure p_{max}, the "Delft equation" is used for cohesionless soils. This equation and approach are widely cited in the literature (Bennett, 2008) and is formulated as follows:

$$p_{max} = u + [\sigma'_0 \cdot (1+\sin\varphi) + c \cdot \cos\varphi + c \cdot \cot\varphi] \cdot \left(\left(\frac{R_0}{R_{pmax}} \right)^2 + \frac{\sigma'_0 \cdot \sin\varphi + c \cdot \cos\varphi}{G} \right)^{\frac{-\sin\varphi}{1+\sin\varphi}} - c \cdot \cot\varphi$$

The parameters are as follows:

- p_{max} = maximum allowable drilling fluid pressure
- u = pore water pressure
- σ'_0 = initial vertical effective stress
- ϕ = angle of internal friction
- R_0 = initial radius of borehole
- $R_{p,max}$ = maximum allowable radius of plastic zone (a factor of safety of 2.5 is applied)
- G = shear modulus
- c = effective cohesion

Based on the preliminary ground model presented earlier and the bore profile indicated on the drawing, it is determined that the bore will be within a layer of stiff to hard sandy silty CLAY with cobbles and boulders for the majority of the crossing. The characteristic parameters are derived from historical borehole data, comparable experience and published literature, and are outlined below:

- The unit weight of the stiff to hard sandy silty CLAY is taken as $20kN/m^3$ below the groundwater table (γ_{sat}) and $19kN/m^3$ (γ') above the groundwater table, based on the advice of BS 8004:2015+A1:2020. This is used to establish the initial vertical effective stress σ'_0.
- The angle of internal friction is taken as 30 degrees and the effective cohesion is take as 0 kPa, based on comparable experience.

- Based on an assessed characteristic E' of 40,000 kPa, the shear modulus G is estimated as 31,000 kPa. Shear modulus is hard to calculate and has a significant impact on the prediction (Staheli et al, 2010), therefore it is chosen conservatively.

The calculation was performed for a pilot hole diameter of 150mm and a final reamer diameter of 609.6mm, corresponding to stages of drilling shown in Figure 6. For the profile as shown in the drawing, and allowing a factor of safety of 2.5 on the value of maximum pressure, the calculated values of p_{max} at the proposed HDD crossings are shown in Figure 7 and Figure 8.

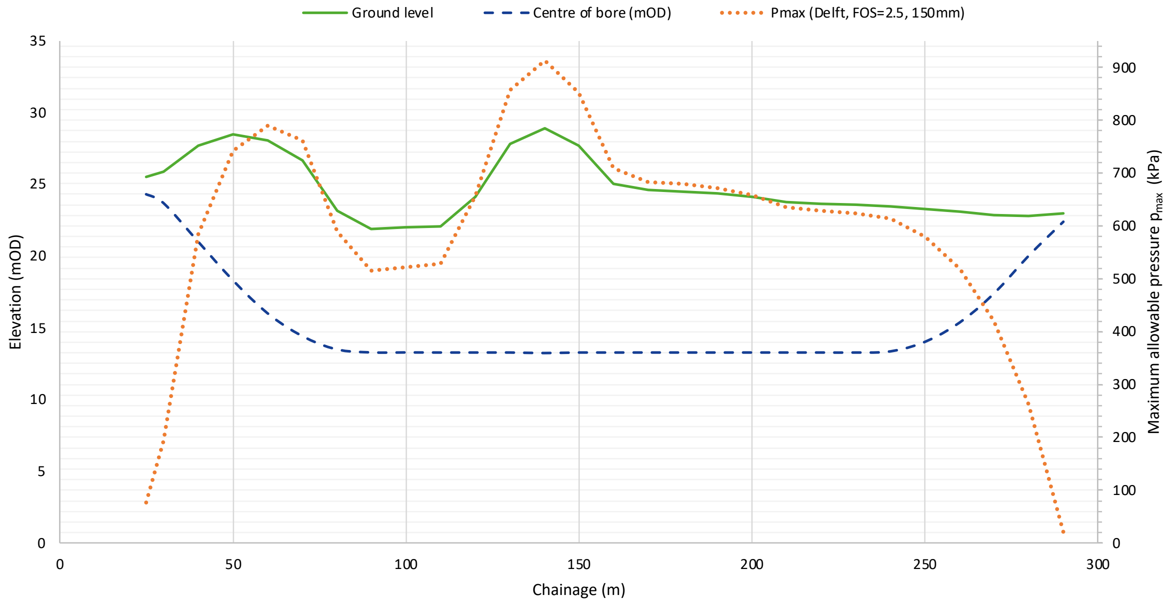

Figure 7 - Maximum allowable pressure p_{max} (on right axis) for 150mm pilot bore

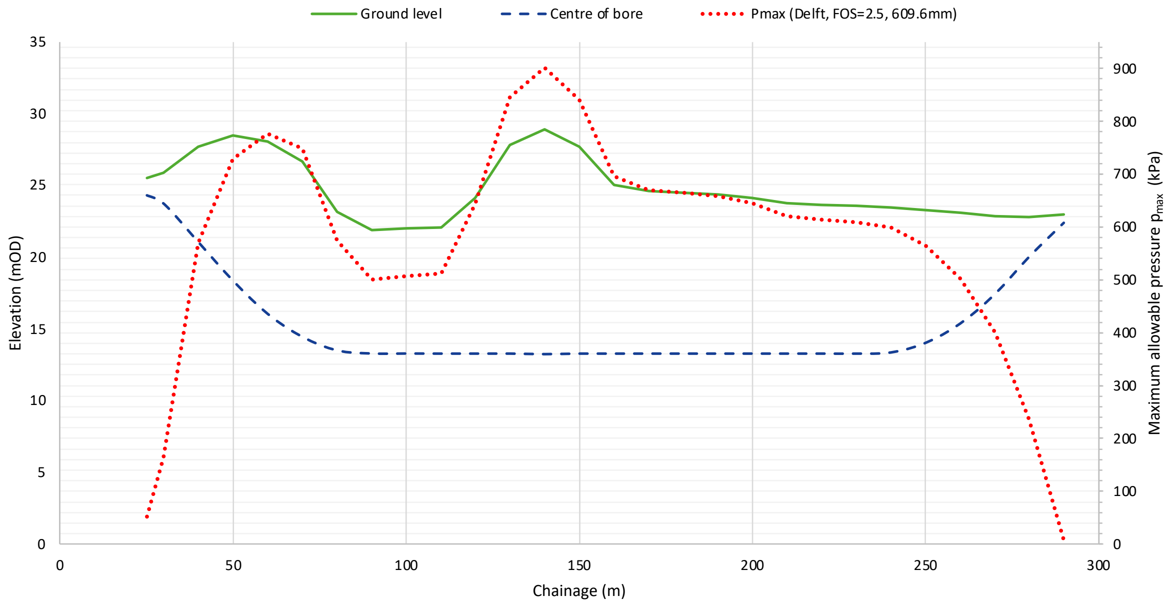

Figure 8 – Maximum allowable pressure p_{max} (on right axis) for 609.6mm reaming run

It is expected that the HDD bore can proceed while maintaining downhole pressures less than the maximum allowable pressure p_{max} shown in Figure 7 and Figure 8.

From the bore cross section shown in Figure 6, the HDD bore diameter is 609.6mm and the five ducts (3 no. 225mm and 2 no. 125mm) may be modelled as an equivalent single duct with an overall diameter of 500mm, therefore a safety factor of 1.2 is achieved on the required bore diameter to notional diameter of product ducts. HDD bore diameters typically range between 1.2x to 1.5x the diameter of the pipeline/duct to be installed, depending on site-specific conditions such as local geology and pipeline/duct stiffness. A factor of safety of 1.2 on the required bore diameter is commonly employed for HDD projects in Boulder Clays in Ireland and is considered reasonable based on the interpreted geology.

Depth of cover is typically maintained above 10x to 15x pipeline/duct diameter for the majority of a HDD profile in Boulder Clays in Ireland, as a conservative measure and depending on local geology. The equivalent single duct diameter for the five cable ducts to be installed is 500mm. A minimum depth of cover of 5.0m – 7.5m is therefore recommended for the majority of the crossing using the rule of thumb figure. This depth of cover is provided for the critical M1 motorway and Dublin-Belfast railway line crossings and for 220m of the overall approximately 280m length of the crossing. The depth of cover provided is considered to be beneficial in terms of minimisation of risk associated with potential inadvertent returns of drilling fluid to the surface.

While the risk of inadvertent returns of drilling fluid to the surface is considered low for the majority of the alignment, measures are expected to be implemented on site to monitor drilling fluid pressures downhole, monitor the surface for inadvertent returns of drilling fluid, and to contain and remove any drilling fluid from affected areas should the situation arise.

Minor escape of drilling fluid to the surface may be expected for the first and final 20m of the alignment where cover is low and mitigation measures should be outlined in the RAMS. These may include foot patrols to watch for signs of drilling fluid escape and the development of clean-up plans.

Section 9 | PRELIMINARY SETTLEMENT ASSESSMENT

Preliminary calculations of likely settlements using the method of O'Reilly & New (1982) and making conservative assumptions on the volume loss due to bentonite shrinkage and the relationship between volume loss in the bore to volume loss at the surface have been carried out. O'Reilly & New (1982) have shown that the immediate surface settlement profile or trough above a bore on a greenfield site can be represented adequately by a simple Gaussian or error function of the form:

$$\frac{s_v}{s_{\max}} = \exp(-y^2 / 2i^2)$$

The parameters are as follows:

s_v = vertical settlement at a horizontal distance at y from the bore centre line,
s_{max} = settlement at the centreline (y=0), and
i = value of y corresponding to the point of inflection of the function.

O'Reilly and New (1982) also proposed a linear relationship between i and z_0, the depth to the bore axis as follows:

$$i = kz_0$$

The k parameter is an empirical settlement trough width parameter related to the soil type and is taken as 0.5 for the stiff to hard sandy silty CLAY with cobbles and boulders controlling settlement, based on the findings of McCabe et al (2012).

The main inputs and results of the calculations are presented in Table 1. The graphs of settlement are shown in Figure 10 and Figure 11. The calculation sheets are attached as Appendix D.

Table 1 – Settlement calculations input and output summary

Location	Soil type	Cover to centre of pipe (m)	k value	Max settlement
M1 crossing	Stiff to hard sandy silty CLAY with cobbles and boulders	8.3	0.5	5.6mm
Railway crossing	Stiff to hard sandy silty CLAY with cobbles and boulders	10.3	0.5	4.5mm

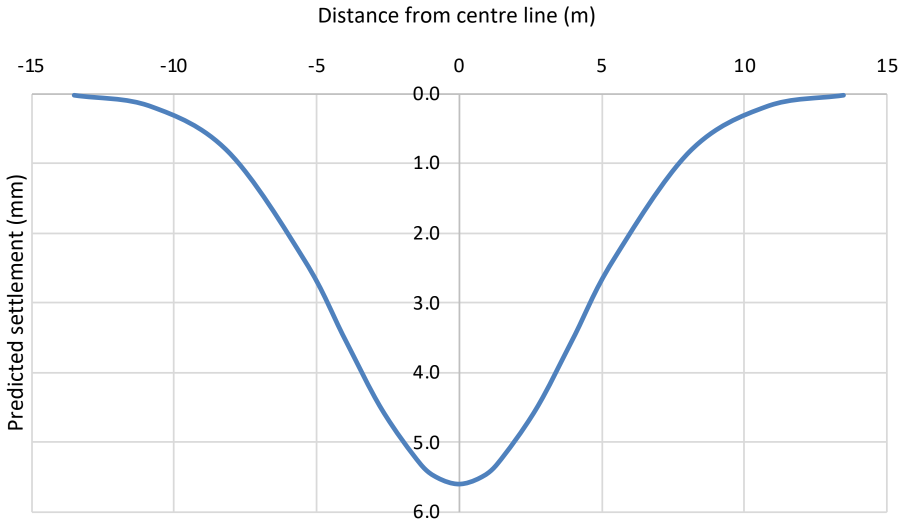

Figure 9 - Outputs from settlement calculations – total settlement - M1 crossing

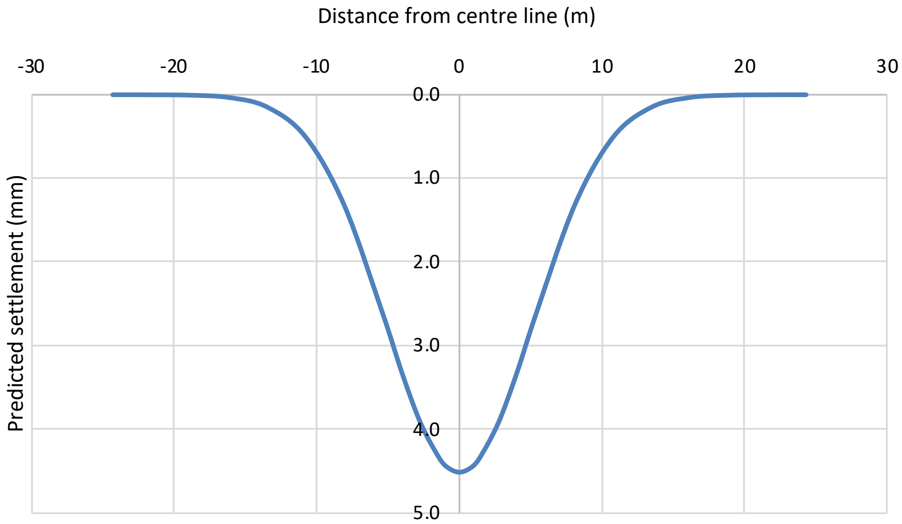

Figure 10 – Outputs from settlement calculations – total settlement – railway crossing

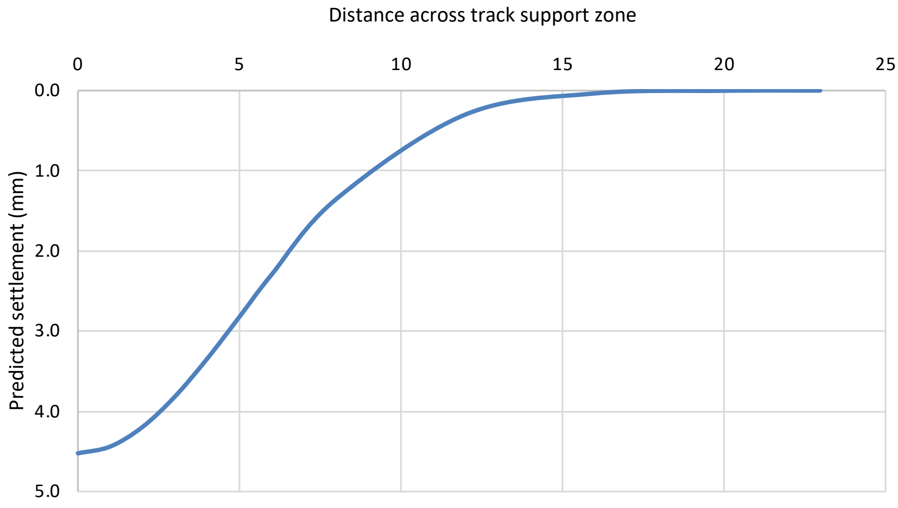

Figure 11 – Outputs from settlement calculations – worst case differential settlement across track support zone for railway crossing

The calculation sheets are attached as Appendix D. The calculations show predicted static twist as 1/4111 or less. Irish Rail requirements for “Green” limits for short twist are 1/500 and for long twist are 1/800. Therefore the predicted twist is below the "Green" trigger level.

Track monitoring shall be undertaken by the nominated surveying specialist in accordance with Córas Iompair Éireann/Iarnród Éireann Specification CCE-TRK-SPN-010 and shall commence at least two weeks before the expected commencement of the works. Settlement limits shall be as per that document.

Section 10 | ASSESSMENT OF HDD SURFACE WORKS ADJACENT TO M1 MOTORWAY AND DUBLIN/BELFAST RAIL LINE

The anticipated extent of the surface headworks for the HDD is shown on the drawing provided in Appendix B. The launch (entry) pit on the west side of the motorway will be located approximately 9m from the slope toe of the northbound ramp slip road, and 22m from the edge of the northbound slip road carriageway. The launch pit will typically be about 5 to 6m long, 2 to 3m wide and about 1.2m deep. It is unlikely that any notable temporary support will be required to maintain the stability of the pit faces. Considering the length of the proposed buried cables the most likely drilling plant will be a crawler mounted self-contained HDD rig of about 50 tonnes pull back capacity, see Appendix C. A temporary works platform about 35m x 75m in area would be located around the pit to ensure a stable area for plant and materials. The platform would be removed on completion.

The size and distance of the launch pit from the nearest motorway infrastructure, namely the toe of the slope of the northbound ramp slip road, is such that the launch pit will have no impact on the slope. Inspection of the slope at this location (20 June 2025) shows that it is about 3 to 4m high at an inclination of 1V:2H comprising cohesive fill with a cover of shrubs and small trees with no adverse signs of erosion or instability.

Following completion of the works the cables will be buried at the required depth. The burial depth will be such that this will allow any extension or modification of the current motorway configuration to be carried out over the buried cables without affecting the cables.

On the eastern side of the motorway the reception pit, which would be a similar size to the launch pit, will be a considerable distance from the motorway. At its nearest point, the reception pit will be approximately 86m from the nearest Irish Rail running rail and some 130m from the toe of the slope of the southbound ramp slip road. Given the distances involved the reception pit and associated temporary works compound will have no impact on the motorway or rail line.

Ideally the reception area should have the most available space as this is where the stringing would occur, hence the reception pit is shown on the east side. Should the HDD be drilled from the east side with the reception pit on the west side then similar comments would apply, though the associated temporary works compound associated with the reception pit would be larger.

Section 11 | CONCLUSIONS

Geo Drilling Solutions (GDS) has been requested by Oriel Windfarm Ltd. to review the use of Horizontal Directional Drilling (HDD) techniques to install a bundle of 3 nr 225mm & 2 nr 125mm SDR11 PE100 ducts under the M1 Motorway & Dublin-Belfast railway line at Junction 14 in County Louth. The activities undertaken in the preparation of this preliminary design report include a site visit, a desk study, and the preparation of drawings and calculations.

This report assess the use of HDD for the crossing by reviewing available local and regional information on ground conditions, assessing any site constraints, and examining the project requirements. The trenchless options available were assessed and recommendations made on suitable methods. A proposed indicative trenchless profile is provided (see Appendix B) and reviewed and the risks of construction including the risks of hydrofracture were assessed.

Based on the anticipated ground conditions and the other constraints reviewed, it is considered that HDD is the method of installation that is most feasible. The proposed profile is considered appropriate, subject to the gathering of further information and detailed design.

Of particular concern is the potential impact on the M1 with respect to the proximity of the proposed cables alignment to the M1 infrastructure. The impact of installing the HDD below the motorway and rail line was assessed for settlement and hydrofracture which showed that any impact from the HDD would be within acceptable tolerances. Notwithstanding this, appropriate measures are to be included in the detailed design and the RAMS for the crossing to ensure compliance.

The surface works associated with the HDD were also assessed. Given the considerable distances from the entry and exit pits to the nearest infrastructure that there will be no significant impact on the M1 motorway or the rail line. All temporary works will be removed on completion and the proposed burial depth of the cables will be sufficient to allow any extension or modification of the current motorway configuration to be carried out over the buried cables without affecting the cables.

The chosen methodology will be subject to the ESB operational and electrical requirements.

11.1 Recommendations

The following recommendations arise out of this report:

- Agreement should be sought with affected landowners, Transport Infrastructure Ireland, and Iarnród Éireann / Irish Rail for the crossing.
- Site-specific ground investigation is recommended and should consist of at least three boreholes to at least 5m below the proposed alignment and at least 20m on plan away from the alignment. Boreholes should be backfilled with bentonite.
- A topographical survey should be commissioned.
- Utility searches to be undertaken at detailed design stage to include GPR and slit trenching to prove utility locations.
- Settlement predictions and settlement monitoring methodology should be confirmed at detailed design and agreed with TII and Iarnród Éireann / Irish Rail.
- Hydrofracture analyses should be confirmed during detailed design and mitigation measures to be developed in RAMS to deal with possible loss of drilling fluid at the start and end of the alignment.

Section 12 | REFERENCES

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McCabe, B.A., Orr, T.L.L., Reilly, C.C. and Curran, B.G. (2012). Settlement trough parameters for tunnels in Irish glacial tills. In: *Tunnelling and Underground Space Technology, 27,* pp. 1-12.

O'Reilly, M.P. and New, B.M. (1982). *Settlements above tunnels in the United Kingdom: their magnitude and prediction.* In: Proceedings of Tunnelling '82 Symposium, London, pp. 173–181.

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APPENDIX A *Historical borehole logs*

SITE INVESTIGATIONS LIMITED
BOREHOLE RECORD

CONTRACT Dunleer-Dundalk Motorway Phase 1 Extension
Borehole No. E7
Sheet 1 of 1
CLIENT M.C. O'Sullivan
Site Address Co. Louth
Boring Commenced 30/11/92
Boring Completed 30/11/92
Type of Boring Shell & Auger
Diameter of Borehole 200 mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests Type	Samples/Tests Depth	Samples/Tests Ref. No.	Samples/Tests Casing Depth	Date	Water Depth
Ground Level 25.90mOD	m	m			m				m
Topsoil	25.55	0.35							
Stiff brown sandy silty stony clay				D	1.00	91924			
				C(28)	1.15				
	23.80	2.10						30/11	Nil
Presumed boulder (Chiselling 2 hrs)									

Remarks:
Moved 1.5m to BH E7 Rebore due to boulder
Chiselling 2 hours

KEY	EXPLANATION
+	Water Strike
D	Disturbed Sample
B	Bulk Disturbed Sample
W	Water Sample
U	Undisturbed Sample
P	Piston Sample
C(N)	Cone Penetration Test
S(N)	Standard Penetration Test
N	Blows /300mm
V	Vane Test

SITE INVESTIGATIONS LIMITED
BOREHOLE RECORD

CONTRACT Dunleer-Dundalk Motorway Phase 1 Extension

Borehole No. E7 Rebore
Sheet 1 of 3

CLIENT M.C. O'Sullivan

Site Address Co. Louth

Boring Commenced 30/11/92

Boring Completed 7/5/93

Type of Boring Shell & Auger and Diamond Drill

Diameter of Borehole 200/TNW mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests Type	Depth	Ref. No.	Casing Depth	Date	Water Depth
Ground Level 25.90mOD	m	m			m				m
Topsoil	22.55	0.35							
Stiff brown sandy silty stony clay with small cobbles				D	2.00	91925			
				C(25)	2.15				
				W	2.50	91931		30/11	2.5+
				D	3.00	91926			
				C(33)	3.15				
	22.00	3.90		D	3.90	91927			
Stiff to hard dark brown silty sandy gravelly clay with cobbles and large boulders (Chiselling 3½ hrs)				C(71)	4.05				
				D	5.00	91928		30/11	4.5
				C(67)	5.15			1/12	2.0
				D	7.00	91929			
				C(57)	7.15				
	17.90	8.00		D	8.00	91930		1/12	6.2
~~Presumed boulder or rock(Chis. 1Hr)~~	~~17.80~~	~~8.10~~		C(*)	8.00			2/12	2.1
Stiff/hard dark brown silty stony clay with cobbles								2/12	2.5

Remarks:

Chiselling 4½ hours
At 8.00m 50 blows for 37mm Refusal
Wavin inserted to 8.1m
Cored from 8.50 to 12.20m and 12.65 to 19.50mBGL.
Open hole drilling from 8.10 to 8.50m and 12.20 to 12.65mBGL
See geological log for detailed rock description

KEY	- EXPLANATION
+	- Water Strike
D	- Disturbed Sample
B	- Bulk Disturbed Sample
W	- Water Sample
▮U	- Undisturbed Sample
▮P	- Piston Sample
↓C(N)	- Cone Penetration Test
↓S(N)	- Standard Penetration Test
N	- Blows /300mm
V	- Vane Test

SITE INVESTIGATIONS LIMITED
BOREHOLE RECORD

CONTRACT Dunleer–Dundalk Motorway Phase 1 Extension

Borehole No. E7 Rebore

Sheet 2 of 3

CLIENT M.C. O'Sullivan

Site Address Co. Louth

Boring Commenced 30/11/92

Boring Completed 7/5/93

Type of Boring Shell & Auger and Diamond Drill

Diameter of Borehole 200/TNW mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests Type	Depth	Ref. No.	Casing Depth	Date	Water Depth
Ground Level 25.90mOD	m	m			m				m
Stiff/hard brown silty sandy gravelly clay with cobbles				C(*)	10.15				
				C(*)	12.35				
	11.70	14.20							
Limestone rock									

Remarks:

At 10.15m 55 blows for 125mm Refusal
At 12.35m 94 blows for 250mm Refusal
See gological log for detailed rock description

KEY	- EXPLANATION
+	- Water Strike
D	- Disturbed Sample
B	- Bulk Disturbed Sample
W	- Water Sample
▮U	- Undisturbed Sample
▮P	- Piston Sample
↓C(N)	- Cone Penetration Test
↓S(N)	- Standard Penetration Test
N	- Blows /300mm
V	- Vane Test

SITE INVESTIGATIONS LIMITED
BOREHOLE RECORD

CONTRACT Dunleer-Dundalk Motorway Phase 1 Extension
Borehole No. E7 Rebore
Sheet 3 of 3
CLIENT M.C. O'Sullivan
Site Address Co. Louth
Boring Commenced 30/11/92
Boring Completed 7/5/93
Type of Boring Shell & Auger and Diamond Drill
Diameter of Borehole 200/TNW mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests Type	Depth	Ref. No.	Casing Depth	Date	Water Depth
Ground Level 25.90mOD	m	m			m				m
Limestone rock	6.40	19.50							
Final Level									

Remarks:

See geological log for detailed rock description

KEY - EXPLANATION
+ - Water Strike
D - Disturbed Sample
B - Bulk Disturbed Sample
W - Water Sample
U - Undisturbed Sample
P - Piston Sample
C(N) - Cone Penetration Test
S(N) - Standard Penetration Test
N - Blows /300mm
V - Vane Test

PROJECT: Dunleer-Dundalk Motorway		BOREHOLE NO.	E7
CLIENT: Louth County Council	CONTRACTOR: Site Investigations Ltd.	SHEET 1	OF 1
MACHINE TYPE: Edeco CORE BARREL: TNX BIT DESIGN: Face Discharge CORE DIAMETER MM: 60 FLUSH: Water	LOCATION GROUND SURFACE ELEVATION M.O.D. INCLINATION: Vertical CASING DEPTH: 0m AZIMUTH FINAL DEPTH M: 19.50	DRILLED BY: S.I. Ltd. DATE STARTED DATE COMPLETED	LOGGED BY: CM

DOWNHOLE DEPTH M	CORE RUN DEPTH M	TOTAL CORE RECOVERY %	SOLID CORE RECOVERY %	ROCK QUALITY DESIGNATION %	FRACTURE SPACING INDEX	DISCONTINUITIES	SYMBOLIC LOG	ELEVATION M.O.D.	DEPTH M	GEOLOGICAL DESCRIPTION	PIEZOMETER DETAILS
9	8.50 – 10.00	35				No recovery - roller drilled			8.50	Angular pebbles, cobbles and boulders of calcisiltite limestone, within an occasional matrix of grey-brown sandy, clay. (? Grey Boulder Clay)	
10	10.00 – 11.20	36									
11	11.20 – 12.20	30									
12	12.20 – 12.60										
13	12.60 – 13.40	35									
14	13.40 – 14.20	48									
15	14.20 – 15.60	100	31	8	0.035	Rough, irregular, clean to clay smeared, very closely spaced discontinuities, dip 20°.			14.20	Buff grey, highly weathered, calcisiltite LIMESTONE, moderately strong, bioclastic. dip 10°, reacts with HCL solution.	
16	15.60 – 16.40	88	68	56	0.108	Rough, irregular, clean to clay smeared, closely spaced discontinuities, dip 20°.			15.60	Dark grey, moderately weathered, calcisiltite LIMESTONE, moderately strong, dip 20°.	
17	16.40 – 17.90	100	65	56	0.108						
18	17.90 – 19.50	88	54	37	0.079				17.90	Buff-grey, moderately weathered, calcisiltite LIMESTONE, moderately strong, reacted with HCL solution.	
19	19.50										

REMARKS

Solid core taken as that with solid diameter (Norbury et al 1986).

REVISED EDITION AS OF 2-11-1993

SCALE 1:50

B J Murphy & Associates, Geological & Geotechnical Consultants, Dublin, Ireland. 353-1-2600020

SITE INVESTIGATIONS LIMITED
BOREHOLE RECORD

CONTRACT Dunleer–Dundalk Motorway Phase 1 Extension
Borehole No. E8
Sheet 1 of 4
CLIENT M.C. O'Sullivan
Site Address Co. Louth
Boring Commenced 25/11/92
Boring Completed 4/5/93
Type of Boring Shell & Auger and Diamond Drill
Diameter of Borehole 200/TNW mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests Type	Samples/Tests Depth	Samples/Tests Ref. No.	Samples/Tests Casing Depth	Date	Water Depth
Ground Level 25.50mOD	m	m			m				m
Topsoil	25.15	0.35							
Stiff brown sandy stony clay				U	1.00	91914			
				D	2.00	91915			
				C(27)	2.15				
				D	3.30	91916			
				C(29)	3.45				
	22.10	3.80							
Stiff/hard dark grey silty sandy gravelly clay with boulders				D	3.80	91917			
				C(59)	3.95				
								25/11	5.0 +
				D	6.20	91918		26/11	4.5
				C(85)	6.35				
				W	6.60	91923			
				D	8.50	91919			

Remarks:

Cored from 12.2 to 13.0 and 15.0 to 29.0mBGL
Open hole drilling from 13.0 to 15.0mBGL
See geological log for detailed rock description

KEY	EXPLANATION
+	Water Strike
D	Disturbed Sample
B	Bulk Disturbed Sample
W	Water Sample
▮U	Undisturbed Sample
▮P	Piston Sample
↓C(N)	Cone Penetration Test
↓S(N)	Standard Penetration Test
N	Blows /300mm
V	Vane Test

SITE INVESTIGATIONS LIMITED
BOREHOLE RECORD

CONTRACT Dunleer-Dundalk Motorway Phase 1 Extension
CLIENT M.C. O'Sullivan
Site Address Co. Louth
Boring Commenced 25/11/92
Type of Boring Shell & Auger and Diamond Drill

Borehole No. E8
Sheet 2 of 4
Boring Completed 4/5/93
Diameter of Borehole 200/TNW mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests Type	Samples/Tests Depth m	Samples/Tests Ref. No.	Samples/Tests Casing Depth	Date	Water Depth m
Ground Level 25.50mOD	m	m							
				C(68)	8.65				
Stiff/hard dark grey silty sandy gravelly clay with boulders (Chiselling 1¼ hrs)									
				D	10.00	91920			
				C(*)	10.15				
								26/11	8.7
								27/11	4.5
				D	11.00	91921			
				C(117)	11.15				
(Chiselling 2 hrs)	13.70	12.20		D	12.20	91922		27/11	6.6
				C(*)	12.20				
Brown gravelly clay	12.90	13.00							
				C(79)	13.15				
Stiff/hard grey gravelly clay with cobbles									
				C(75)	14.65				
	10.70	15.20							
Brown gravelly clay with cobbles	10.00	15.90							
Limestone rock									

Remarks:

Chiselling 6 hours
At 10.15m 50 blows for 25mm REfusal
At 12.20m 50 blows for 62mm Refusal
Inserted 110mm wavin to 12.20m

See geological log for detailed rock description

KEY	- EXPLANATION
+	- Water Strike
D	- Disturbed Sample
B	- Bulk Disturbed Sample
W	- Water Sample
▌U	- Undisturbed Sample
▌P	- Piston Sample
↓C(N)	- Cone Penetration Test
↓S(N)	- Standard Penetration Test
N	- Blows /300mm
V	- Vane Test

SITE INVESTIGATIONS LIMITED
BOREHOLE RECORD

CONTRACT Dunleer–Dundalk Motorway Phase 1 Extension

CLIENT M.C. O'Sullivan

Site Address Co. Louth

Boring Commenced 25/11/92

Type of Boring Shell & Auger and Diamond Drill

Borehole No. E8

Sheet 3 of 4

Boring Completed 4/5/93

Diameter of Borehole 50 mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests Type	Depth m	Ref. No.	Casing Depth	Date	Water Depth m
Ground Level 25.50mOD	m	m							
				C(74)	20.25				
Limestone rock				C(79)	21.65				

Remarks:

See geological log for detailed rock description

KEY	- EXPLANATION
+	- Water Strike
D	- Disturbed Sample
B	- Bulk Disturbed Sample
W	- Water Sample
U	- Undisturbed Sample
P	- Piston Sample
C(N)	- Cone Penetration Test
S(N)	- Standard Penetration Test
N	- Blows /300mm
V	- Vane Test

SITE INVESTIGATIONS LIMITED
BOREHOLE RECORD

CONTRACT Dunleer–Dundalk Motorway Phase 1 Extension

Borehole No. E8

CLIENT M.C. O'Sullivan

Site Address Co. Louth

Boring Commenced 25/11/92

Boring Completed 4/5/93

Type of Boring Shell & Auger and Diamond Drill

Diameter of Borehole 200/TNW mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests Type	Depth m	Ref. No.	Casing Depth	Date	Water Depth m
Ground Level 25.50mOD	m	m							
Limestone rock	-3.50	29.00							
Final Level									

Remarks:

See geological log for detailed rock description

KEY	EXPLANATION
+	Water Strike
D	Disturbed Sample
B	Bulk Disturbed Sample
W	Water Sample
▮U	Undisturbed Sample
▮P	Piston Sample
↓C(N)	Cone Penetration Test
↓S(N)	Standard Penetration Test
N	Blows /300mm
V	Vane Test

PROJECT: Dunleer-Dundalk Motorway		BOREHOLE NO. E8
CLIENT Louth County Council	CONTRACTOR Site Investigations Ltd.	SHEET 1 OF 2

MACHINE TYPE: Edeco CORE BARREL: TNX BIT DESIGN: Face Discharge CORE DIAMETER MM: 60 FLUSH: Water	LOCATION GROUND SURFACE ELEVATION M.O.D. INCLINATION: Vertical CASING DEPTH: 0m	AZIMUTH FINAL DEPTH M: 29.00	DRILLED BY: S.I. Ltd. LOGGED BY: CM DATE STARTED DATE COMPLETED

DOWNHOLE DEPTH M	CORE RUN DEPTH M	TOTAL CORE RECOVERY %	SOLID CORE RECOVERY %	ROCK QUALITY DESIGNATION %	FRACTURE SPACING INDEX	DISCONTINUITIES	SYMBOLIC LOG	ELEVATION M.O.D.	DEPTH M	GEOLOGICAL DESCRIPTION	PIEZOMETER DETAILS
12											
	12.20	28							12.20	Dark grey, now desiccated, CLAY with angular pebbles and cobbles of calcisiltite limestone. (? Grey Boulder Clay)	
13	13.00	CPT from 13.00 to 13.65m									
14		CPT from 14.50 to 14.95m				No Recovery					
15	15.00	100									
	15.20	37									
	15.90										
16		85	66	63	0.183	Rough, irregular, clean to clay smeared, very closely spaced discontinuities, dip 20°.			15.90	Dark grey, slightly weathered, fine grained calcisiltite LIMESTONE, strong, dip 20°.	
17	17.00	95	48	40	0.095						
	17.40	100	0	0	0.000	Clay band from 17.6 to 18.60m, not recovered (Drillers report).				Clay band from 17.6 to 18.60m, not recovered (Drillers report).	
18	18.10	34	32	20	0.080				18.10	Buff-grey, moderately weathered, dolomitised calcisiltite LIMESTONE, strong, dip 20°.	
	18.60								18.60	Dark grey, highly weathered, calcisiltite (argillaceous) LIMESTONE, moderately strong, largely non-intact, dip 20°.	
19		19	0	0	0.000						
20	20.10	0	0	0	0.000	No Recovery					
		CPT from 20.10 to 20.60m									
	20.60										
21		31	0	0	0.000						
	21.50	CPT from 21.50 to 21.95m (no recovery).									
22											

REMARKS

Solid core taken as that with solid diameter (Norbury et al 1986). REVISED EDITION AS OF 23-11-1993"

SCALE 1:50

B J Murphy & Associates, Geological & Geotechnical Consultants, Dublin, Ireland, 353-1-2600020

PROJECT: Dunleer-Dundalk Motorway		BOREHOLE NO.	E8
CLIENT: Louth County Council	CONTRACTOR: Site Investigations Ltd.	SHEET 2	OF 2

MACHINE TYPE	Edeco	LOCATION	DRILLED BY: S.I. Ltd.
CORE BARREL	TNX	GROUND SURFACE ELEVATION M O.D.	LOGGED BY: CM
BIT DESIGN	Face Discharge	INCLINATION: Vertical	AZIMUTH
CORE DIAMETER MM	60		DATE STARTED
FLUSH	Water	CASING DEPTH: 0m	FINAL DEPTH M: 29.00 / DATE COMPLETED

DOWNHOLE DEPTH M	CORE RUN DEPTH M	TOTAL CORE RECOVERY %	SOLID CORE RECOVERY %	ROCK QUALITY DESIGNATION %	FRACTURE SPACING INDEX	DISCONTINUITIES	SYMBOLIC LOG	ELEVATION M O.D.	DEPTH M	GEOLOGICAL DESCRIPTION	PIEZOMETER DETAILS
22	21.50	CPT from 21.5 to 21.95 no recovery				Rough, irregular, clean to clay smeared, very closely spaced discontinuities, dip 20°.				Dark grey, highly weathered, calcisiltite (argillaceous) LIMESTONE, moderately strong, largely non-intact.	
		48	0	0	0.000						
23	23.00	64	0	0	0.000						
24	24.00	29	0	0	0.000						
25											
26	25.70	87	27	13	0.090						
27	26.70	63	0	0	0.000						
	27.60	45	0	0	0.000						
28	27.80	65	16	0	0.063						
29	29.00								29.00		

REMARKS

Solid core taken as that with solid diameter (Norbury et al 1986). "REVISED EDITION AS OF 23-11-1993"

SITE INVESTIGATIONS LIMITED
BOREHOLE RECORD

CONTRACT Dunleer–Dundalk Motorway Phase 1 Extension
Borehole No. E9
Sheet 1 of 3
CLIENT M.C. O'Sullivan
Site Address Co. Louth
Boring Commenced 2/12/92
Boring Completed 22/4/93
Type of Boring Shell & Auger and Diamond Drill
Diameter of Borehole 200 /TNW mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests				Date	Water Depth
Ground Level 25.80mOD	m	m		Type	Depth m	Ref. No.	Casing Depth		m
Topsoil	25.50	0.30							
Stiff brown sandy silty stony clay with small cobbles				U	1.00	91932			
				D	2.00	91933			
				C(25)	2.15				
				D	3.20	91934		2/12	3.2+
				C(27)	3.35				
	22.00	3.80							
Stiff dark brown silty sandy gravelly clay with cobbles and boulders (Chiselling 4½ hrs)								2/12	Nil
								3/12	3.5
				D	4.50	91935			
				C(59)	4.65				
				D	5.50	91936			
				C(37)	5.65				
				D	8.50	91937			

Remarks:

Slight seepage of water at 3.20m
Open hole drilling from 15.0 to 16.2mBGL to 23.5mBGL
See geological log for detialed rock description

KEY	- EXPLANATION
+	- Water Strike
D	- Disturbed Sample
B	- Bulk Disturbed Sample
W	- Water Sample
▮U	- Undisturbed Sample
▮P	- Piston Sample
↓C(N)	- Cone Penetration Test
↓S(N)	- Standard Penetration Test
N	- Blows /300mm
V	- Vane Test

SITE INVESTIGATIONS LIMITED
BOREHOLE RECORD

CONTRACT Dunleer-Dundalk Motorway Phase 1 Extension
Borehole No. E9
Sheet 2 of 3
CLIENT M.C. O'Sullivan
Site Address Co. Louth
Boring Commenced 2/12/92
Boring Completed 22/4/93
Type of Boring Shell & Auger and Diamond Drill
Diameter of Borehole 200/TNW mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests Type	Samples/Tests Depth m	Samples/Tests Ref. No.	Samples/Tests Casing Depth	Date	Water Depth m
Ground Level 25.80mOD	m	m							
				C(60)	8.65				
				W	9.00	91942		3/12	Nil
								8/12	3.3
Stiff dark brown silty sandy gravelly clay with cobbles and boulders (Chiselling 1½ hrs)				D	9.70	91938			
				D	11.50	91939			
				C(77)	11.65				
				D	13.30	91940		8/12	Nil
				C(86)	13.45			9/12	6.2
	12.00	13.80							
Presumed boulder or rock(Ch. 1½ hrs)	11.80	14.00		D	14.00	91941		9/12	9.00
				C(*)	14.00				
Hard grey gravelly clay with cobbles									
	9.80	16.00							
Limestone rock									

Remarks:

Chiselling 7½ hours
At 14.00m 78 blows for 150mm Refusal
Inserted 110mm wavin to 14m
See geological log for detailed rock description

KEY	- EXPLANATION
+	- Water Strike
D	- Disturbed Sample
B	- Bulk Disturbed Sample
W	- Water Sample
U	- Undisturbed Sample
P	- Piston Sample
C(N)	- Cone Penetration Test
S(N)	- Standard Penetration Test
N	- Blows /300mm
V	- Vane Test

SITE INVESTIGATIONS LIMITED
BOREHOLE RECORD

CONTRACT Dunleer–Dundalk Motorway Phase 1 Extension

Borehole No. E9

CLIENT M.C. O'Sullivan

Site Address Co. Louth

Boring Commenced 2/12/92

Boring Completed 22/4/93

Type of Boring Shell & Auger and Diamond Drill

Diameter of Borehole 200/TNW mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests				Date	Water Depth
				Type	Depth m	Ref. No.	Casing Depth		m
Ground Level 25.80mOD	m	m							
Limestone rock	2.30	23.50							
Final Level									

Remarks:

See geological log for detailed rock description

KEY - EXPLANATION

- + - Water Strike
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- W - Water Sample
- U - Undisturbed Sample
- P - Piston Sample
- C(N) - Cone Penetration Test
- S(N) - Standard Penetration Test
- N - Blows /300mm
- V - Vane Test

PROJECT: Dunleer-Dundalk Motorway			BOREHOLE NO. B9
CLIENT Louth County Council	CONTRACTOR Site Investigations Ltd.		SHEET 1 OF 1
MACHINE TYPE Edeco CORE BARREL TNX BIT DESIGN Face Discharge CORE DIAMETER MM 60 FLUSH Water	LOCATION GROUND SURFACE ELEVATION M.O.D. INCLINATION Vertical CASING DEPTH 0m	AZIMUTH FINAL DEPTH M 23.50	DRILLED BY S.I. Ltd. / LOGGED BY CM DATE STARTED DATE COMPLETED

DOWNHOLE DEPTH M	CORE RUN DEPTH M	TOTAL CORE RECOVERY %	SOLID CORE RECOVERY %	ROCK QUALITY DESIGNATION %	FRACTURE SPACING INDEX	DISCONTINUITIES	SYMBOLIC LOG	ELEVATION M.O.D.	DEPTH M	GEOLOGICAL DESCRIPTION	PIEZOMETER DETAILS
14	14.00	40							14.00	Grey Clay with pebbles and cobbles of calcisiltite limestone. (? Grey Boulder Clay).	
15	15.00	No Recovery - Roller Drilled 15.00-16.00m.								Rock rolled from 15.00 to 16.00m - grey gravelly clay. (Drillers Report).	
16	16.00	CPT from 16.00 to 16.10m - no recovery									
		100	22	0	0.028	Rough, irregular, clean to clay smeared, closely spaced discontinuities, dip 20°.			16.20	Dark grey, slightly weathered, calcisiltite LIMESTONE, strong, dip 20°.	
17	16.70	95	82	82	0.246						
18	18.20	85	22	0	0.090						
	18.60	92	20	20	0.120						
19	19.20	90	63	63	0.190						
20	19.50	97	60	43	0.116						
21	20.85	94	53	45	0.133						
22	21.85	95	82	82	0.169	From 21.85 to 21.97m clean fracture, dip 70°.					
23	23.50										

REMARKS

Solid core taken as that with solid diameter (Norbury et al 1986). REVISED EDITION AS OF 23-11-1993"

SCALE 1:50

B J Murphy & Associates, Geological & Geotechnical Consultants, Dublin, Ireland, 353-1-2600020

SITE INVESTIGATIONS LIMITED
BOREHOLE RECORD

CONTRACT Dunleer-Dundalk Motorway Phase 1 Extension

Borehole No. E15
Sheet 1 of 3

CLIENT M.C. O'Sullivan

Site Address Co. Louth

Boring Commenced 9/12/92

Boring Completed 22/3/93

Type of Boring Shell & Auger and Diamond Drill

Diameter of Borehole 200/TNW mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests Type	Samples/Tests Depth m	Samples/Tests Ref. No.	Casing Depth	Date	Water Depth m
Ground Level 25.62mOD	m	m							
Topsoil	25.32	0.30							
Stiff brown sandy gravelly clay with cobbles and boulders (Chiselling 1 hr)				D C(15)	1.00 1.15	91943			
				D C(30)	2.00 2.15	91944			
	22.82	2.80							
Stiff dark brown sandy gravelly clay				D C(36)	2.80 2.95	91945			
								9/12 10/12	Nil Nil
	21.62	4.00		U	4.00	91946			
Stiff dark brown silty sandy gravelly clay with boulders (Chiselling 2¼ hrs)				D C(50)	5.00 5.15	91947			
				D C(37)	6.30 6.45	91948			
				D C(35)	7.40 7.55	91949			
				D	8.50	91950			

Remarks:

KEY	- EXPLANATION
+	- Water Strike
D	- Disturbed Sample
B	- Bulk Disturbed Sample
W	- Water Sample
U	- Undisturbed Sample
P	- Piston Sample
C(N)	- Cone Penetration Test
S(N)	- Standard Penetration Test
N	- Blows /300mm
V	- Vane Test

SITE INVESTIGATIONS LIMITED
BOREHOLE RECORD

CONTRACT Dunleer-Dundalk Motorway Phase 1 Extension
Borehole No. E15
Sheet 2 of 3
CLIENT M.C. O'Sullivan
Site Address Co. Louth
Boring Commenced 9/12/92
Boring Completed 22/3/93
Type of Boring Shell & Auger and Diamond Drill
Diameter of Borehole 200/TNW mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests				Date	Water Depth
Ground Level 25.62mOD	m	m		Type	Depth m	Ref. No.	Casing Depth		m
Stiff dark brown silty sandy gravelly clay with cobbles and boulders (Chiselling 2½ hrs)				C(58)	8.65				
								10/12	Nil
								11/12	8.7
				D	9.50	98951			
				C(69)	9.65				
				D	10.50	98352			
				C(66)	10.65				
				W	11.00	98353			
	14.12	11.50						11/12	11.0
Stiff/hard brown boulder clay with cobbles				C(62)	12.85				
				C(61)	14.45				
	10.02	15.60							
Grey boulder clay with cobbles				C(68)	15.75				
	8.62	17.00							

Remarks:

Clay cutter unable to work due to getting stuck in boulder at 11.50m
Chiselling 5¾ hours
Inserted 110mm Ø wavin pipe to 11.50m
Open hole drilling from 11.5 to 12.4m and 14.3 to 17.0mBGL. Cored from12.4 to 14.3m and 17.0 to 25.15 mBGL.
See geological log for detailed rock description

KEY	EXPLANATION
+	Water Strike
D	Disturbed Sample
B	Bulk Disturbed Sample
W	Water Sample
▌U	Undisturbed Sample
▌P	Piston Sample
↓C(N)	Cone Penetration Test
↓S(N)	Standard Penetration Test
N	Blows /300mm
V	Vane Test

SITE INVESTIGATIONS LIMITED
BOREHOLE RECORD

CONTRACT Dunleer-Dundalk Motorway Phase 1 Extension
Borehole No. E15
Sheet 3 of 3
CLIENT M.C. O'Sullivan
Site Address Co. Louth
Boring Commenced 9/12/92
Boring Completed 22/3/93
Type of Boring Shell & Auger and Diamond Drill
Diameter of Borehole 200/TNW mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests				Date	Water Depth m
				Type	Depth m	Ref. No.	Casing Depth		
Ground Level 25.62mOD	m	m							
Limestone rock interbedded with siltstone	0.47	25.15							
Final Level									

Remarks:
See geological log for detailed rock description

KEY - EXPLANATION
- \+ - Water Strike
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- W - Water Sample
- U - Undisturbed Sample
- P - Piston Sample
- C(N) - Cone Penetration Test
- S(N) - Standard Penetration Test
- N - Blows /300mm
- V - Vane Test

PROJECT Dunleer-Dundalk Motorway

CLIENT Louth County Council		CONTRACTOR Site Investigations Ltd.	BOREHOLE NO. E15
			SHEET 1 OF 2
MACHINE TYPE	Edeco	LOCATION	DRILLED BY S.I. Ltd.
CORE BARREL	TNX	GROUND SURFACE ELEVATION M O.D.	LOGGED BY CM
BIT DESIGN	Face Discharge	INCLINATION Vertical	DATE STARTED
CORE DIAMETER MM	60	AZIMUTH	DATE COMPLETED
FLUSH	Water	CASING DEPTH 0m	FINAL DEPTH M 25.15

CORE RUN DEPTH M	TOTAL CORE RECOVERY %	SOLID CORE RECOVERY %	ROCK QUALITY DESIGNATION %	FRACTURE SPACING INDEX	DISCONTINUITIES	SYMBOLIC LOG	ELEVATION M O.D.	DEPTH M	GEOLOGICAL DESCRIPTION	PIEZOMETER DETAILS
12.40 – 12.70	100							12.40	Brown, sandy, silty, CLAY with pebbles and cobbles of angular micritic, bioclastic calcisiltite limestone. (Probable Brown Boulder Clay).	
12.70 – 13.50	CPT from 12.70 to 13.50m. No recovery									
13.50 – 14.30	24									
14.30 – 17.00	CPT from 14.30 to 14.75m. CPT from 15.60 to 16.05m (no recovery). 20				No recovery from 14.30 to 15.60m.					
17.00 – 18.50	90	48	45	0.144	Rough, irregular, clean to clay smeared, closely spaced discontinuities, dip 30°			17.00	Dark grey, slightly weathered, fine micritic, bioclastic, calcisiltite LIMESTONE, strong, occasionally thinly interbedded with black, slightly weathered, calcareous MUDSTONE, moderately strong, dip 30°.	
18.50 – 19.90	100	84	79	0.293	From 18.50 to 20.50 predominantly moderately spaced discontinuities.					
19.90 – 20.50	100	95	77	0.285						
20.50 – 21.90	100	51	46	0.118						
21.90 – 22.60	100	77	66	0.180					From 22.40 to 22.47 highly weathered calcisiltite limestone, moderately strong.	

REMARKS

Solid core taken as that with solid diameter (Norbury et al 1986).

REVISED EDITION AS OF 23-11-1993*

SCALE 1:50

SITE INVESTIGATIONS LIMITED 88(22

BOREHOLE RECORD

CONTRACT Dunleer-Dundalk Motorway
CLIENT Louth County Council
Site Address Co. Louth
Boring Commenced 8/11/91
Type of Boring Shell & Auger /Diamond Drilling

Borehole No. M24 (291133.513N)
Sheet 1 of 3 (303494.769E)
Boring Completed 29/2/92
Diameter of Borehole 200 /NW mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests Type	Depth m	Ref. No.	Casing Depth	Date	Water Depth m
Ground Level 25.50mOD	m	m							
Topsoil	25.10	0.40							
Firm brown silty sandy stony clay				U	1.00	80351			
				D	2.00	80352			
				C(18)	2.15				
	23.10	2.40						8/11	2.4+
Stiff grey silty sandy stony clay				D	3.00	80353			
				C(30)	3.15				
				D	4.00	80354			
				C(55)	4.15				
				D	5.00	80355			
				C(56)	5.15				
	19.90	5.60							
Presumed boulder (Chiselling 1½ hrs)	19.70	5.80							
Hard brown silty stony clay with cobbles and boulders									

Remarks:
Installed 100mm Ø plastic pipe
Chiselling 1½ hours
Shell & Auger to 5.6mBGL
Cored from 5.6 to 7.0, 8.5 to 9.5 and 12.7 to 13.2mBGL
Rock rolled from 7.0 to 8.5, 9.5 to 12.7mBGL and 13.2 to 21.5mBGL

KEY	EXPLANATION
+	Water Strike
D	Disturbed Sample
B	Bulk Disturbed Sample
W	Water Sample
U	Undisturbed Sample
P	Piston Sample
C(N)	Cone Penetration Test
S(N)	Standard Penetration Test
N	Blows /300mm
V	Vane Test

88422

SITE INVESTIGATIONS LIMITED
BOREHOLE RECORD

CONTRACT Dunleer-Dundalk Motorway
CLIENT Louth County Council
Site Address Co. Louth
Boring Commenced 8/11/91
Type of Boring Shell & Auger /Diamond Drilling

Borehole No. M24 (291133.513N)
Sheet 2 of 3 (303494.769E)
Boring Completed 29/2/92
Diameter of Borehole 200/NW mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests				Date	Water Depth
Ground Level 25.50mOD	m	m		Type	Depth m	Ref. No.	Casing Depth		m
Hard brown silty stony clay with cobbles and boulders									

Remarks:

KEY - EXPLANATION
+ - Water Strike
D - Disturbed Sample
B - Bulk Disturbed Sample
W - Water Sample
U - Undisturbed Sample
P - Piston Sample
C(N) - Cone Penetration Test
S(N) - Standard Penetration Test
N - Blows /300mm
V - Vane Test

SITE INVESTIGATIONS LIMITED

BOREHOLE RECORD

88427

CONTRACT Dunleer-Dundalk Motorway

CLIENT Louth County Council

Site Address Co. Louth

Boring Commenced 8/11/91

Type of Boring Shell & Auger / Diamond Drilling

Borehole No. M24 (291133.513N)

Sheet 3 of 3 (303494.769E)

Boring Completed 29/2/92

Diameter of Borehole 200/NW mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests				Date	Water Depth
Ground Level 25.50mOD	m	m		Type	Depth m	Ref. No.	Casing Depth		m
Hard brown silty stony clay with cobbles and boulders	5.20	20.30							
Broken rock	4.00	21.50							
Final Level									

Remarks:

KEY	- EXPLANATION
+	- Water Strike
D	- Disturbed Sample
B	- Bulk Disturbed Sample
W	- Water Sample
U	- Undisturbed Sample
P	- Piston Sample
C(N)	- Cone Penetration Test
S(N)	- Standard Penetration Test
N	- Blows /300mm
V	- Vane Test

SITE INVESTIGATIONS LIMITED
BOREHOLE RECORD

88423

CONTRACT Dunleer-Dundalk Motorway
CLIENT Louth County Council
Site Address Co. Louth
Boring Commenced 24/10/91
Type of Boring Shell & Auger

Borehole No. M25 (291131.739N)
Sheet 1 of 1 (303446.247E)
Boring Completed 24/10/91
Diameter of Borehole 200 mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests Type	Samples/Tests Depth m	Samples/Tests Ref. No.	Samples/Tests Casing Depth	Date	Water Depth m
Ground Level 25.59mOD	m	m							
Topsoil	25.29	0.30							
Stiff brown silty sandy stony clay with cobbles				B C(31)	1.00 1.15	89549			
	23.59	2.00		B	2.00	89550		24/10	Nil
Final Level									

Remarks:

Boulder obstruction at 2.0m
Location moved 2.5m to BHM25A

KEY	- EXPLANATION
+	- Water Strike
D	- Disturbed Sample
B	- Bulk Disturbed Sample
W	- Water Sample
U	- Undisturbed Sample
P	- Piston Sample
C(N)	- Cone Penetration Test
S(N)	- Standard Penetration Test
N	- Blows /300mm
V	- Vane Test

SITE INVESTIGATIONS LIMITED

BOREHOLE RECORD

88474

CONTRACT Dunleer–Dundalk Motorway

CLIENT Louth County Council

Site Address Co. Louth

Boring Commenced 24/10/91

Type of Boring Shell & Auger

Borehole No. M25A

Sheet 1 of 1

Boring Completed 25/10/91

Diameter of Borehole 200 mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests Type	Depth m	Ref. No.	Casing Depth	Date	Water Depth m
Ground Level	m	m							
Topsoil		0.30							
Brown silty sandy stony clay with cobbles		2.10		B C(17)	2.10 2.25	89652			
Firm brown silty stony clay		2.80							
Stiff grey silty stony clay				U	3.50	89653			
				B C(43)	4.80 4.95	89654		24/10 24/10	4.8 + Nil
		6.60		B C(38)	6.00 6.15	89655			
Presumed boulder or weathered rock (Chiselling 1½ hours)		7.10						25/10	Nil
Final Level									

Remarks:

Small seepage at 4.80mBGL

No recovery of undisturbed sample at 3.0mBGL

Chiselling 1½ hours

KEY	EXPLANATION
+	Water Strike
D	Disturbed Sample
B	Bulk Disturbed Sample
W	Water Sample
▮U	Undisturbed Sample
▮P	Piston Sample
↓C(N)	Cone Penetration Test
↓S(N)	Standard Penetration Test
N	Blows /300mm
V	Vane Test

SITE INVESTIGATIONS LIMITED

BOREHOLE RECORD

88(,25

CONTRACT Dunleer-Dundalk Motorway
CLIENT Louth County Council
Site Address Co. Louth
Boring Commenced 13/3/92
Type of Boring Shell & Auger

Borehole No. M25B (291131.255N)
Sheet 1 of 2 (303442.156E)
Boring Completed 18/3/92
Diameter of Borehole 200 mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests				Date	Water Depth
Ground Level 25.79mOD	m	m		Type	Depth m	Ref. No.	Casing Depth		m
Overburden	20.79	5.00		B C(84)	5.00 5.15	91544			
Stiff to hard grey silty stony clay				B C(98)	6.00 6.15	91545		6/3	6.3+
				B C(74)	7.00 7.15	91546		13/3 18/3	6.9 1.7
				B C(53)	8.00 8.15	91547			

Remarks:

KEY	- EXPLANATION
+	- Water Strike
D	- Disturbed Sample
B	- Bulk Disturbed Sample
W	- Water Sample
▌U	- Undisturbed Sample
▌P	- Piston Sample
↓C(N)	- Cone Penetration Test
↓S(N)	- Standard Penetration Test
N	- Blows /300mm
V	- Vane Test

SITE INVESTIGATIONS LIMITED

88425

BOREHOLE RECORD

CONTRACT Dunleer-Dundalk Motorway
CLIENT Louth County Council
Site Address Co. Louth
Boring Commenced 13/3/92
Type of Boring Shell & Auger

Borehole No. M25B (291131.255N)
Sheet 2 of 2 (303442.156E)
Boring Completed 18/3/92
Diameter of Borehole 200 mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests Type	Depth	Ref. No.	Casing Depth	Date	Water Depth
Ground Level 25.79mOD	m	m			m				m
Stiff to hard grey silty stony clay (Chiselling 1¼ hrs)	15.49	10.30		B C(*) B C(69)	9.00 9.15 10.00 10.15	91548 91549			
Hard grey silty stony clay (Chiselling 4 hrs)	14.29	11.50		B C(*)	11.00 11.00	91550			
Final Level									

Remarks:

At 11.0mBGL 78 blows for 145mm Refusal
At 9.15mBGL 74 blows for 225mm Refusal
Chiselling 5¼ hours
Borehole backfilled on completion

KEY	EXPLANATION
+	Water Strike
D	Disturbed Sample
B	Bulk Disturbed Sample
W	Water Sample
▮U	Undisturbed Sample
▮P	Piston Sample
↓C(N)	Cone Penetration Test
↓S(N)	Standard Penetration Test
N	Blows /300mm
V	Vane Test

SITE INVESTIGATIONS LIMITED
BOREHOLE RECORD

80426

CONTRACT Dunleer-Dundalk Motorway
CLIENT Louth County Council
Site Address Co. Louth
Boring Commenced 11/11/91
Type of Boring Shell & Auger

Borehole No. M26 (291198.768N)
Sheet 1 of 1 (303440.535E)
Boring Completed 11/11/91
Diameter of Borehole 200 mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests				Date	Water Depth
Ground Level 23.16mOD	m	m		Type	Depth m	Ref. No.	Casing Depth		m
Topsoil	22.86	0.30							
Firm/stiff brown mottled silty sandy stony clay				U	1.00	80356			
				D	2.00	80357			
				C(21)	2.15				
	19.96	3.20		D	3.00	80358			
				C(8)	3.15			11/11	3.2+
Loose brown fine to coarse clayey gravel	18.86	4.30		D	4.00	80359			
				C(39)	4.15				
Stiff grey silty sandy stony clay				D	5.00	80360			
				C(57)	5.15				
				D	6.00	80361			
				C(62)	6.15				
				D	6.50	80362			
	16.16	7.00							
Final Level									

Remarks:

KEY	EXPLANATION
+	Water Strike
D	Disturbed Sample
B	Bulk Disturbed Sample
W	Water Sample
U	Undisturbed Sample
P	Piston Sample
C(N)	Cone Penetration Test
S(N)	Standard Penetration Test
N	Blows /300mm
V	Vane Test

SITE INVESTIGATIONS LIMITED
BOREHOLE RECORD

88428

CONTRACT Dunleer–Dundalk Motorway
CLIENT Louth County Council
Site Address Co. Louth
Boring Commenced 22/10/91
Type of Boring Shell & Auger

Borehole No. M27A (291316.248N)
Sheet 1 of 1 (303512.831E)
Boring Completed 23/10/91
Diameter of Borehole 200 mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests Type	Samples/Tests Depth m	Samples/Tests Ref. No.	Samples/Tests Casing Depth	Date	Water Depth m
Ground Level 19.80mOD	m	m							
Topsoil	19.60	0.20							
Grey brown silt with roots	18.60	1.20		B	1.20	89543			
				C(16)	1.35				
Firm grey brown silt				B	2.00	89544			
				C(10)	2.15				
	17.40	2.40		U	2.40	89545			
Stiff grey brown gravelly silt				B	3.50	89546			
				C(26)	3.65				
								22/10	Nil
				U	4.80	89547		23/10	1.8
	14.40	5.40							
Stiff grey silty stony clay with cobbles	13.80	6.00		B	6.00	89548			
Stiff grey silty stony clay with cobbles and boulders				C(39)	6.15				
	12.70	7.10							
Final Level									

Remarks:

Water sealed off at 6.0mBGL

KEY	EXPLANATION
+	Water Strike
D	Disturbed Sample
B	Bulk Disturbed Sample
W	Water Sample
▮U	Undisturbed Sample
▮P	Piston Sample
↓C(N)	Cone Penetration Test
↓S(N)	Standard Penetration Test
N	Blows /300mm
V	Vane Test

SITE INVESTIGATIONS LIMITED

80427

BOREHOLE RECORD

CONTRACT Dunleer - Dundalk Motorway

CLIENT Louth County Council

Site Address Co. Louth

Boring Commenced 9/10/91

Type of Boring JCB

TRIAL PIT No. M27 (291315.350N) (303528.504E)

Sheet 1 of 1

Boring Completed 9/10/91

Diameter of Borehole - mm

Description of Strata	Reduced Level	Depth	Legend	Samples/Tests				Date	Water Depth
				Type	Depth m	Ref. No.	Casing Depth		m
Ground Level 19.70mOD	m	m							
Topsoil	19.45	0.25							
Stiff grey silt	19.05	0.65							
Brown silty sand	18.05	1.65		B	1.00	81967			
Stiff grey silt	17.70	2.00		B	1.80	81968		9/10	Nil
Final Level									

Remarks:

KEY	- EXPLANATION
+	- Water Strike
D	- Disturbed Sample
B	- Bulk Disturbed Sample
W	- Water Sample
▌U	- Undisturbed Sample
▌P	- Piston Sample
↓C(N)	- Cone Penetration Test
↓S(N)	- Standard Penetration Test
N	- Blows /300mm
V	- Vane Test

APPENDIX B *Drawing*

LEGEND:

- Existing Ground Level (Client data)
- HDD Bore Profile
- Existing Borehole
- Existing Trial Pit
- Existing Eir Network

NOTES:

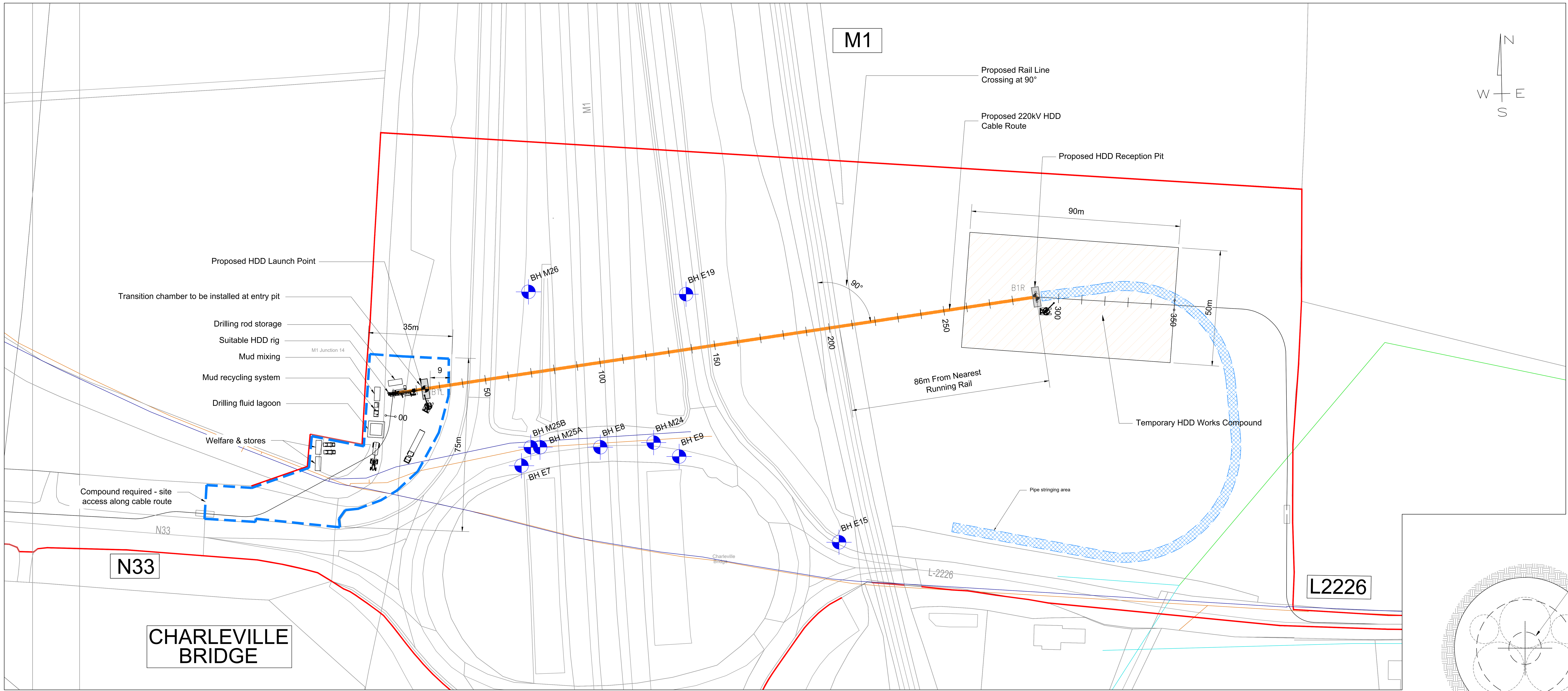
1. This drawing is based on topographical data obtained from our client and commercial sources.
2. Coordinates are given in Irish Transverse Mercator format & datum is Ordnance Datum Malin Head.
3. Utilities information has been provided by our client and has not been verified by us. It is the responsibility of the Contractor to locate, identify, and protect all utilities.
4. All excavations to be undertaken to a Safe System of Work plan and take account of the Code of Practice for Avoiding Danger from Underground Services.
5. Traffic Management Plans shall be the responsibility of the Contractor

INTERPRETATION OF GROUND CONDITIONS:

1. Ground conditions are interpreted based on historic ground investigation as shown on the drawing, publicly-available information, and observations from our site visit.
2. Interpretation of ground conditions is for guidance only and no liability can be accepted for its accuracy.
3. Assessment of thermal resistance of the ground and the effect on cable ratings is to be carried out by others.

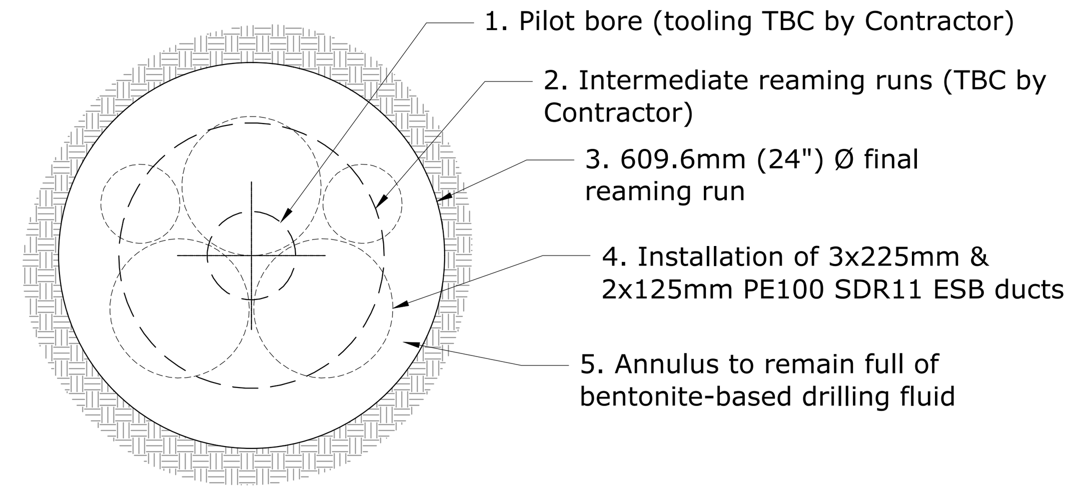
LAUNCH / RECEPTION SETTING OUT (ITM)

Position X	Position Y	SP
703325.455	791170.124	B1L
703589.091	791209.846	B1R



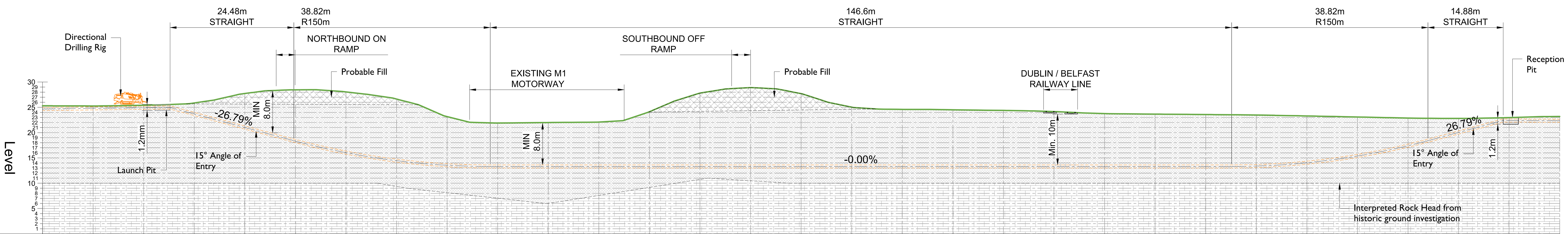
M1 & RAIL CROSSING HDD - GENERAL ARRANGEMENT BORE 1

Scale 1:1000



M1 & RAIL CROSSING HDD - CROSS SECTION BORE 1

Scale 1:10



Chainage	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	100.000	110.000	120.000	130.000	140.000	150.000
Existing Levels	25.300	25.261	25.420	25.868	27.730	28.462	28.045	26.643	23.164	21.898	21.991	22.079	24.128	27.812	28.899	27.710
Depth to Bore Ctr.	-0.624	-0.467	-0.508	-2.177	-6.719	-10.130	-12.007	-12.193	-9.620	-8.595	-8.689	-8.777	-10.825	-14.509	-15.597	-14.407

Chainage	160.000	170.000	180.000	190.000	200.000	210.000	220.000	230.000	240.000	250.000	260.000	270.000	280.000	290.000	300.000
Existing Levels	25.029	24.587	24.513	24.388	24.157	23.761	23.653	23.572	23.469	23.291	23.085	22.879	22.804	22.970	23.191
Depth to Bore Ctr.	-11.727	-11.284	-11.211	-11.086	-10.854	-10.459	-10.350	-10.270	-10.088	-9.249	-7.705	-5.465	-2.768	-0.575	-0.842

Horiz. Geo			
	L =9.781m	L =280.545m	L =59.674m

M1 & RAIL CROSSING HDD - PROFILE BORE 1

Scale 1:500

Profile topo data from Bluesky DTM
Resolution 5m
Accuracy XY: ± Up to 1m rmse
Accuracy Z: ± Up to 1.5m rmse
Projection: ITM95

GEO DRILLING SOLUTIONS

GEO TRENCHLESS SOLUTIONS LTD.
NEWRATH, CASTLEBELLINGHAM, COUNTY LOUTH, IRELAND. A91 X30R

CLIENT: Oriel Windfarm Limited

PROJECT: Oriel Windfarm

DRAWING TITLE: M1 & Dublin-Belfast Rail Line Crossing

Date:	Drawn:	Checked:	Approved:
21.08.2025	JL	CR	NM

Scale at A1: AS SHOWN

Suitability: S3 - Suitable for Internal Review

DRAWING NUMBER: 03117-GDS-ZZ-XX-DR-C-0001

Rev. P01

APPENDIX C *Review Of Available Methodologies*

Options Include:

HDD

HDD is a steerable trenchless method of installing underground pipe, conduit, or cable in a shallow arc along a prescribed bore path by using a surface-launched drilling rig, with minimal impact on the surrounding area. It is suitable for a variety of soil and rock formations and applications including road, rail and river crossings. It is limited by formations such as cobbles, gravel, boulders, weathered and broken bedrock.

The HDD rig that best suits the crossings that are <300 metres, would have a pullback of approximately 40 tons, weigh approximately 20 tons, will be crawler mounted and self-contained, apart from the drilling fluid recycling system.

A mud motor, DTH hammer or a Dual pipe specific rig. For upsizing the borehole hole openers, either

PDC or TCI cutters will be required.

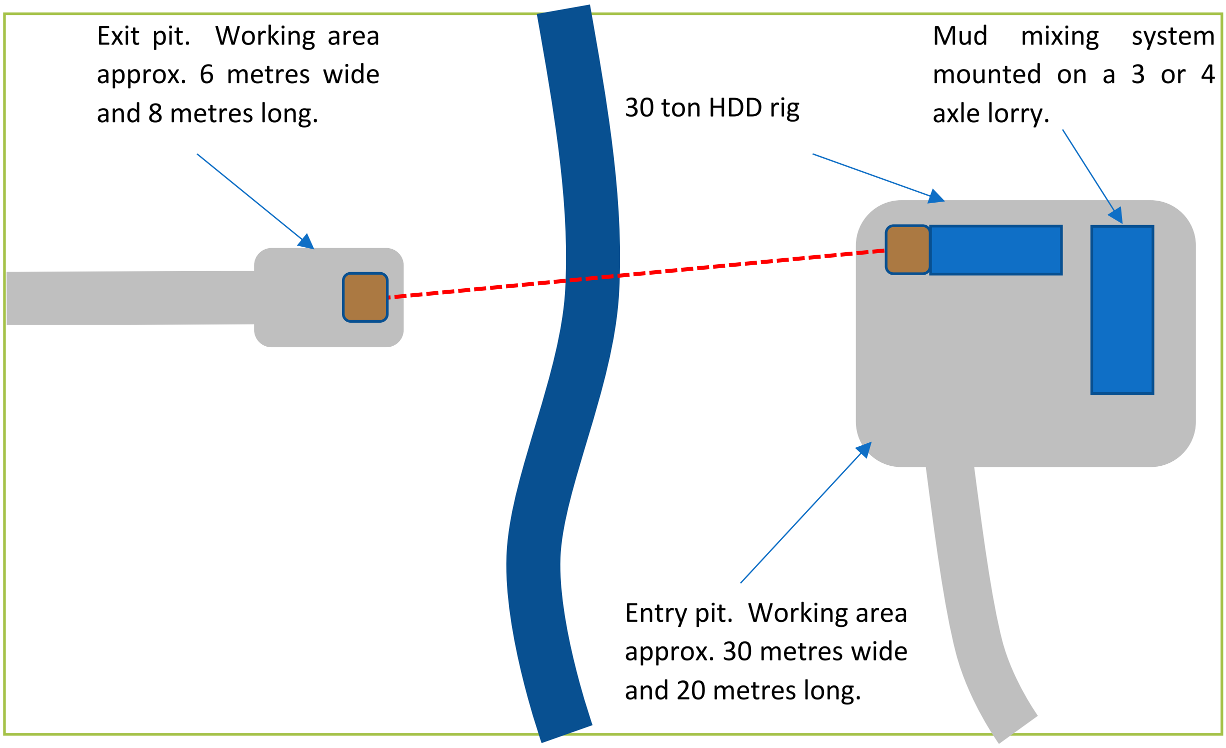


Figure 12 – A typical site layout for the 20 ton HDD rig.

Guidance Systems

Wireline Location

Horizontal positioning accuracy requires careful control, especially where multiple closely spaced bores are required. Common practice where a high degree of accuracy is required is to use a surface coil/grid to induce a local magnetic field within which the downhole steering tool can be correctly orientated. When combined with a system employing inertial guidance the position of each bore can be accurately tracked. Alternatively, a gyro based steering tool may be deployed. Should a borehole become off position the downhole assembly is typically withdrawn some distance and then sent off on a revised course. In rock formation the unused section of hole may be grouted to enable the drilling bit to leave the old hole alignment.

Directional control is accomplished by rotating the drill string to orientate a bent housing on the BHA, 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 housing to the desired orientation.

The trajectory of the pilot hole is determined by taking periodic surface readings of the inclination and azimuth of the BHA. These readings in conjunction with measurements of the distance drilled since the last survey are used to calculate the horizontal and vertical co-ordinates of the BHA relative to the entry point at the surface.

Surface readings are taken by a survey, which is placed in a non-magnetic drill collar connected to the BHA. Inclination and azimuth are obtained by sensing the angles between the reference frame in the down-hole survey package and the earth's magnetic and gravitational fields. This information is transmitted as a signal to the surface computation unit where it is reduced to the X, Y and Z coordinates of the down-hole sensors; i.e. the BHA. Directional surveys are taken every six meters when a joint of drill string is added, or more often if required. Survey co-ordinates 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.

Walkover Locators

A walkover location system uses a 3-dimensional field view with a single button user interface and graphically driven menu. It operates at depths up to 110 metres with 0.1 percent sensitive pitch. An active display enables look-ahead capability with target-in-the-box locating for Intuitive transmitter tracking. Includes basic locating capabilities of directional tracking and depth plus advanced features of Off-Trak locating and Target Steering to easily and accurately navigate the drill even when obstacles prevent tracking over the drill head. An enhanced Target Steering function on the menu allows the operator to place the receiver in front of the drill head, along the bore path, using a target on the remote display to steer.

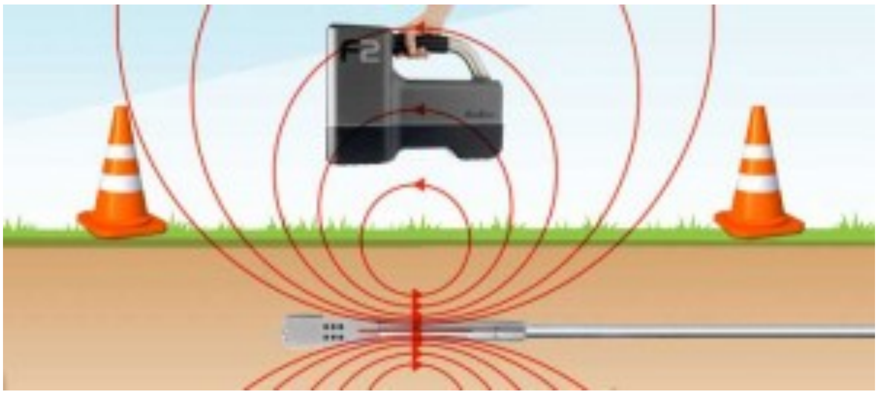


Figure 13 – Walkover location system

The operator can view in real-time the distance and depth of the transmitter relative to the receiver. A real-time, bird's-eye view provides operators with critical on-the-fly steering ability. A 4-channel radio enables multiple

The system is limited by interference from other utilises such as power and if rebar is buried in mass concrete.

Drilling Fluids.

The Drilling Mud is typically a mixture of naturally occurring or Polymer modified Bentonite clays and water. Becoming more common now is environmentally friendly drilling fluids such as Clear bore. The drilling mud is pumped down to the BHA from the surface through hollow stem Drill Pipe. Individual sections of Drill Pipe are added at the Drilling Rig and pushed forward to advance the BHA from the Entry Point to the Exit Point. Ground cut by the drill bit is carried back in the annular space by the drilling mud and returned to the entry side where it is deposited in a shallow launch pit. The drilling mud is pumped from the pit to a Mud Recycling System that removes the cut solids enabling the cleaned Mud to be reused for drilling. Recycling reduces waste and limits the disposal costs.

The drilling fluid has several functions which include the following:

- Transportation of drilled solids and fluid out of the borehole.
- 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 product pipe/ducts during pullback, reducing the pull force on the pipe /ducts.
- 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 product pipes /ducts.

APPENDIX D *Preliminary Settlement Calculations*

Project	Page No
Oriel Offshore Windfarm M1 Motorway & Dublin–Belfast Railway Crossing	1 of 1
Element	Date
M1 Motorway Crossing Settlement Calculations	10/09/2025
Client	Produced by
Parkwind	CR

SETTLEMENT CALCULATION

Settlements predicted after the method of O'Reilly & New (1982).

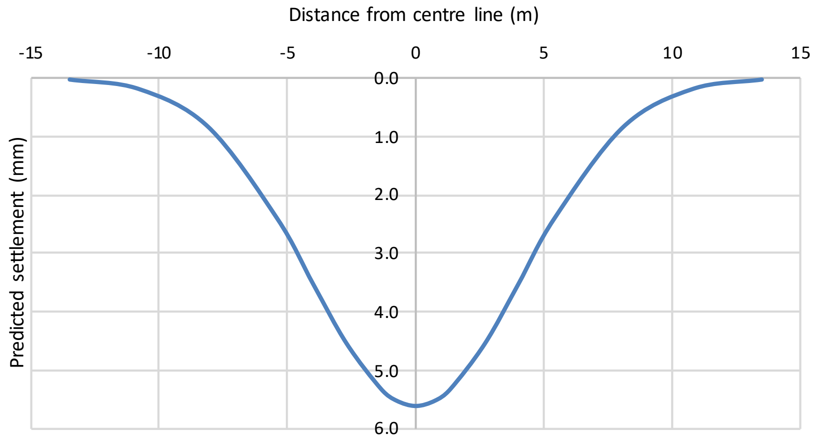
Soil type controlling settlement: Clay

Volume loss source: 20% bentonite shrinkage based on comparable experience

INPUT PARAMETERS:				Source
Depth from road to centre of bore	z_0	**8.3**	m	
Borehole diameter	Dext	**0.6096**	m	
Product pipe OD	Dp	**0.5**	m	
Predicted volume loss	V_L	**20.0%**		
Gaussian trough width parameter	K	**0.5**		McCabe et al (2012)

CALCULATIONS - SETTLEMENT ACROSS ALIGNMENT			
Volume of settlement trough	V_S	**0.0584**	m^3/m
Point of inflection	$i = Kz_0$	**4.15**	m
Maximum settlement at C/L	δ_{max}	**5.6**	mm

PREDICTED SETTLEMENT PROFILE OVER PIPE JACK



Settlements of less than 6.0mm are predicted based on volume loss of 20% due to consolidation/shrinkage of the drilling fluid in the annulus. Typically settlements up to 10mm are considered acceptable for crossings under major roads. The maxiumum settlement predicted is considered tolerable by the M1 Motorway.

Project	Page No
Oriel Offshore Windfarm M1 Motorway & Dublin–Belfast Railway Crossing	1 of 2
Element	Date
Dublin-Belfast Railway Crossing Settlement Calculations	10/09/2025
Client	Produced by
Parkwind	CR

SETTLEMENT CALCULATION

Settlements predicted after the method of O'Reilly & New (1982).

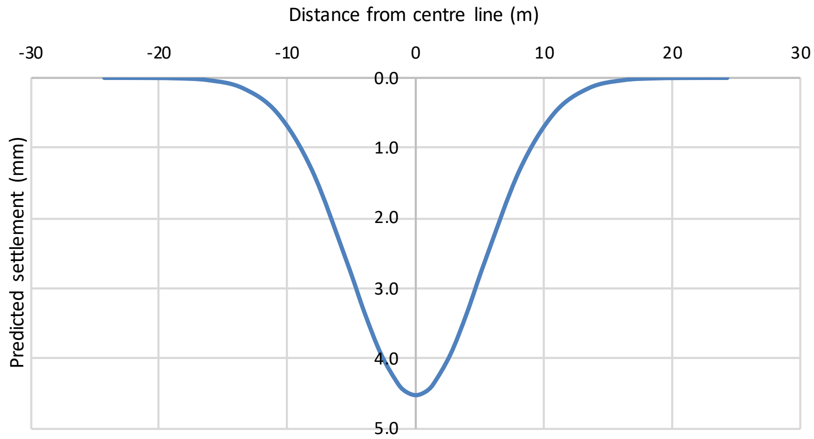
Soil type controlling settlement: Clay

Volume loss source: 20% bentonite shrinkage based on comparable experience

INPUT PARAMETERS:				Source
Depth from railway to centre of bore	z_0	**10.3**	m	
Borehole diameter	Dext	**0.6096**	m	
Product pipe OD	Dp	**0.5**	m	
Predicted volume loss	V_L	**20.0%**		
Gaussian trough width parameter	K	**0.5**		McCabe et al (2012)

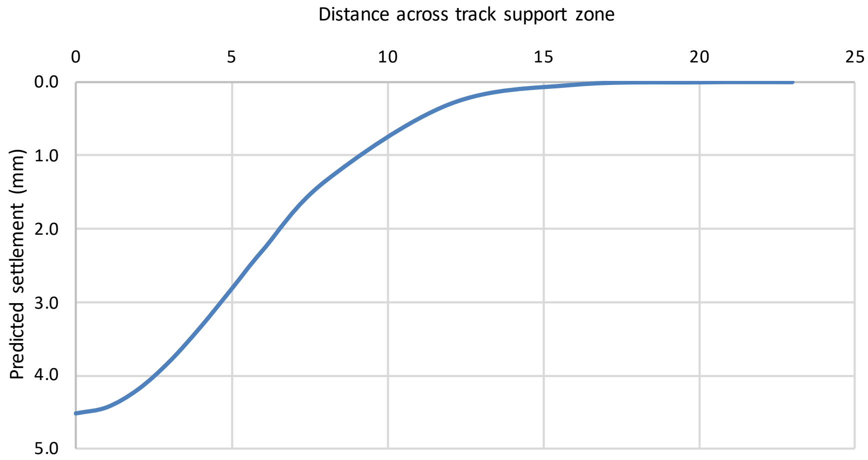
CALCULATIONS - SETTLEMENT ACROSS ALIGNMENT			
Volume of settlement trough	V_S	**0.0584**	m^3/m
Point of inflection	$i = Kz_0$	**5.15**	m
Maximum settlement at C/L	δ_{max}	**4.5**	mm

PREDICTED SETTLEMENT PROFILE OVER HDD



Settlements of up to 4.5mm are predicted based on volume loss of 20% due to consolidation/shrinkage of the drilling fluid in the annulus. The maxiumum settlement predicted is considered tolerable by the railway line. Checks on twist are presented on the next sheet.

ALLOWANCE FOR DIFFERENTIAL SETTLEMENT ACROSS TRACK SUPPORT ZONE



HDD alignment is at 90 degrees to the rail.

CALCULATIONS - DIFFERENTIAL SETTLEMENT ACROSS TRACK SUPPORT ZONE

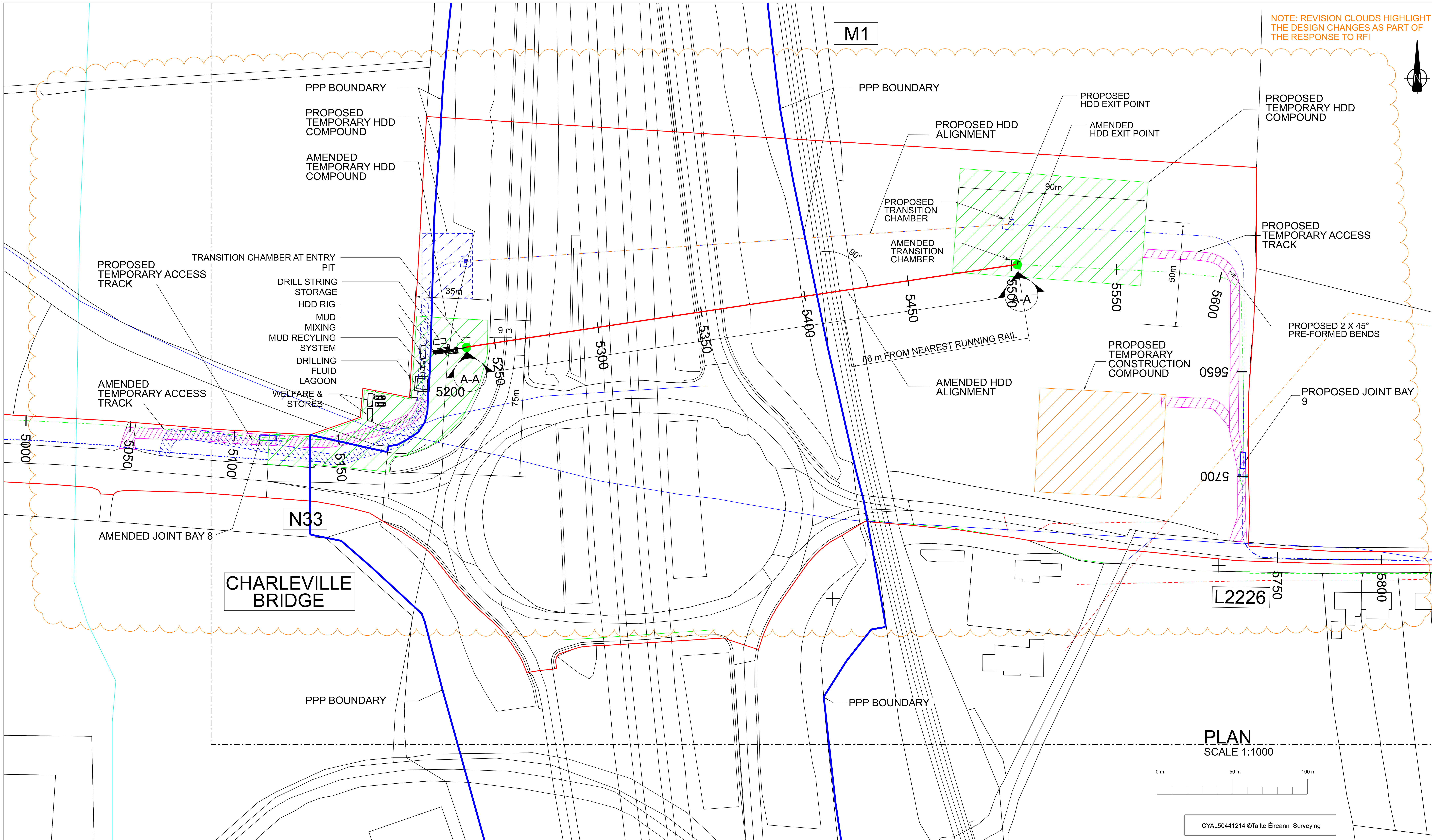
Max settlement trough gradient - from i above	5.152	m across track support zone	
Max differential settlement between rails	4.31	mm	Calculated based on i
Max twist over 2.7m on one rail	3.940	mm	
Gradient over 2.7m	0.02		
Max static twist	1/	4111	
Irish Rail requirements - "Green" short twist	1/	500	CCE-TRK-SPN-010
Irish Rail requirements - "Green" long twist	1/	800	CCE-TRK-SPN-010

Predicted twist below "Green" trigger level? **OK**

Track monitoring shall be undertaken by the nominated surveying specialist in accordance with Córas Iompair Éireann/Iarnród Éireann Specification CCE-TRK-SPN-010 and shall commence at least two weeks before the expected commencement of the works. Settlement limits shall be as per that document.

Annex B

Drawing of HDD compound layout



KEY PLAN: 2 3 4 5 6 7 8 9 10 11 12 13

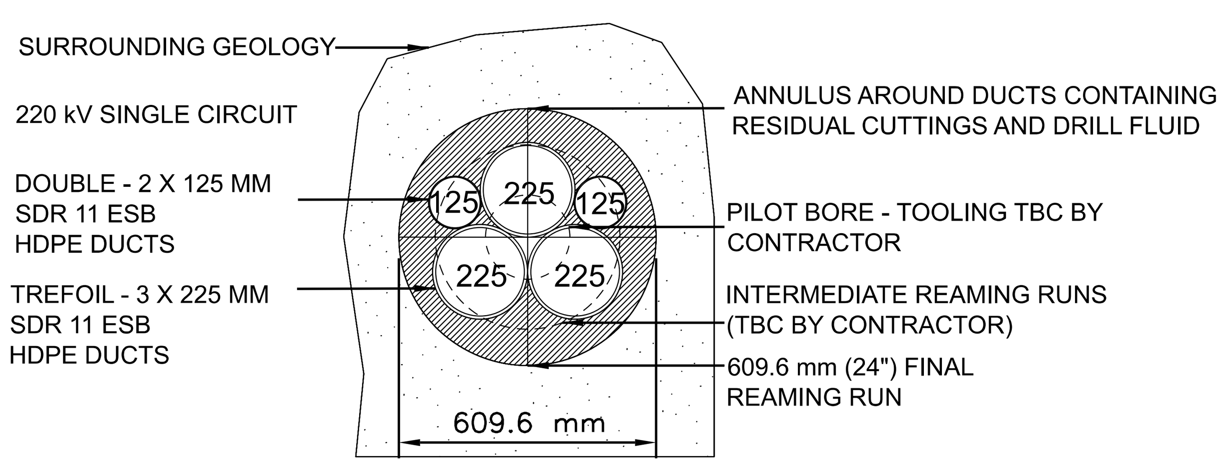
LEGEND:

- PROPOSED 220 kV ONSHORE CABLE ROUTE
- AMENDED 220 kV ONSHORE CABLE ROUTE
- PROPOSED HDD HORIZONTAL ALIGNMENT
- AMENDED HDD HORIZONTAL ALIGNMENT
- PROPOSED TEMPORARY HORIZONTAL DIRECTIONAL DRILL WORKING AREA
- PROPOSED TEMPORARY ACCESS TRACK
- AMENDED TEMPORARY HORIZONTAL DIRECTIONAL DRILL WORKING AREA
- AMENDED TEMPORARY ACCESS TRACK
- PROPOSED TEMPORARY CONSTRUCTION COMPOUND
- APPLICATION BOUNDARY
- LANDOWNER PROPERTY BOUNDARY
- AMENDED JOINT BAY (2.5 m × 8 m)
- AMENDED C2 CHAMBER
- AMENDED LINK BOX CHAMBER
- PROPOSED TRANSITION CHAMBER
- PROPOSED JOINT BAY (8 m × 2.5 m)
- PROPOSED C2 CHAMBER
- PROPOSED LINK BOX CHAMBER
- PROPOSED TRANSITION CHAMBER
- EXISTING GROUND PROFILE
- PROPOSED HDD LONGITUNDINAL ALIGNMENT
- EXISITING HIGH VOLTAGE OVERHEAD LINE
- EXISTING MEDIUM VOLTAGE OVERHEAD LINE
- EXISTING LOW VOLTAGE OVERHEAD LINE
- EXISTING MEDIUM VOLTAGE UNDERGROUND CABLE
- EXISTING LOW VOLTAGE UNDERGROUND CABLE
- EXISTING WATER MAIN
- EXISTING GRAVITY SEWER
- EXISTING HIGH PRESSURE TRANSMISSION GAS PIPELINE
- EXISTING TELECOMS OVERHEAD LINE
- EXISTING TELECOMS UNDERGROUND CABLE

NOTES :

1. FOR PLANNING PURPOSES ONLY, NOT FOR CONSTRUCTION
2. ALL DIMENSIONS IN METERS, UNLESS OTHERWISE NOTED
3. THE CABLE SHALL BE INSTALLED WITHIN THE SITE BOUNDARY. THE FINAL ALIGNMENT WITHIN THE SITE BOUNDARY SHALL BE DETERMINED FOLLOWING DETAILED DESIGN, WHICH WOULD PROCEED POST-PLANNING.
4. THE SITE BOUNDARY IS THE EXTENT OF THE PROPOSED PROJECT SITE. IT SHOULD BE ASSUMED TO EXTEND TO THE EDGE OF THE CARRIAGEWAY ALONG PUBLIC ROADS, EXCEPT WHERE OTHERWISE INDICATED.
5. 220 kV CABLES TO BE INSTALLED AS PER DRAWING PE605-D027-083-001 (LATEST REVISION), WHICH IS A TYPICAL TRENCH LAYOUT. THE OVERALL DEPTH, WIDTH AND FORMATION OF THE TRENCH MAY CHANGE, DEPENDING ON GROUND CONDITIONS AND DETAILED DESIGN.
6. REFER TO EIRGRID DWG OFD-SSS-524 FOR TRANSITION CHAMBER SPECIFICATIONS. TRANSITION CHAMBER TO BE USED IF DUCT COUPLER NOT AVAILABLE FOR DUCT SIZING
7. ALL LEVELS ARE RELATIVE TO MALIN HEAD DATUM
8. ALL DRAINAGE DEPTHS ON PROFILE ARE INDICATIVE ONLY AND HAVE NOT BEEN SURVEYED. DRAINAGE INFORMATION OBTAINED FROM LOUTH COUNTY COUNCIL DRAWINGS DDM/D104 & DDM/B5-04. REFER TO GEO DRILLING PRELIMINARY REPORT 03117-GDS-ZZ-XX-RP-C-0000 FOR FURTHER INFORMATION.

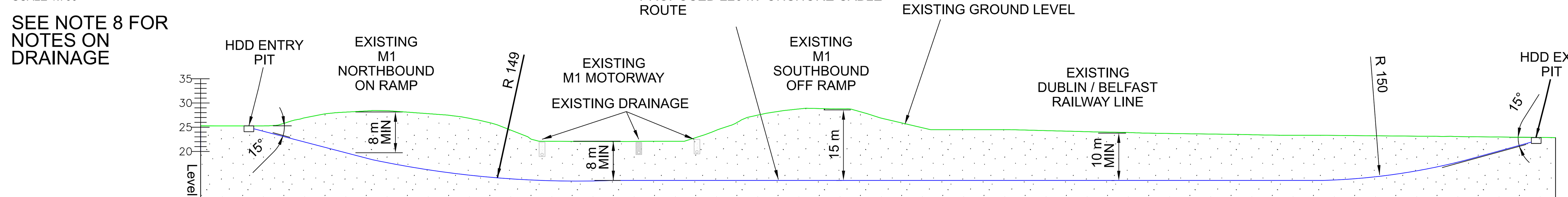
PROPOSED BORE DETAIL
SCALE 1:15



FINAL BORE SIZE WILL DEPEND ON THE RESULTS OF GROUND INVESTIGATION

PROPOSED HDD PROFILE SECTION A-A
SCALE 1:750

SEE NOTE 8 FOR NOTES ON DRAINAGE



Chainage	Existing Levels	Bore Depth
0.00	25.420	-1.2
10.0	25.868	-4.1
20.0	27.730	-8.4
30.0	28.462	-11.4
40.0	28.045	-12.0
50.0	26.643	-11.2
60.0	23.164	-8.1
70.0	21.898	-8.1
80.0	21.991	-8.1
90.0	22.079	-8.2
100.0	24.128	-11.3
110.0	27.812	-14.0
120.0	28.899	-15.0
130.0	27.710	-12.9
140.0	25.029	-10.8
150.0	24.587	-10.4
160.0	24.513	-10.2
170.0	24.388	-10.1
180.0	24.157	-10.0
190.0	23.761	-9.4
200.0	23.653	-9.3
210.0	21.548	-9.3
220.0	23.572	-9.3
230.0	23.469	-8.7
240.0	23.291	-7.3
250.0	23.085	-5.4
260.0	22.800	-2.3
266.0	22.970	-1.2

A-A A-A

REV.	DATE	REVISION DESCRIPTION	DRN	PROD	VER	APP
000		FIRST ISSUE	NB	NB	RD	RD

PURPOSE OF ISSUE - PRELIMINARY UNLESS INDICATED

CLIENT APPROVAL [ ] PLANNING [X] TENDER [ ] CONSTRUCTION [ ] AS-BUILT [ ]

Client: Oriel Wind Farm Limited

Project: ORIEL WIND FARM PROJECT

Contract:

Drawing Title: PROPOSED M1/RAIL LINE HDD CROSSING ALIGNMENT & PROFILE AT CHARLEVILLE BRIDGE PPP BOUNDARY SHOWN AT HDD LOCATION

Production Unit: Civil, Environmental and Renewable Engineering

Energy for generations
Engineering and Major Projects,
One Dublin Airport Central, Dublin Airport,
Cloghran, Co. Dublin, K67 XF72, Ireland.
Tel: +353 (0)1 703 8000 Web: www.esb.ie
Engineering and Major Projects is a division of ESB.

DRAWN	PRODUCED	VERIFIED	APPROVED	APPROVAL DATE
Bell_Neil	Bell_Neil	R.Doyle	M.Hogan	17/12/2025

CLIENT REF	No. OF SHTS	SIZE	SCALE
TC222883	1/1	A1	1:2500

DRAWING NUMBER: PE605-D027-026-003-000 (SHEET / REV)

Annex C

Stability output

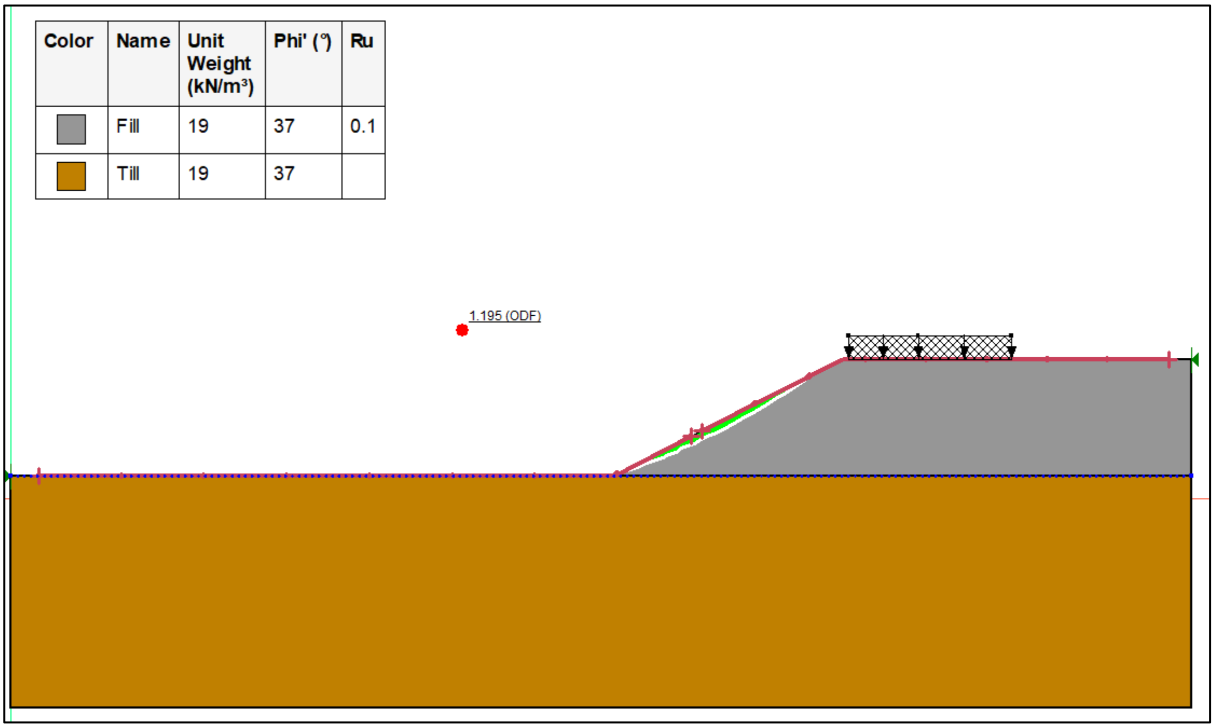


Figure 3 Case 1 – critical failure surface

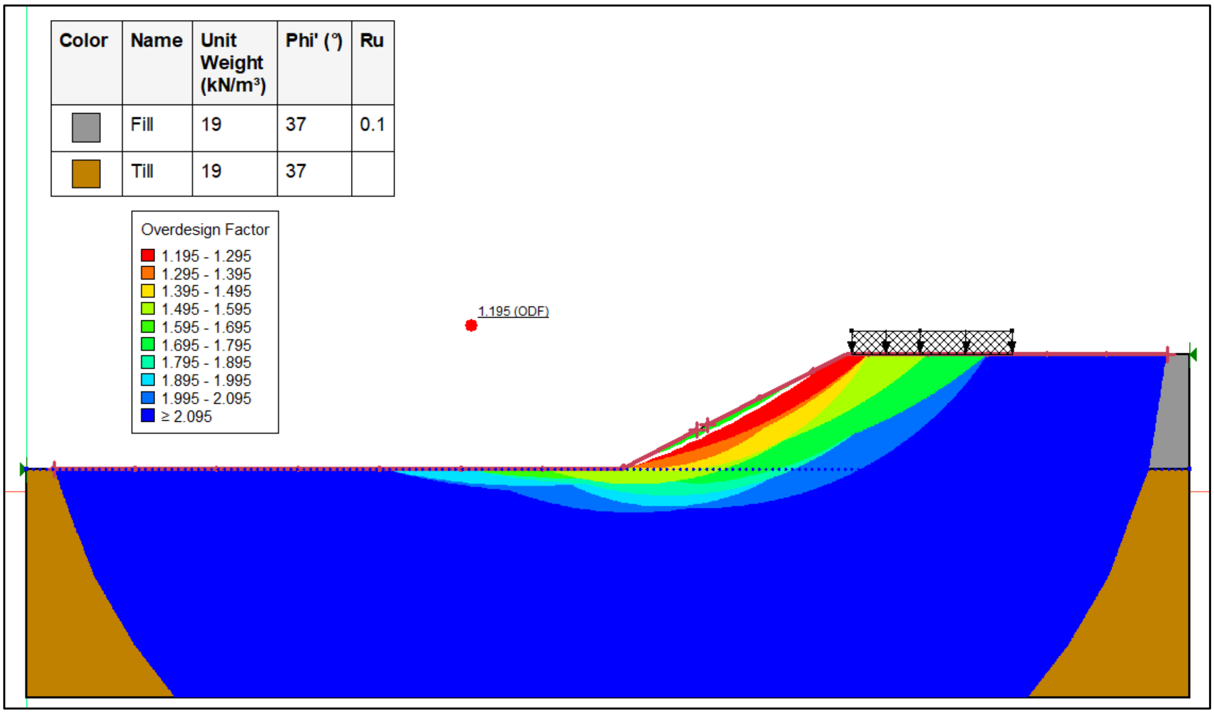


Figure 4 Case 1 – range of ODF for all failure surfaces

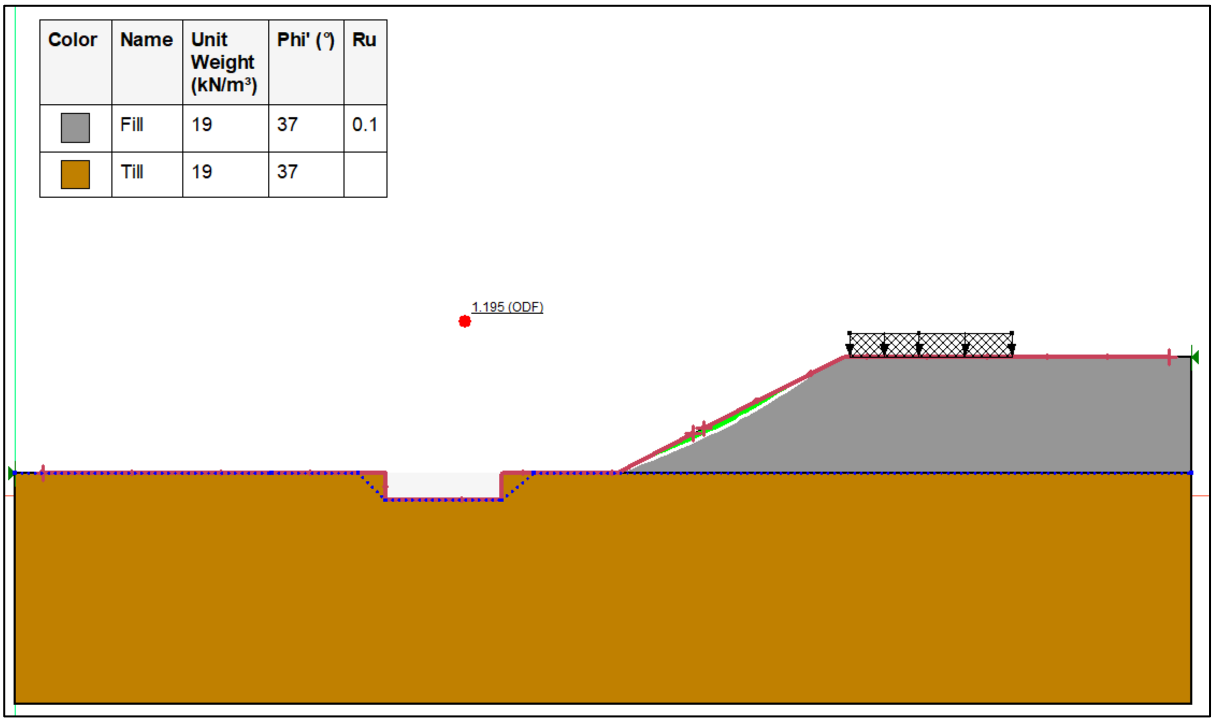


Figure 5 Case 2 – critical failure surface

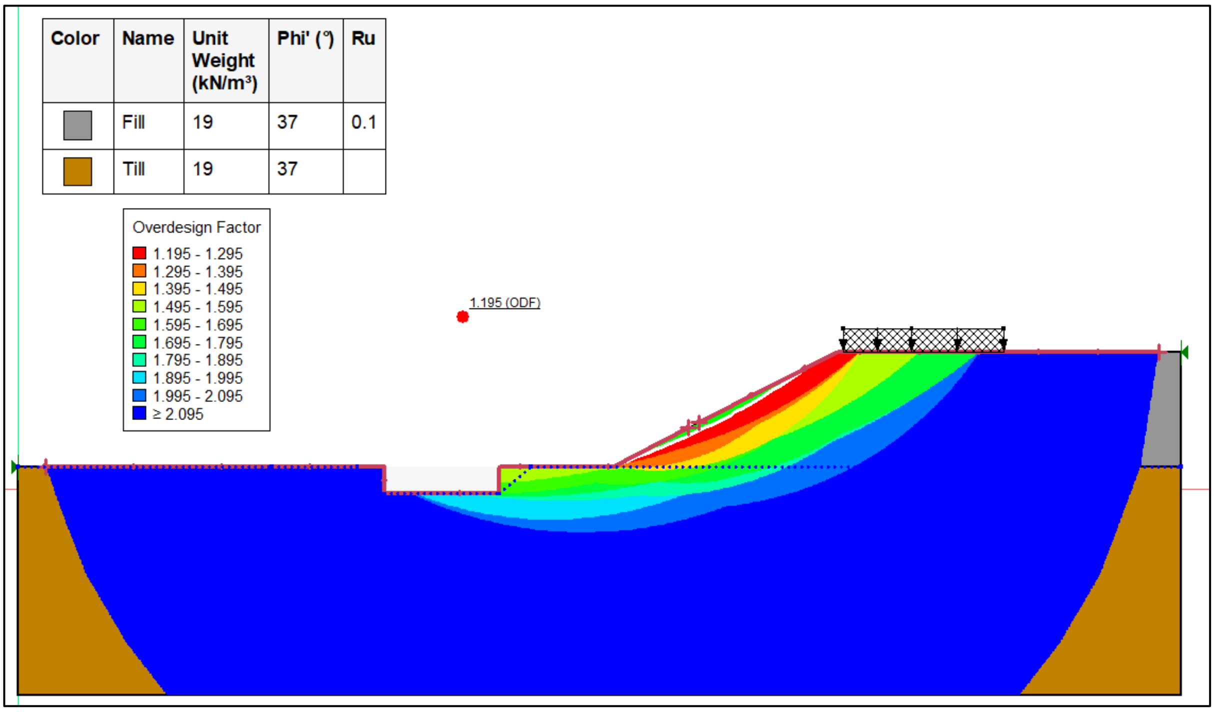


Figure 6 Case 2 – range of ODF for all failure surfaces

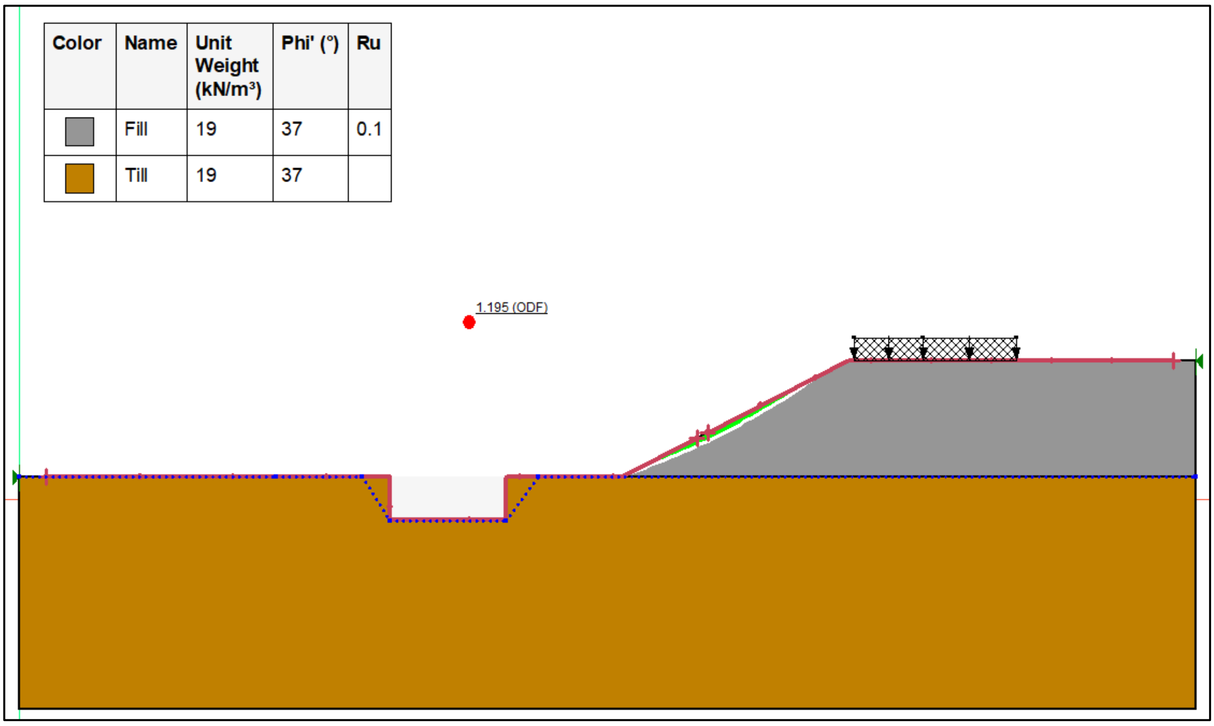


Figure 7 Case 3 – critical failure surface

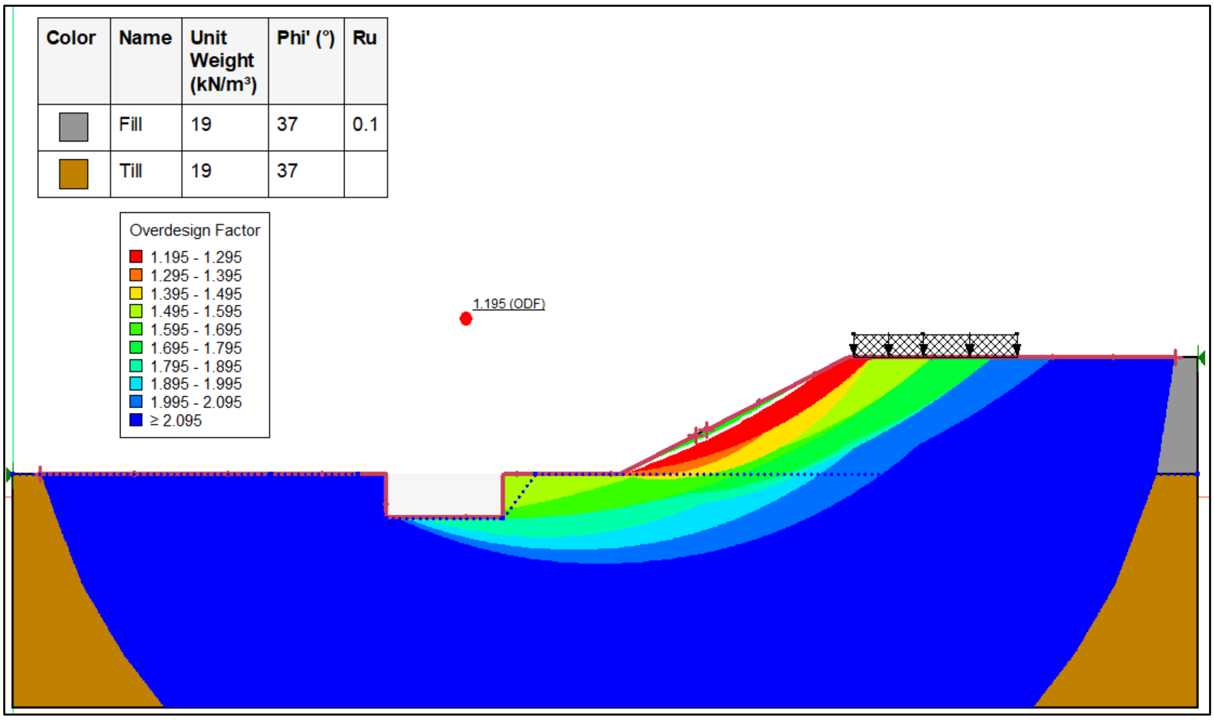


Figure 8 Case 3 – range of ODF for all failure surfaces

Annex D

HDD predicted maximum settlement

Input parameters from GDS

Depth from road to centre of bore	z_o	8.3 m	
Borehole diameter	D_{ext}	0.6096 m	
Product pipe OD	D_p	0.5 m	
Predicted volume loss	V_l	20%	Due to bentonite shrinkage
Gaussian trough width parameter	k	0.5	McCabe et al (2012)
Point of inflection	$i = k \cdot z_o$	4.15	

Determine volume of tunnel excavation as proportion of surface ground loss (V_s):

$(4V_s) / (\pi\ D^2)$ re- arrange $V_s = V_l\,(\pi\ D^2) / 4$

V_s of tunnel excavation

$Vs = 0.0584\ m^3$

Determine maximum vertical settlement over centre-line of tunnel (S_{max}):

$V_s = S_{max}\,(2\pi)^{0.5}\ i$ re- arrange $S_{max} = V_s / ((2\pi)^{0.5}\ i)$

$S_{max} = 0.0056\ m$

Notes

(1) The method described by O'Reilly and New (1982) is used where the transverse distance to the point of inflection of the settlement trough is assumed to be linear with HDD bore depth.

(2) The simplified form assumes i = k.zo, where zo is the depth from the ground surface to the HDD bore axis and k is a trough width parameter that varies between 0.4 and 0.7 for cohesive soils and between 0.2 and 0.3 for granular soils. For Irish glacial till a value of 0.5 is used (McCabe et al 2012).

(3) Lower values of the trough width parameter will result in narrow troughs with a greater settlement above the bore axis, whereas higher values will result in wider troughs with less settlement above the bore axis.

(4) The above analysis has been used to predict the maximum settlement for greater depths of the HDD bore. Where the HDD bore is within bedrock the settlement would effectively be zero or a nominal amount, assumed nominally as 0.3mm.

References

O'Reilly, M.P. and New, B.M. (1991). Tunnelling induced ground movements: predicting their magnitude and effect. 4th Int. Conf. on Ground Movements and Structures. Cardiff.

Taylor, R.N. (1995). Tunnelling in soft ground in the UK. Underground Construction in Soft Ground, Fujita & Kusakabe (eds). Balkema, Rotterdam.

McCabe, B. A., Orr, T. L. L., Reilly, C. C. & Curran, B. G. (2012). Settlement trough parameters for tunnels in Irish glacial tills. Tunnelling & Underground Space Technology, 27, 1-12.