AGL15060_01

Report

on the

Geophysical Investigation

For

Greater Dublin Drainage Scheme,

Offshore Portmarnock, Dublin

For

Irish Water

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1st December 2015

PRIVATE AND CONFIDENTIAL

THE FINDINGS OF THIS REPORT ARE THE RESULT OF A GEOPHYSICAL SURVEY USING NON-INVASIVE SURVEY TECHNIQUES CARRIED OUT AT THE GROUND SURFACE. INTERPRETATIONS CONTAINED IN THIS REPORT ARE DERIVED FROM A KNOWLEDGE OF THE GROUND CONDITIONS, THE GEOPHYSICAL RESPONSES OF GROUND MATERIALS AND THE EXPERIENCE OF THE AUTHOR. APEX GEOSERVICES LTD. HAS PREPARED THIS REPORT IN LINE WITH BEST CURRENT PRACTICE AND WITH ALL REASONABLE SKILL, CARE AND DILIGENCE IN CONSIDERATION OF THE LIMITS IMPOSED BY THE SURVEY TECHNIQUES USED AND THE RESOURCES DEVOTED TO IT BY AGREEMENT WITH THE CLIENT. THE INTERPRETATIVE BASIS OF THE CONCLUSIONS CONTAINED IN THIS REPORT SHOULD BE TAKEN INTO ACCOUNT IN ANY FUTURE USE OF THIS REPORT.

PROJECT NUMBER	AGL15060		
AUTHOR	**CHECKED**	**REPORT STATUS**	**DATE**
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1. EXECUTIVE SUMMARY

APEX Geoservices Limited was requested by Irish Water to conduct a combined terrestrial and marine geophysical investigation for the Greater Dublin Drainage Scheme prior to construction of a proposed outfall pipeline.

The marine area under investigation is located offshore Portmarnock, Co. Dublin and covers approximately 135Ha. The terrestrial investigation was undertaken across c. 300m of Velvet Strand in Portmarnock.

The marine investigation consisted of multichannel analysis of surface waves (MASW), sub bottom profiler single channel seismic reflection and seismic refraction surveys and the investigation on the beach consisted of MASW and seismic refraction.

The investigation was carried out using the above techniques which were combined with client supplied borehole data to produce an integrated geological ground model.

The objectives of the survey were to map the type and thickness of the sediment layers, determine sediment stiffness, map the depth to bedrock, map variation in bedrock type and rock quality and determine engineering parameters.

The results of the investigation are presented in a series of maps, figures and tables and are presented in **Appendix A**: Drawings and **Appendix B**: Tabular Data with Engineering Parameters.

The findings of the geophysical investigation should be reviewed following any further intrusive investigations.

2. INTRODUCTION

APEX Geoservices Limited was requested by Irish Water to carry out a geophysical investigation as part of a ground investigation for a proposed outfall pipeline for the Greater Dublin Drainage Scheme. The investigation consisted of multichannel analysis of surface waves (MASW), sub bottom profiler single channel seismic reflection and seismic refraction surveys.

The investigation involved terrestrial geophysical investigations on Velvet Strand in Portmarnock and marine geophysical investigations offshore Portmarnock.

2.1 Survey Objectives

The objectives of the investigation were:

- Map type and thickness of sediments
- Establish sediment stiffness
- Map the depth to bedrock across the survey area
- Map variation in bedrock type and rock quality
- Determine engineering parameters including dynamic moduli (Gmax)

2.2 Site Background

The survey area is located to the east of Velvet strand at Portmarnock Co. Dublin. The survey lines run approximately 5km from the coast into the sea.

The client supplied chainage for the route of the proposed pipeline for the scheme commences at Baldoyle Bay and covers Portmarnock Golf Club, Velvet Strand and extends c. 4.5km out to sea. The chainage starts at CH 0 and extends to CH 6000.

The location of the geophysical survey area is shown in Figs. 2.1 and 2.2. Figure 2.2 shows the survey profile layout referenced to client supplied chaiange. The survey layout referenced to chainage and Irish National Grid coordinates is shown in more detail in **Appendix A: Drawings**.

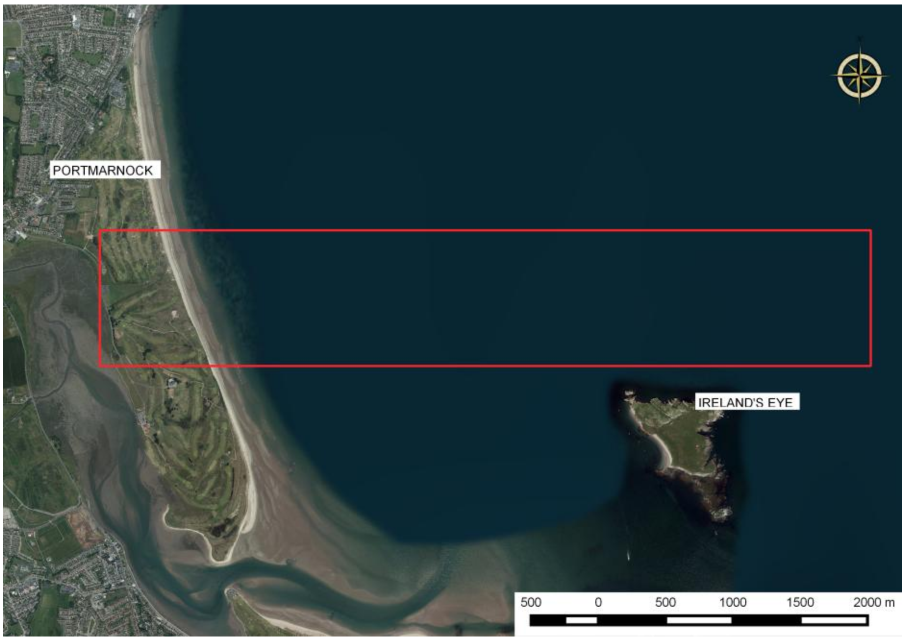

Fig 2.1: Location map (generalised survey area outlined in red).

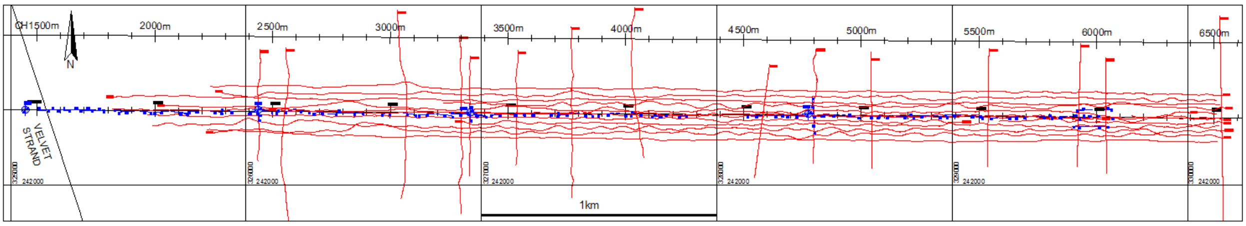

Fig 2.2: Location map showing survey profiles with client supplied chainage.

2.2.1 Geology

The GSI terrestrial bedrock geology map (Fig. 2.3) shows the Portmarnock Beach / Velvet Strand area is underlain by the Malahide Formation, which is described as argillaceous bioclastic limestone and shale. Ireland's Eye, which lies offshore and is to the south of the area under investigation, is underlain by the Bray Group. The Bray Group contains greywacke, quartzite and slate.

The GSI marine bedrock geology map (Fig. 2.4) shows the survey area is underlain by limestones and calcareous shales of Mississipian age. The map also shows a series of southeast – northwest trending faults in this part of the Irish Sea. Three faults are indicated, one to the south of Howth Head, one close to the southwest coast of Ireland's Eye and one to the northeast of Lambay island. The central fault, close to Ireland's Eye, has an alignment which brings it in close proximity to previously acquired borehole BH05. The approximate trajectory of this fault is shown within the survey area in **Appendix A: Drawings.**

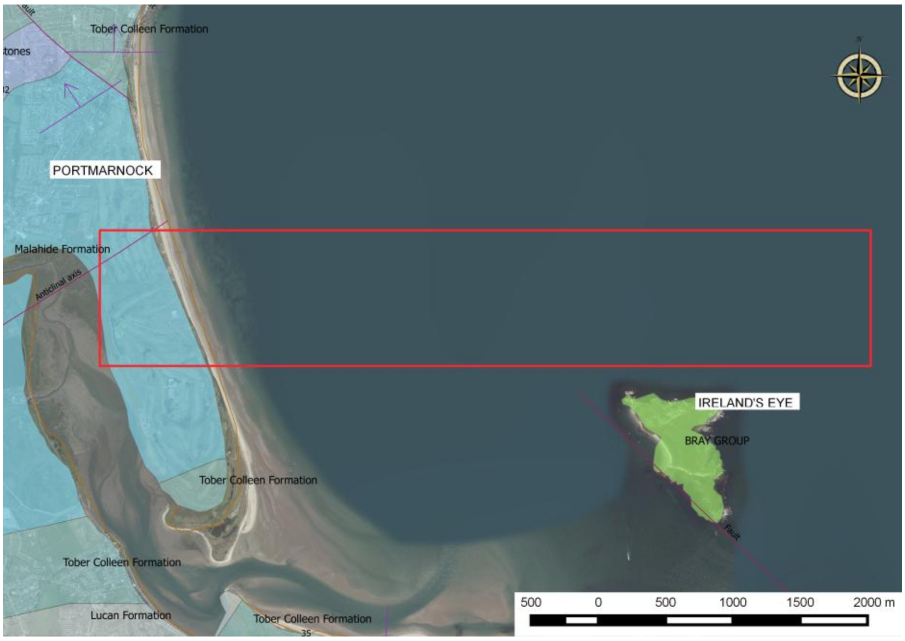

Fig. 2.3: The GSI bedrock map (generalised survey area outlined in red).

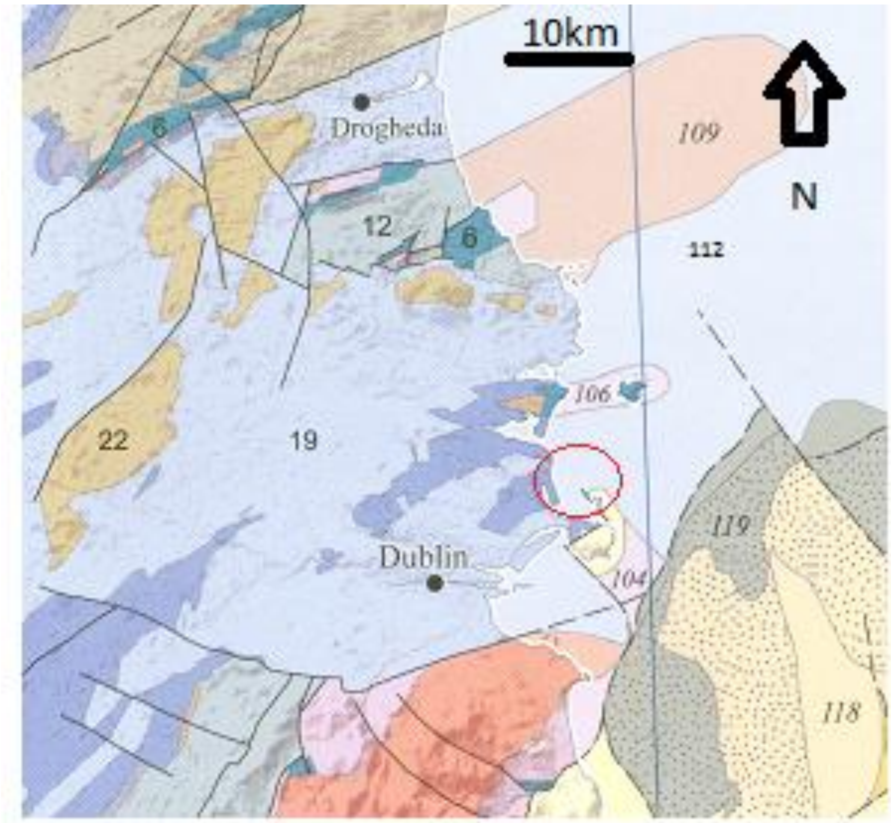

Fig. 2.4: The GSI Marine geology map (survey area highlighted in red). Bedrock type 112 described as limestones and calcareous shales of Mississpian age.

2.2.2 Soils

The soil of the onshore part of the site, along Velvet Strand in Portmarnock, consists primarily of blown sand in dunes (marked blue on Fig.2.5), with minor beach sand along the edges of the strand (marked orange on Fig.2.5).

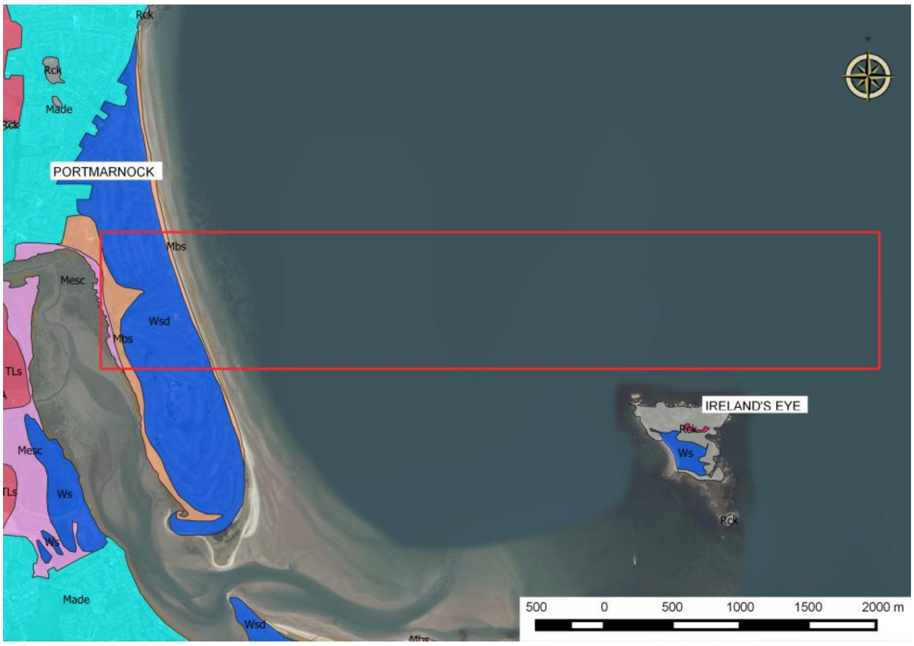

Fig 2.5: The Teagasc soil map (site marked in magenta). Blue = blown sand in dunes, orange = beach sand, purple = estuarine sediments (silts/clays).

2.2.3 Direct Investigation Data

A series of client acquired vibrocore and borehole datasets were supplied for incorporation into this report. In total ten vibrocores and four boreholes were supplied. The vibrocores BHVC02 – BHVC11 were acquired along the proposed pipeline route between client supplied chainage CH 1990 – Ch5980. The boreholes include BH01 on Velvet Strand at approx. chainage CH 1450 and boreholes BH03, BH05 and BH08, at sea, at approximate chainage CH 2440, CH 3340 and CH 4775 respectively.

No recovery is recorded for two of the vibrocores and the remaining eight show 1 – 1.85m of dense silty sand. The vibrocores terminate at depths in the range 0.3m – 1.85m bgl.

The terrestrial borehole, BH01 (CH 1450), describes medium dense to dense silty sand and gravelly sand to 12.9m below ground level (bgl) over c. 1.60m of stiff gravelly clay. Depth to bedrock is recorded as 14.50m bgl. The bedrock is described as partially weathered to unweathered argillaceous limestone. The borehole terminates in limestone described as medium strong to strong at a depth of 59.90m bgl.

The most westerly of the marine boreholes - BH03 (CH 2450), shows medium dense to dense silty sand to a depth of 4.0m bgl over c. 4.50m of very stiff silty gravelly clay over a thin layer of very dense gravel. Depth to bedrock is recorded as 10.30m bgl. The bedrock is described as partially weathered to unweathered argillaceous limestone. The borehole terminates in limestone described as medium strong to strong at a depth of 58.30m bgl.

Borehole BH05 (CH 3350) shows 3.10m of medium dense sand over dense gravel over c. 12.2m of firm to stiff to very stiff sandy gravelly clay. Depth to weak fractured highly weathered mudstone is recorded at 17.0m bgl. Between 17.0m and 33.4m bgl the log describes highly weathered mudstone and highly weathered sandstone and siltstone returned as layers of firm to stiff to very stiff sandy gravelly clays. Depth to weak carbonaceous mudstone is recorded as 33.4 m bgl. Layers of argillaceous limestone, sandstone, siltstone and mudstone are recorded to the borehole termination depth of 55.0m bgl. The borehole terminates in a layer of limestone described as weak to medium strong.

The easterly borehole, BH08 (CH 4775), shows medium dense to very dense gravelly clay over medium dense gravel to 6.2m bgl over stiff to very stiff gravelly silty clay. The depth to slightly weathered to unweathered argillaceous limestone is 8.7m bgl. The borehole terminates in limestone at 45.60m bgl.

2.3 Survey Rationale

A number of geophysical surveying techniques were utilised to generate an integrated geological ground model for the terrestrial and marine sites under investigation and to achieve the objectives of the survey. These methods included Multi-Channel Analysis of Surface Waves (MASW), seismic refraction profiling and sub bottom profiling.

The **MASW** method is used to estimate shear-wave (S-wave) velocities in the sediment material. The MASW data is acquired as a series of 1D soundings to allow for determination of lateral variation in the stiffness of sediment material and derivation of engineering parameters of the sedimentary units including dynamic moduli (Gmax).

Seismic Refraction Profiling in the marine environment measures the velocity of refracted seismic waves through rock material and allows an assessment of the quality of the bedrock material to be made. Lateral variation in the bedrock velocity will indicate changes in the competency of the bedrock. In the marine environment the sediment velocities are generally not determined as they are masked by water velocity.

Sub Bottom Profiling utilises the single channel seismic reflection method to continuously profile the sub seabed structure to assess the nature and morphology of the sediment layering and to determine the structure of the top of the bedrock lithology.

The above geophysical methods, in conjunction with client supplied borehole information, were used to generate an integrated geological model for determination of sediment layering thickness, type and stiffness along with engineering parameters. The combined methodology also gives information on bedrock topography, depth, lithology type, quality, excavatability and faulting / fracturing.

3. RESULTS

The marine and terrestrial investigation was carried out between the 26th August and the 30th September 2015 and involved the acquisition of Multi-Channel Analysis of Surface Wave (MASW), seismic refraction and sub bottom profiler data.

The results of the investigation are displayed in **Appendix A: Drawings**. All data is displayed referenced to client supplied chainage along the route of the proposed pipeline. Data acquisition covered approximate chainage CH 1500 – 6600.

No MASW or seismic refraction data was acquired across an exclusion zone, centred on the fibre optic cable between approx. chainage 4250 – 4520, but survey results were interpolated across this gap for interpretation and data display purposes.

3.1 MASW

A total of seventy one MASW spreads were recorded in conjunction with the seismic refraction survey (S1-S71). Each marine spread was c. 67.85m in length with 24 hydrophones and a hydrone spacing of 2.95m. Each terrestrial spread was 46m in length with 24 geophones and geophone spacing of 2m.Each spread results in the acquisition of a 1D MASW sounding situated at the centre of the spread. The spread locations are shown in **Appendix A: Drawing No. AGL15060_01**.

The shear wave (S-wave) data for the sediment layers (overburden) has been generally interpreted on the following basis:

Layer	***S-Wave Seismic Velocity (m/s)***	***Interpretation***	***Stiffness/Rock Quality***
1	130 - 175	Sediment / overburden	Soft /Loose
2	175 - 250	Sediment / overburden	Firm / Medium Dense
3	250 - 350	Sediment / overburden	Stiff / Dense
4	350 - 430	Sediment / overburden	Very Stiff / Very Dense

The following table shows shear wave velocity (m/s) and related material type for cohesive and granular sediments / soils.

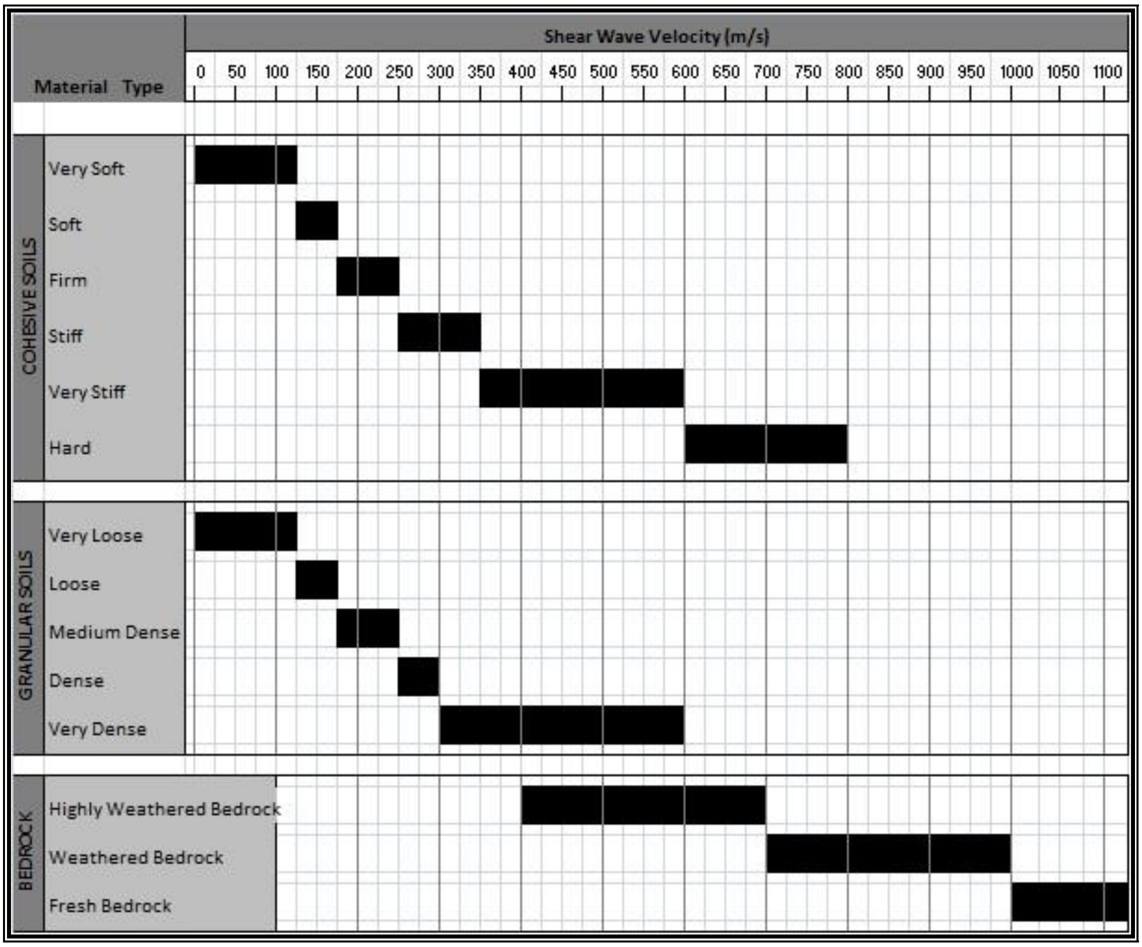

Fig.3.1. Shear-wave velocity and corresponding sediment cohesion.

3.2 Sub Bottom Profiler

A total of twenty eight sub bottom profiles were acquired using the single channel seismic reflection Sparker system. Twelve inlines, with a nominal line spacing of 20m, were acquired parallel to the proposed pipeline route and sixteen crosslines were acquired with a south – north orientation. Three crosslines were sailed at or close to boreholes BH03, BH05 and BH08. The data acquisition rate along each profile was 0.5 seconds equating to data points every c.1.15m.

The data was acquired over an area measuring c. 4800m x 200m. Data acquisition commenced c. 250m east of Velvet Strand and extended c. 500m to the east of the proposed diffuser head.

The data results show a number of defined layers within the sedimentary units and the top of rock.

3.3 Seismic Refraction Profiling

A total of seventy one seismic refraction spreads were recorded across the site. Sixty five (S1-S65) were acquired in the marine environment and an additional six were acquired on Velvet Strand. The marine spreads were acquired with 24 hydrophones with a hydrone spacing of 2.95m and a spread length of c. 67.85m. Four of the marine spreads were acquired approximately 30m and 40m north and south of the proposed location of the diffuser head. The spreads on Velvet Strand used 24 geophones with a geophone spacing of 2m and a spread length of 46m. All spreads were generally aligned along the proposed pipeline with some spreads slightly non parallel to the route.

The locations of the seismic refraction spreads are shown in **Appendix A: Drawing No. AGL15060_01**.

The results of the seismic refraction survey were used to determine bedrock information only. The bedrock velocities vary across the site from 2200 – 5600m/s. The bedrock velocity model is displayed in **Appendix A Drawing No. AGL15060_02**. The data is displayed to 5m below the top of rock and indicates the bulk velocity rather than a discrete velocity at an exact depth. The Vp velocity data for competent bedrock has generally been interpreted on the following basis:

Layer	***P-Wave Seismic Velocity (m/s)***	***Interpretation***	***Rock Quality***	***Excavatibility***
1	2200 - 3400	Mudstone Bedrock	Fair - Good	Break / Blast
2	3400 - 4400	Sandstone / Siltstone Bedrock	Good	Break / Blast
3	4400 - 5600	Limestone Bedrock	Good	Break / Blast

Weathered rock may be present at the top of the bedrock layer. This interpretation correlates with the borehole data.

4. DISCUSSION

The geophysical datasets, in conjunction with client supplied borehole information, were used to generate an integrated geological model for determination of sediment layering thickness, type and stiffness along with engineering parameters. The combined methodology also gives information on bedrock topography, depth, lithology type, quality, excavatability and faulting / fracturing. Combining several techniques maximises the advantages and minimises the limitations of each individual method.

The MASW and the sub bottom profiler data have been used together with the overburden information from the boreholes to give a combined interpretation of the sediment layers. Up to five sediment layers have been identified and interpreted on the sub bottom profiler data which correlates well with the results of the MASW data (See **Appendix A: Drawing No. AGL1506_02**).

The data acquired on Velvet Strand over approx chainage CH 1500 – 1800 generally shows higher overburden velocity than the marine data. This is because the type of wave processed from terrestrial MASW has a higher velocity than the wave type processed for the marine MASW data.

The MASW data shows a general increase in sediment stiffness with depth, from soft / loose to very stiff / very dense, along the length of the proposed pipeline route. Small areas of Vs velocity inversions, representing decreases in stiffness, do exist. The main areas of Vs velocity inversion are present in the deeper water between borehole BH08 and the area around the proposed diffuser head (approx chainage CH 4500 – 6000).

Localised areas of very stiff – very dense sediment layers are present where the depth to bedrock is greatest or within small channels in the top of the bedrock. These areas exist over approx. chainages: CH 2800 – 3900, CH 4550, CH 4750, CH5350 and CH 5650.

The depth to bedrock and bedrock elevation maps were produced for the marine environment only. The terrestrial data was acquired along the centreline chainage only and therefore no maps were produced for the velvet Strand area.

The depth to bedrock interpretation, displayed in **Appendix A: Drawing No. AGL15060_01** and **AGL15060_02**, for the centreline, show the bedrock depth across the survey area varies between c. 5.0m and c. 24m. While there is a general increase in depth to bedrock from west to east there are areas where bedrock is < 10m bgl. These are over approximate chainages CH 2300 – 2800, CH 4800 – 5800. The area of deepest bedrock (maximum sediment thickness) is recorded over chainage CH5 900 – CH6550. In this area bedrock dips to the northeast.

The bedrock elevation map for the survey area, displayed in **Appendix A: Drawing No. AGL15060_01** shows the elevation ranges from c. -12m to -48m MSL from west to east. The area of minimum elevation, c. -34m to -48m MSL, is present over chainage CH5900 – 6550 and shows the northeast bedrock dip.

There is a strong correlation between the results of the geophysical investigation and a number of the client supplied borehole results. The depth to bedrock recorded in borehole data BH01, BH03 and BH08, acquired west to east with chainage, ties closely with the bedrock interpretation from the sub bottom profiler data. The borehole data indicates the top of rock from the geophysical investigation represents the top of the weathered rock. This weathered layer, described as weak to moderate in the boreholes, is c. 2.1m – 4.3m thick.

The results from borehole BH05 describe highly weathered mudstone (returned as clay) at a depth of c. 17.0m. The top of bedrock is interpreted from the geophysical data at c. 16.6m bgl. The non intact nature of the returns from the borehole and reduced reflectivity on the sub bottom profiler data indicates a fault / fracture zone may be present in this part of the survey area. The bedrock interpretation displayed in **Appendix A: Drawing No. AGL15060_02** also shows a transition from limestone to mudstone to sandstone / siltstone bedrock within the vicinity of BH05. This also correlates with the interpreted southeast – northwest trending fault shown on GSI mapping on the southern side of Ireland’s Eye. The approximate trend of this fault is shown in **Appendix A: Drawing No. AGL15060_01.** This approximate trend is c. 290m to the east of BH05 (CH 3350).

5. REFERENCES

Bell F.G., 1993;
'Engineering Geology', Blackwell Scientific Press.

Deere, D. U., Hendron, A. J., Patton, F.D., and Cording, E.J. 1967;
'Design of surface and near surface construction in rock. Failure and breakage of rocks', proceedings 8th U.S. symposium rock mechanics, New York: Soc. Min Engrs, Am. Inst. Min Metall. Petroleum Engrs.

GSI., 2014;
'Bedrock Geology of Ireland, Scale 1:1,000,000'. Department of Communications Energy and Natural Resources.

Hagedoorn, J.G., 1959;
'The plus - minus method of interpreting seismic refraction sections', Geophysical Prospecting, 7, 158 - 182.

KGS, 2000;
'Surfseis Users Manual', Kansas Geological Survey.

Mari, J. L., Glangeud, F. And Coppens, F., 1999;
'Signal Processing for geologists and geophysicists', Editions Technip.

Palmer, D., 1980;
'The Generalized Reciprocal Method of seismic refraction interpretation', SEG.

Park, C.B., Miller, R.D., and Xia, J., 1998;
'Ground roll as a tool to image near-surface anomaly':SEG Expanded Extracts, 68th Annual Meeting, New Orleans, Louisiana, 874-877.

Park, C.B., Miller, R.D., and Xia, J., 1999;
'Multi-channel analysis of surface waves (MASW)': Geophysics, May-June issue.

Press, F., 1966;
'Seismic velocities. Handbook of Physical Constants'. Clark, S. G. (Ed.). 195 – 218 Geological Society of America.

Redpath, B.B., 1973;
'Seismic refraction exploration for engineering site investigations', NTIS, U.S. Dept. of Commerce

Sandmeier, K.J., 1998;
'ReflexW User Manual'

Van Heerden, W. L., 1987;
'General Relations Between Static and Dynamic Moduli of Rocks': International Journal Rock Mechanics Mineral Sciences and Geomechanics, V24, No.6, pp381-385.

Yilmaz, O., 1987;
'Seismic Data Processing', Society of Exploration Geophysicists.

6. APPENDIX A: DRAWINGS

The information derived from the geophysical investigation as well as correlation with the available direct investigation is presented in the following drawings:

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Fig.1	Geophysical Investigation Location Map	Scale 1:5000 @ A0
Fig.2	Seabed Elevation Map	Scale 1:5000 @ A0
Fig.3	Sediment Thickness Map	Scale 1:5000 @ A0
Fig.4	Bedrock Elevation Map	Scale 1:5000 @ A0

AGL15060_02

Fig.1	Bedrock Elevation Map	Scale 1:5000 @ A0
Fig.2	Centreline Cross Section Sparker Data & Structural Interpretation	Scale 1:5000 @ A0
Fig.3	Centreline Cross Section with Overburden Vs Velocity	Scale 1:5000 @ A0
Fig.4	Centreline Cross Section with Bedrock Vp Velocity	Scale 1:5000 @ A0
Fig.5	Centreline Cross Section with Interpretation	Scale 1:5000 @ A0

AGL15060_03

Fig.1	Seabed Elevation Map	Scale 1:5000 @ A0
Fig.2	Bedrock Elevation Map	Scale 1:5000 @ A0
Fig.3	Centreline Cross Section with GMax	Scale 1:5000 @ A0
Fig.4	Centreline Cross Section with Relative RQD	Scale 1:5000 @ A0
Fig.5	Centreline Cross Section with Interpretation	Scale 1:5000 @ A0

FIGURE 1: Geophysical Investigation Location Map
Scale 1:5000

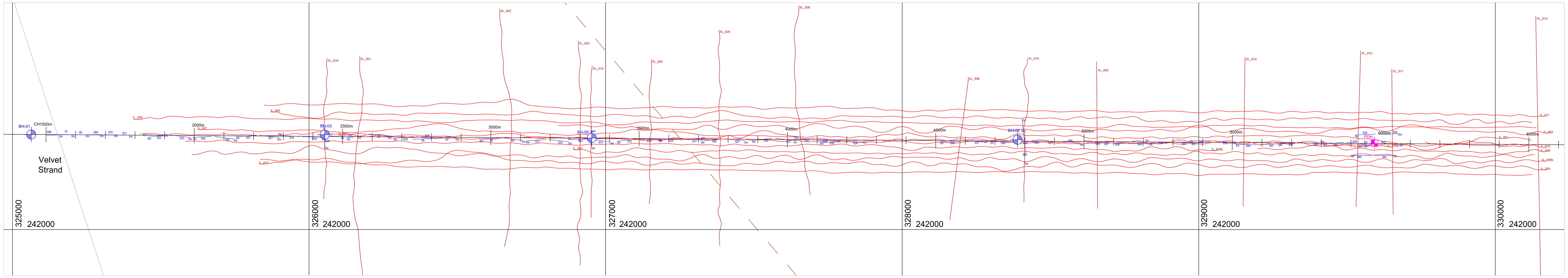


FIGURE 2: Seabed Elevation Map
Scale 1:5000

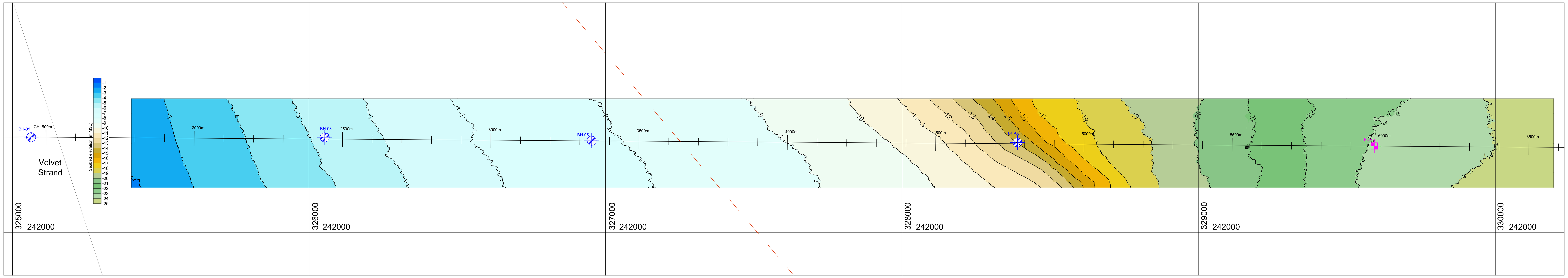


FIGURE 3: Sediment Thickness Map
Scale 1:5000

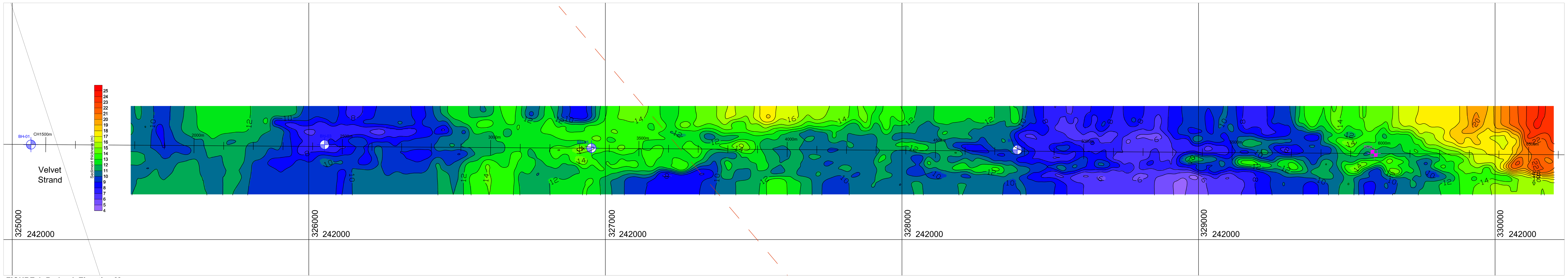
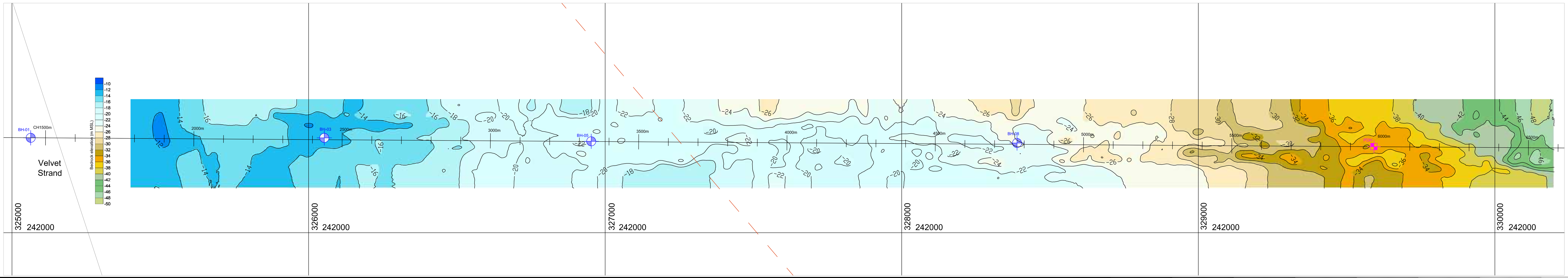


FIGURE 4: Bedrock Elevation Map
Scale 1:5000



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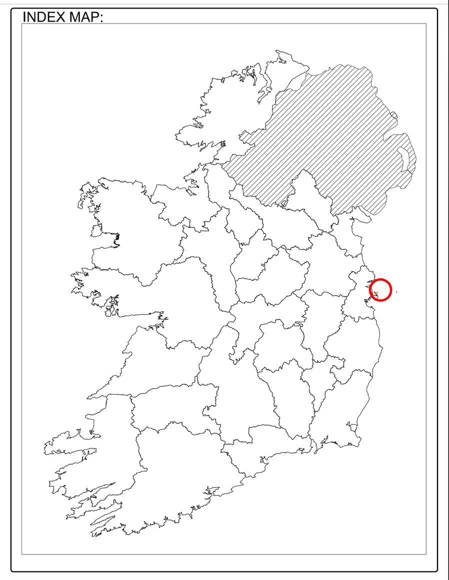

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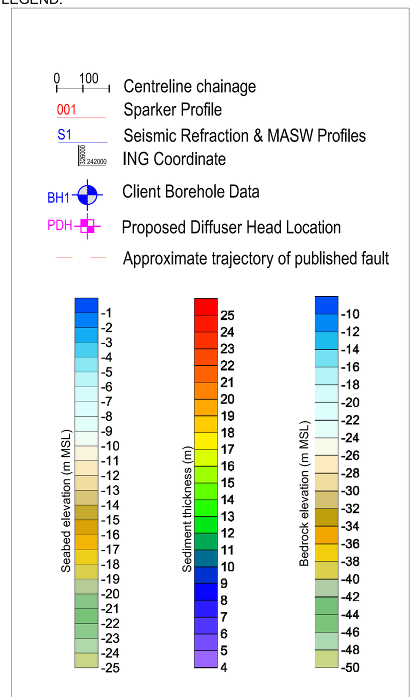

NOTES:

PROJECT:
GREATER DUBLIN DRAINAGE SCHEME
GEOPHYSICAL INVESTIGATION

CLIENT:
IRISH WATER

DRAWING NUMBER:
AGL15060_01

SCALE:
1:5000 @ A0

DATE:
16th NOVEMBER 2015

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REVISION:	DATE:	DRAWN:	CHECKED:
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FIGURE 1: Bedrock Elevation Map, Scale 1:5000

FIGURE 2: Centreline Cross Section Sparker Data & Structural Interpretation, Scale 1:5000

FIGURE 3: Centreline Cross Section with Overburden Vs Velocity, Scale 1:5000

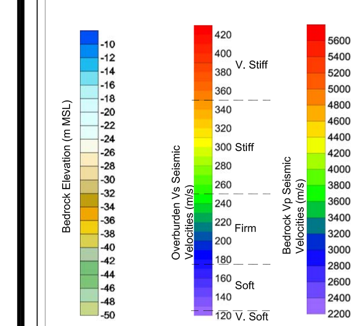
FIGURE 4: Centreline Cross Section with Bedrock Vp Velocity, Scale 1:5000

FIGURE 5: Centreline Cross Section with Interpretation, Scale 1:5000

INDEX MAP:

LEGEND:

- Centre line chainage
- Sparker Profile
- Seismic Refraction & MASW Profiles
- ING Coordinate
- Borehole
- Proposed Diffuser Head
- Approximate trajectory of published fault
- Sediment Thickness from Borehole
- Seabed
- Internal Overburden Layer Boundary
- Top of Bedrock
- Silty CLAY
- Stiff - Very Stiff Sandy SILT
- Medium Dense Silty SAND
- Medium Dense Sandy GRAVEL
- Medium Dense - Very Dense Sandy GRAVEL
- Firm - Stiff Silty/Sandy/Gravelly CLAY (Till)
- Stiff - V.Stiff Silty/Sandy/Gravelly CLAY (Till)
- LIMESTONE
- SANDSTONE / SILTSTONE
- MUDSTONE
- Interpolation across exclusion zone data gap



NOTES:

PROJECT:
GREATER DUBLIN DRAINAGE SCHEME
GEOPHYSICAL INVESTIGATION

CLIENT:
IRISH WATER

DRAWING NUMBER:
AGL15060_02

SCALE:
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DATE:
16th NOVEMBER 2015

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FIGURE 1: Seabed Elevation Map, Scale 1:5000

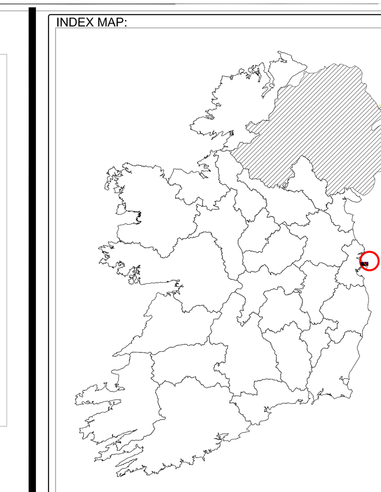
FIGURE 2: Bedrock Elevation Map, Scale 1:5000

FIGURE 3: Centreline Cross Section with GMax, Scale 1:5000

FIGURE 4: Centreline Cross Section with Relative RQD, Scale 1:5000

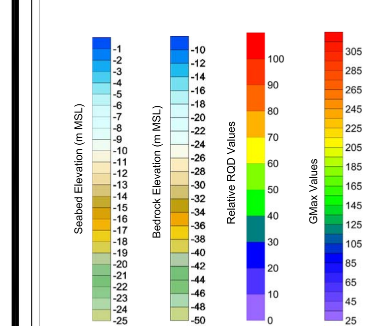
FIGURE 5: Centreline Cross Section with Interpretation, Scale 1:5000

INDEX MAP:



LEGEND:

- Centre line chainage
- Sparker Profile
- Seismic Refraction & MASW Profiles
- ING Coordinate
- Borehole
- Proposed Diffuser Head
- Approximate trajectory of published fault
- Sediment Thickness from Borehole
- Seabed
- Internal Overburden Layer Boundary
- Top of Bedrock
- Silty CLAY
- Stiff - Very Stiff Sandy SILT
- Medium Dense Silty SAND
- Medium Dense Sandy GRAVEL
- Medium Dense - Very Dense Sandy GRAV
- Firm - Stiff Silty/Sandy/Gravelly CLAY (Till)
- Stiff - V.Stiff Silty/Sandy/Gravelly CLAY (Ti
- LIMESTONE
- SANDSTONE / SILTSTONE
- MUDSTONE
- Interpolation across exclusion zone data gap



NOTES:

PROJECT: GREATER DUBLIN DRAINAGE SCHEME GEOPHYSICAL INVESTIGATION

CLIENT: IRISH WATER

DRAWING NUMBER: AGL15060_03

SCALE: 1:5000 @ A0

DATE: 16th NOVEMBER 2015

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7. APPENDIX B: TABULAR DATA WITH ENGINEERING PARAMETERS

The information derived from the geophysical investigation at the locations of the 1D MASW soundings is presented along chainage in the attached tables.

The information presented in the tables is based on the following calculations and assumed parameters;

- For the sediment layers dynamic moduli, Gmax, was calculated based on an assumed density of $1.6Kg/m^3$ for loose – medium dense / soft – firm sediments, $1.8Kg/m^3$ for medium dense / firm sediments and $2.0Kg/m^3$ for dense – very dense / stiff – very stiff sediments. Gmax (Mpa) was calculated using the formula;

$$Gmax\ (Mpa) = (Vs^2 * \rho) / 100$$

Where Vs = Shear Wave Velocity (m/s)
ρ = Density (kg/m^3)

- The SPT value calculations for sediments are based on Imai et al * (1976) for both granular and cohesive sediments. The SPT values were calculated using the formula;

SPT = 0.0011 * Vs2 – 0.1665* Vs + 7.1017 (Granular)
SPT = 0.2061 * Vs – 23.076 (cohesive)

- The depth below seabed values displayed in the tables for the sediment layers and the bedrock layer are based on time to depth conversion of the time domain layering from the sub bottom profiler data using a conversion velocity of 1700m/s.

- For the bedrock data the relative R.Q.D. values were calculated based on an assumed laboratory velocity (V lab) of 6,000m/s. Typical Vp values for sandstones range 1,400m/s to 4,500m/s and for limestones range 1,700m/s to 6,400m/s for soft – crystalline limestone (Press, 1966).

- For the bedrock data the lihological specific R.Q.D. values were calculated based on assumed laboratory velocities (V lab) of 5000m/s for mudstone and sandstone / siltstone and 6000m/s for limestone. The interpretation of the bedrock type along the centreline chainage was based on the seismic refraction Vp velocities (see section 3.3 above) and the bedrock descriptions from the client supplied borehole data.

- Bedrock R.Q.D calculations are based on Deere et al. ** (1967).

- Estimated stiffness and bedrock quality are based on Imai et al 1976.

Chainage (m)	S66	1525
Easting ING		325139
Northing ING		242319
Sea Bed Elevation (MSL)		-1.72

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Silty	SAND	0.00	0.20	159.57	41		LOOSE	8 N
Silty	SAND	0.20	0.66	162.13	42		LOOSE	9 N
Silty	SAND	0.66	1.23	159.65	41		LOOSE	8 N
Silty	SAND	1.23	1.94	151.43	37		LOOSE	7 N
Silty	SAND	1.94	2.83	145.52	34		LOOSE	6 N
Silty	SAND	2.83	3.94	162.26	42		LOOSE	9 N
Sandy	SILT	3.94	5.33	192.14	66		MEDIUM DENSE	15 N
Silty	SAND	5.33	7.07	227.27	93		MEDIUM DENSE	26 N
Silty	SAND	7.07	9.24	265.89	141		DENSE	40 N
		9.24						

Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
SNDST / SLTST		-10.97		3536	50	35	FAIR	

Chainage (m)	S67	1572
Easting ING		325187
Northing ING		242320
Sea Bed Elevation (MSL)		-2.02

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Silty	SAND	0.00	0.25	166.72	44		LOOSE to MEDIUM DENSE	9 N
Silty	SAND	0.25	0.81	168.45	45		LOOSE to MEDIUM DENSE	10 N
Silty	SAND	0.81	1.52	162.67	42		LOOSE	9 N
Silty	SAND	1.52	2.40	157.85	40		LOOSE	8 N
Silty	SAND	2.40	3.50	167.19	45		LOOSE to MEDIUM DENSE	10 N
Sandy	SILT	3.50	4.88	196.02	69		MEDIUM DENSE	16 N
Silty	SAND	4.88	6.60	238.14	102		MEDIUM DENSE	29 N
Silty	SAND	6.60	8.75	284.68	162		DENSE	48 N
Sandy Gravelly	CLAY	8.75	11.44	327.28	214		STIFF to VERY STIFF	44 N
		11.44						

Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
SNDST / SLTST		-13.46		5063	100	71	EXCELLENT	

Chainage (m)	S68	1620
Easting ING		325235
Northing ING		242319
Sea Bed Elevation (MSL)		-2.02

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Silty	SAND	0.00	0.20	160.24	41		LOOSE	8 N
Silty	SAND	0.20	0.66	152.29	37		LOOSE	7 N
Silty	SAND	0.66	1.23	146.40	34		LOOSE	6 N
Silty	SAND	1.23	1.94	141.26	32		LOOSE	5 N
Silty	SAND	1.94	2.83	143.97	33		LOOSE	5 N
Sandy	SILT	2.83	3.94	170.33	46		LOOSE to MEDIUM DENSE	10 N
Sandy	SILT	3.94	5.33	206.70	77		MEDIUM DENSE	19 N
Silty	SAND	5.33	7.07	236.23	100		MEDIUM DENSE	29 N
Sandy Gravelly	CLAY	7.07	9.24	265.34	141		STIFF	31 N
		9.24						

Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
Argillaceous LSTN		-11.26		4921	67	67	FAIR	

Chainage (m)	S69	1667
Easting ING		325282
Northing ING		242320
Sea Bed Elevation (MSL)		-2.08

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Silty	SAND	0.00	0.25	158.23	40		LOOSE	8 N
Silty	SAND	0.25	0.81	159.20	41		LOOSE	8 N
Silty	SAND	0.81	1.52	156.11	39		LOOSE	7 N
Silty	SAND	1.52	2.40	142.47	32		LOOSE	5 N
Silty	SAND	2.40	3.50	129.37	27		VERY LOOSE to LOOSE	3 N
Sandy	SILT	3.50	4.88	155.12	38		LOOSE	7 N
Silty	SAND	4.88	6.60	203.41	74		MEDIUM DENSE	18 N
Sandy Gravelly	CLAY	6.60	8.75	230.16	95		FIRM	24 N
		8.75						

Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
MUDST		-10.83		2593	27	19	POOR	

Chainage (m)	S70	1718
Easting ING		325333
Northing ING		242319
Sea Bed Elevation (MSL)		-2.13

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Silty	SAND	0.00	0.20	155.75	39		LOOSE	7 N
Silty	SAND	0.20	0.66	158.03	40		LOOSE	8 N
Silty	SAND	0.66	1.23	154.48	38		LOOSE	7 N
Silty	SAND	1.23	1.94	142.03	32		LOOSE	5 N
Silty	SAND	1.94	2.83	138.33	31		LOOSE	5 N
Silty	SAND	2.83	3.94	177.52	57		LOOSE to MEDIUM DENSE	12 N
Sandy	SILT	3.94	5.33	222.56	89		MEDIUM DENSE	24 N
Silty	SAND	5.33	7.07	252.67	128		MEDIUM DENSE to DENSE	35 N
Sandy Gravelly	CLAY	7.07	9.24	282.90	160		STIFF	35 N
		9.24						

Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
MUDST		-11.37		3691	54	38	FAIR	

Chainage (m)	S71	1766
Easting ING		325380
Northing ING		242318
Sea Bed Elevation (MSL)		-2.20

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Silty	SAND	0.00	0.25	150.37	36		LOOSE	6 N
Silty	SAND	0.25	0.81	147.36	35		LOOSE	6 N
Silty	SAND	0.81	1.52	145.42	34		LOOSE	6 N
Silty	SAND	1.52	2.40	135.27	29		LOOSE	4 N
Silty	SAND	2.40	3.50	132.60	28		VERY LOOSE to LOOSE	4 N
Sandy	SILT	3.50	4.88	161.75	42		LOOSE	8 N
Silty	SAND	4.88	6.60	209.00	79		MEDIUM DENSE	20 N
Sandy Gravelly	CLAY	6.60	8.75	239.42	103		FIRM	26 N
		8.75						

Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
Argillaceous LSTN		-10.95		4921	67	67	FAIR	

S22

Chainage (m)	Easting ING	Northing ING	Sea Bed Elevation (MSL)
1877	325490	242318	-2.29

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Silty	SAND	0.00	2.51	166.10	44	LOOSE to MEDIUM DENSE	9 N
Sandy	SILT	2.51	5.33	215.86	84	MEDIUM DENSE	22 N
Sandy Gravelly	CLAY	5.33	7.39	259.61	135	STIFF	30 N
		7.39					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
SNDST / SLTST	-9.69	3592	52	36	FAIR

S23

Chainage (m)	Easting ING	Northing ING	Sea Bed Elevation (MSL)
1954	325567	242317	-3.16

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Silty	SAND	0.00	2.51	161.00	41	LOOSE	8 N
Sandy	SILT	2.51	5.33	230.88	96	MEDIUM DENSE	27 N
Sandy Gravelly	CLAY	5.33	7.49	210.17	80	FIRM	20 N
		7.49					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
SNDST / SLTST	-10.65	4332	75	52	GOOD

S24

Chainage (m)	Easting ING	Northing ING	Sea Bed Elevation (MSL)
2026	325639	242317	-3.17

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Silty	SAND	0.00	2.60	154.69	38	LOOSE	7 N
Sandy	SILT	2.60	5.94	232.30	97	MEDIUM DENSE	27 N
Sandy Gravelly	CLAY	5.94	8.32	252.21	127	FIRM to STIFF	28 N
		8.32					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
SNDST / SLTST	-11.49	3295	43	30	POOR

S25

Chainage (m)	Easting ING	Northing ING	Sea Bed Elevation (MSL)
2102	325715	242316	-3.64

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Silty	SAND	0.00	2.50	158.05	40	LOOSE	8 N
Sandy	SILT	2.50	5.96	216.15	84	MEDIUM DENSE	22 N
Sandy Gravelly	CLAY	5.96	8.17	273.52	150	STIFF	33 N
		8.17					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
Argillaceous LSTN	-11.81	4736	62	62	FAIR

S20

Chainage (m)	Easting ING	Northing ING	Sea Bed Elevation (MSL)
2175	325788	242316	-4.03

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Silty	SAND	0.00	2.21	150.72	36	LOOSE	6 N
Sandy	SILT	2.21	7.02	207.55	78	MEDIUM DENSE	19 N
Sandy Gravelly	CLAY	7.02	8.02	287.15	165	STIFF	36 N
		8.02					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
Argillaceous LSTN	-12.05	5220	76	76	GOOD

S21

Chainage (m)	Easting ING	Northing ING	Sea Bed Elevation (MSL)
2252	325865	242315	-4.36

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Silty	SAND	0.00	2.53	153.74	38	LOOSE	7 N
Sandy	SILT	2.53	6.86	224.18	90	MEDIUM DENSE	25 N
Sandy Gravelly	CLAY	6.86	8.74	301.68	182	STIFF	39 N
		8.74					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
Argillaceous LSTN	-13.10	5122	73	73	FAIR

S18

Chainage (m)	Easting ING	Northing ING	Sea Bed Elevation (MSL)
2320	325933	242315	-4.68

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Silty	SAND	0.00	2.21	149.00	36	LOOSE	6 N
Sandy	SILT	2.21	7.02	229.14	95	MEDIUM DENSE	26 N
Sandy Gravelly	CLAY	7.02	8.87	341.08	233	STIFF to VERY STIFF	47 N
		8.87					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
Argillaceous LSTN	-13.54	4909	67	67	FAIR

S19

Chainage (m)	Easting ING	Northing ING	Sea Bed Elevation (MSL)
2399	326012	242314	-5.02

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Silty	SAND	0.00	2.26	149.32	36	LOOSE	6 N
Sandy	SILT	2.26	7.04	235.34	100	MEDIUM DENSE	28 N
Sandy Gravelly	CLAY	7.04	9.56	358.51	257	STIFF to VERY STIFF	50 N
		9.56					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
Argillaceous LSTN	-14.58	5082	72	72	FAIR

S2

Chainage (m)	2490
Easting ING	326102
Northing ING	242313
Sea Bed Elevation (MSL)	-5.42

Sediment

Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Silty SAND	0.00	2.30	158.50	40	LOOSE	8 N
Sandy SILT	2.30	2.35	201.54	73	MEDIUM DENSE	18 N
Sandy SILT	2.35	5.88	233.87	98	MEDIUM DENSE	28 N
Sandy Gravelly CLAY	5.88	8.16	330.71	219	STIFF to VERY STIFF	45 N
	8.16					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
Argillaceous LSTN	-13.57	4990	69	69	FAIR

S3

Chainage (m)	2548
Easting ING	326160
Northing ING	242313
Sea Bed Elevation (MSL)	-5.65

Sediment

Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Silty SAND	0.00	2.10	131.97	28	VERY LOOSE to LOOSE	4 N
Sandy SILT	2.10	2.67	233.13	98	MEDIUM DENSE	28 N
Sandy SILT	2.67	6.40	234.36	99	MEDIUM DENSE	28 N
Sandy Gravelly CLAY	6.40	9.37	349.50	244	STIFF to VERY STIFF	48 N
	9.37					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
Argillaceous LSTN	-15.02	4477	56	56	FAIR

S4

Chainage (m)	2621
Easting ING	326234
Northing ING	242313
Sea Bed Elevation (MSL)	-5.91

Sediment

Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Silty SAND	0.00	2.39	152.10	37	LOOSE	7 N
Sandy SILT	2.39	2.70	216.98	85	MEDIUM DENSE	22 N
Sandy SILT	2.70	6.40	245.18	108	MEDIUM DENSE to DENSE	32 N
Sandy Gravelly CLAY	6.40	10.08	322.71	208	STIFF to VERY STIFF	43 N
	10.08					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
SNDST / SLTST	-15.99	3707	55	38	FAIR

S38

Chainage (m)	2705
Easting ING	326318
Northing ING	242312
Sea Bed Elevation (MSL)	-6.20

Sediment

Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Silty SAND	0.00	2.31	209.78	79	MEDIUM DENSE	20 N
Sandy GRAVEL	2.31	3.50	207.31	77	MEDIUM DENSE	19 N
Sandy GRAVEL	3.50	4.04	224.60	91	MEDIUM DENSE	25 N
Sandy SILT	4.04	5.09	254.33	129	MEDIUM DENSE to DENSE	35 N
Sandy Gravelly CLAY	5.09	9.40	288.79	167	STIFF	36 N
	9.40					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
SNDST / SLTST	-15.60	4232	72	50	FAIR

S39

Chainage (m)	2783
Easting ING	326396
Northing ING	242312
Sea Bed Elevation (MSL)	-6.44

Sediment

Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Silty SAND	0.00	2.22	174.86	49	LOOSE to MEDIUM DENSE	11 N
Sandy GRAVEL	2.22	3.20	195.38	69	MEDIUM DENSE	16 N
Sandy GRAVEL	3.20	3.86	224.77	91	MEDIUM DENSE	25 N
Sandy GRAVEL	3.86	6.18	245.02	108	MEDIUM DENSE to DENSE	32 N
Sandy Gravelly CLAY	6.18	9.75	316.19	200	STIFF	42 N
	9.75					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
SNDST / SLTST	-16.19	3557	51	35	FAIR

S7

Chainage (m)	2849
Easting ING	326462
Northing ING	242311
Sea Bed Elevation (MSL)	-6.73

Sediment

Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Silty SAND	0.00	2.11	230.17	95	MEDIUM DENSE	27 N
Sandy GRAVEL	2.11	2.70	246.09	109	MEDIUM DENSE to DENSE	32 N
Sandy GRAVEL	2.70	3.35	256.56	132	DENSE	36 N
Sandy GRAVEL	3.35	6.34	243.33	107	MEDIUM DENSE to DENSE	31 N
Sandy Gravelly CLAY	6.34	10.88	376.93	284	VERY STIFF	>50 N
	10.88					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
MUDST	-17.60	3094	38	27	POOR

S9

Chainage (m)	2996
Easting ING	326609
Northing ING	242310
Sea Bed Elevation (MSL)	-7.18

Sediment

Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Silty SAND	0.00	2.30	193.95	68	MEDIUM DENSE	16 N
Sandy GRAVEL	2.30	2.57	200.52	72	MEDIUM DENSE	17 N
Sandy GRAVEL	2.57	4.03	173.58	48	LOOSE to MEDIUM DENSE	11 N
Sandy GRAVEL	4.03	5.74	275.34	152	DENSE	44 N
Sandy Gravelly CLAY	5.74	8.81	310.83	193	STIFF	40 N
Sandy Gravelly CLAY	8.81	11.86	329.21	217	STIFF to VERY STIFF	44 N
	11.86					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
SNDST / SLTST	-19.03	3781	57	40	FAIR

S8

Chainage (m)	3074
Easting ING	326687
Northing ING	242310
Sea Bed Elevation (MSL)	-7.35

Sediment

Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Silty SAND	0.00	2.30	191.93	66	MEDIUM DENSE	15 N
Silty SAND	2.30	3.17	189.28	64	MEDIUM DENSE	14 N
Sandy GRAVEL	3.17	4.24	182.48	60	MEDIUM DENSE	13 N
Sandy GRAVEL	4.24	8.00	245.91	109	MEDIUM DENSE to DENSE	32 N
Sandy Gravelly CLAY	8.00	9.38	310.50	193	STIFF	40 N
Sandy Gravelly CLAY	9.38	12.04	310.50	193	STIFF	40 N
	12.04					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
MUDST	-19.39	3052	37	26	POOR

	S11		S10
Chainage (m)	3152	Chainage (m)	3230
Easting ING	326765	Easting ING	326843
Northing ING	242309	Northing ING	242309
Sea Bed Elevation (MSL)	-7.46	Sea Bed Elevation (MSL)	-7.61

S11 – Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Silty	SAND	0.00	2.81	196.20	69		MEDIUM DENSE	16 N
Sandy	GRAVEL	2.81	3.84	149.57	36		LOOSE	6 N
Sandy	GRAVEL	3.84	6.00	250.02	125		MEDIUM DENSE to DENSE	34 N
Sandy	GRAVEL	6.00	8.89	318.87	203		VERY DENSE	>50 N
Sandy Gravelly	CLAY	8.89	10.03	320.92	206		STIFF to VERY STIFF	43 N
Sandy Gravelly	CLAY	10.03	11.95	416.67	347		VERY STIFF	>50 N
		11.95						

S11 – Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
SNDST / SLTST		-19.41		4168	70	48	FAIR	

S10 – Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Silty	SAND	0.00	2.30	173.25	48		LOOSE to MEDIUM DENSE	11 N
Silty	SAND	2.30	2.98	155.35	39		LOOSE	7 N
Sandy	GRAVEL	2.98	3.33	186.75	63		MEDIUM DENSE	14 N
Sandy	GRAVEL	3.33	6.52	219.71	87		MEDIUM DENSE	23 N
Sandy Gravelly	CLAY	6.52	11.67	309.59	192		STIFF	40 N
Sandy Gravelly	CLAY	11.67	13.46	310.72	193		STIFF	40 N
		13.46						

S10 – Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
SNDST / SLTST		-21.07		3479	48	34	POOR	

	S13		S12
Chainage (m)	3295	Chainage (m)	3371
Easting ING	326908	Easting ING	326984
Northing ING	242308	Northing ING	242308
Sea Bed Elevation (MSL)	-7.73	Sea Bed Elevation (MSL)	-7.87

S13 – Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Silty	SAND	0.00	3.10	166.05	44		LOOSE to MEDIUM DENSE	9 N
Silty	SAND	3.10	3.22	238.81	103		MEDIUM DENSE	30 N
Sandy	GRAVEL	3.22	6.77	249.10	112		MEDIUM DENSE to DENSE	33 N
Sandy Gravelly	CLAY	6.77	12.22	332.21	221		STIFF to VERY STIFF	45 N
Sandy Gravelly	CLAY	12.22	15.40	358.09	256		STIFF to VERY STIFF	50 N
		15.40						

S13 – Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
SNDST / SLTST		-23.13		3768	57	39	FAIR	

S12 – Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Silty	SAND	0.00	2.70	182.37	60		MEDIUM DENSE	13 N
Silty	SAND	2.70	3.09	219.92	87		MEDIUM DENSE	23 N
Sandy	GRAVEL	3.09	3.70	188.01	64		MEDIUM DENSE	14 N
Sandy	GRAVEL	3.70	4.66	234.54	99		MEDIUM DENSE	28 N
Sandy Gravelly	CLAY	4.66	11.64	298.56	178		STIFF	38 N
Sandy Gravelly	CLAY	11.64	15.34	399.52	319		VERY STIFF	>50 N
		15.34						

S12 – Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
SNDST / SLTST		-23.21		3692	55	38	FAIR	

	S15		S14
Chainage (m)	3460	Chainage (m)	3535
Easting ING	327073	Easting ING	327148
Northing ING	242307	Northing ING	242306
Sea Bed Elevation (MSL)	-8.03	Sea Bed Elevation (MSL)	-8.15

S15 – Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Silty	SAND	0.00	2.30	164.19	43		LOOSE	9 N
Silty	SAND	2.30	3.05	203.34	74		MEDIUM DENSE	18 N
Sandy	GRAVEL	3.05	3.41	224.11	90		MEDIUM DENSE	25 N
Sandy	GRAVEL	3.41	6.85	252.86	128		MEDIUM DENSE to DENSE	35 N
Sandy Gravelly	CLAY	6.85	12.35	363.48	264		STIFF to VERY STIFF	>50 N
Sandy Gravelly	CLAY	12.35	13.65	426.35	364		VERY STIFF	>50 N
		13.65						

S15 – Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
SNDST / SLTST		-21.68		4075	66	46	FAIR	

S14 – Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Silty	SAND	0.00	2.50	170.19	46		LOOSE to MEDIUM DENSE	10 N
Silty	SAND	2.50	2.80	234.78	99		MEDIUM DENSE	28 N
Sandy	GRAVEL	2.80	3.51	223.63	90		MEDIUM DENSE	24 N
Sandy	GRAVEL	3.51	6.23	248.30	111		MEDIUM DENSE to DENSE	33 N
Sandy Gravelly	CLAY	6.23	11.30	317.89	202		STIFF	42 N
Sandy Gravelly	CLAY	11.30	13.23	418.18	350		VERY STIFF	>50 N
		13.23						

S14 – Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
MUDST		-21.38		2520	25	18	POOR	

	S16		S17
Chainage (m)	3600	Chainage (m)	3680
Easting ING	327213	Easting ING	327293
Northing ING	242306	Northing ING	242306
Sea Bed Elevation (MSL)	-8.27	Sea Bed Elevation (MSL)	-8.41

S16 – Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Silty	SAND	0.00	2.56	199.59	72		MEDIUM DENSE	17 N
Sandy	GRAVEL	2.56	3.72	174.31	49		LOOSE to MEDIUM DENSE	11 N
Sandy	GRAVEL	3.72	7.66	252.59	128		MEDIUM DENSE to DENSE	35 N
Sandy Gravelly	CLAY	7.66	11.47	356.31	254		STIFF to VERY STIFF	50 N
Sandy Gravelly	CLAY	11.47	13.06	403.18	325		VERY STIFF	>50 N
		13.06						

S16 – Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
SNDST / SLTST		-21.32		3794	58	40	FAIR	

S17 – Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Silty	SAND	0.00	2.00	166.75	44		LOOSE to MEDIUM DENSE	9 N
Silty	SAND	2.00	2.52	165.36	44		LOOSE to MEDIUM DENSE	9 N
Sandy	GRAVEL	2.52	4.00	190.76	65		MEDIUM DENSE	15 N
Sandy	GRAVEL	4.00	8.31	280.39	157		DENSE	46 N
Sandy Gravelly	CLAY	8.31	11.74	359.40	258		STIFF to VERY STIFF	50 N
Sandy Gravelly	CLAY	11.74	13.94	420.25	353		VERY STIFF	>50 N
		13.94						

S17 – Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
SNDST / SLTST		-22.35		4229	72	50	FAIR	

S26

Chainage (m)	3744
Easting ING	327357
Northing ING	242305
Sea Bed Elevation (MSL)	-8.53

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Silty	SAND	0.00	2.50	137.49	30		LOOSE	5 N
Sandy	GRAVEL	2.50	2.80	178.80	58		LOOSE to MEDIUM DENSE	12 N
Sandy	GRAVEL	2.80	3.98	199.02	71		MEDIUM DENSE	17 N
Sandy	GRAVEL	3.98	4.62	211.84	81		MEDIUM DENSE	21 N
Sandy	GRAVEL	4.62	9.50	278.59	155		DENSE	46 N
Sandy Gravelly	CLAY	9.50	10.51	358.66	257		STIFF to VERY STIFF	50 N
Sandy Gravelly	CLAY	10.51	11.85	358.64	257		STIFF to VERY STIFF	50 N
		11.85						

Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
SNDST / SLTST		-20.38		4177	70	48	FAIR	

S27

Chainage (m)	3823
Easting ING	327436
Northing ING	242305
Sea Bed Elevation (MSL)	-8.69

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Silty	SAND	0.00	2.50	135.35	29		LOOSE	4 N
Silty	SAND	2.50	2.62	181.30	59		MEDIUM DENSE	13 N
Sandy	GRAVEL	2.62	4.57	184.32	61		MEDIUM DENSE	13 N
Sandy	GRAVEL	4.57	6.49	241.92	105		MEDIUM DENSE to DENSE	31 N
Sandy	GRAVEL	6.49	9.42	289.98	168		DENSE	>50 N
Sandy Gravelly	CLAY	9.42	10.54	303.05	184		STIFF	39 N
Sandy Gravelly	CLAY	10.54	13.45	329.08	217		STIFF to VERY STIFF	44 N
		13.45						

Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
SNDST / SLTST		-22.14		4037	65	45	FAIR	

S30

Chainage (m)	3954
Easting ING	327567
Northing ING	242304
Sea Bed Elevation (MSL)	-8.93

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Silty	SAND	0.00	2.01	167.58	45		LOOSE to MEDIUM DENSE	10 N
Silty	SAND	2.01	2.30	182.98	60		MEDIUM DENSE	13 N
Sandy	GRAVEL	2.30	4.33	185.28	62		MEDIUM DENSE	14 N
Sandy	GRAVEL	4.33	5.77	212.17	81		MEDIUM DENSE	21 N
Sandy	GRAVEL	5.77	8.03	229.48	95		MEDIUM DENSE	26 N
Sandy Gravelly	CLAY	8.03	10.44	225.29	91		FIRM	23 N
		10.44						

Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
Argillaceous LSTN		-19.38		4788	64	64	FAIR	

S31

Chainage (m)	3993
Easting ING	327606
Northing ING	242303
Sea Bed Elevation (MSL)	-9.00

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Silty	SAND	0.00	2.01	152.30	37		LOOSE	7 N
Sandy	GRAVEL	2.01	2.80	166.45	44		LOOSE to MEDIUM DENSE	9 N
Sandy	GRAVEL	2.80	4.33	187.65	63		MEDIUM DENSE	14 N
Sandy	GRAVEL	4.33	5.77	213.36	82		MEDIUM DENSE	21 N
Sandy	GRAVEL	5.77	8.24	246.07	109		MEDIUM DENSE to DENSE	32 N
Sandy Gravelly	CLAY	8.24	10.88	259.10	134		STIFF	30 N
		10.88						

Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
Argillaceous LSTN		-19.88		5020	70	70	FAIR	

S32

Chainage (m)	4058
Easting ING	327671
Northing ING	242303
Sea Bed Elevation (MSL)	-9.10

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Sandy	GRAVEL	0.00	4.04	159.37	41		LOOSE	8 N
Sandy	GRAVEL	4.04	5.67	232.43	97		MEDIUM DENSE	27 N
Sandy	GRAVEL	5.67	8.52	242.77	106		MEDIUM DENSE to DENSE	31 N
Sandy Gravelly	CLAY	8.52	9.95	253.97	129		FIRM to STIFF	29 N
		9.95						

Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
Argillaceous LSTN		-19.05		4768	63	63	FAIR	

S33

Chainage (m)	4135
Easting ING	327748
Northing ING	242302
Sea Bed Elevation (MSL)	-9.31

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Sandy	GRAVEL	0.00	1.72	206.67	77		MEDIUM DENSE	19 N
Sandy	GRAVEL	1.72	2.30	205.82	76		MEDIUM DENSE	19 N
Sandy	GRAVEL	2.30	3.85	195.05	68		MEDIUM DENSE	16 N
Sandy	GRAVEL	3.85	5.59	234.17	99		MEDIUM DENSE	28 N
Sandy	GRAVEL	5.59	8.75	231.76	97		MEDIUM DENSE	27 N
Sandy Gravelly	CLAY	8.75	9.78	274.16	150		STIFF	33 N
		9.78						

Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
Argillaceous LSTN		-19.09		5122	73	73	FAIR	

S34

Chainage (m)	4222
Easting ING	327835
Northing ING	242302
Sea Bed Elevation (MSL)	-9.54

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Sandy	GRAVEL	0.00	1.70	189.14	64		MEDIUM DENSE	14 N
Sandy	GRAVEL	1.70	2.00	206.76	77		MEDIUM DENSE	19 N
Sandy	GRAVEL	2.00	3.10	188.21	64		MEDIUM DENSE	14 N
Sandy	GRAVEL	3.10	3.96	194.64	68		MEDIUM DENSE	16 N
Sandy	GRAVEL	3.96	4.79	241.03	105		MEDIUM DENSE to DENSE	30 N
Sandy	GRAVEL	4.79	8.00	243.78	107		MEDIUM DENSE to DENSE	31 N
Sandy Gravelly	CLAY	8.00	10.10	274.16	150		STIFF	33 N
		10.10						

Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
Argillaceous LSTN		-19.64		4425	54	54	FAIR	

S36

Chainage (m)	4550
Easting ING	328163
Northing ING	242300
Sea Bed Elevation (MSL)	-11.15

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Sandy	GRAVEL	0.00	1.64	239.95	104		MEDIUM DENSE	30 N
Sandy	GRAVEL	1.64	3.30	215.73	84		MEDIUM DENSE	22 N
Sandy	GRAVEL	3.30	3.99	239.69	103		MEDIUM DENSE	30 N
Sandy	GRAVEL	3.99	5.87	239.69	103		MEDIUM DENSE	30 N
Sandy	GRAVEL	5.87	9.54	279.58	156		DENSE	46 N
Sandy Gravelly	CLAY	9.54	11.36	333.62	223		STIFF to VERY STIFF	45 N
		11.36						

Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
SNDST / SLTST		-22.50		3868	60	42	FAIR	

	S37	S42
Chainage (m)	4630	4718
Easting ING	328243	328331
Northing ING	242299	242299
Sea Bed Elevation (MSL)	-11.95	-13.12

S37 – Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Sandy	GRAVEL	0.00	2.03	210.93	80	MEDIUM DENSE	20 N
Sandy	GRAVEL	2.03	3.10	218.29	86	MEDIUM DENSE	23 N
Sandy	GRAVEL	3.10	3.34	236.16	100	MEDIUM DENSE	29 N
Sandy	GRAVEL	3.34	5.56	236.16	100	MEDIUM DENSE	29 N
Sandy	GRAVEL	5.56	7.75	244.82	108	MEDIUM DENSE to DENSE	32 N
Sandy Gravelly	CLAY	7.75	8.40	299.82	180	STIFF	38 N
		8.40					

S37 – Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
Argillaceous LSTN	-20.35	4640	60	60	FAIR

S42 – Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Sandy	GRAVEL	0.00	2.46	210.10	79	MEDIUM DENSE	20 N
Sandy	GRAVEL	2.46	2.86	227.08	93	MEDIUM DENSE	26 N
Sandy	GRAVEL	2.86	3.76	227.08	93	MEDIUM DENSE	26 N
Sandy	GRAVEL	3.76	3.90	253.79	129	MEDIUM DENSE to DENSE	35 N
Sandy	GRAVEL	3.90	7.79	251.24	126	MEDIUM DENSE to DENSE	34 N
Sandy Gravelly	CLAY	7.79	10.01	268.51	144	STIFF	32 N
		10.01					

S42 – Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
Argillaceous LSTN	-23.13	5192	75	75	FAIR

	S47	S43
Chainage (m)	4872	4797
Easting ING	328485	328410
Northing ING	242298	242298
Sea Bed Elevation (MSL)	-15.84	-14.31

S47 – Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Sandy	GRAVEL	0.00	1.64	260.54	136	DENSE	38 N
Sandy	GRAVEL	1.64	3.14	234.14	99	MEDIUM DENSE	28 N
Sandy	GRAVEL	3.14	4.30	249.61	112	MEDIUM DENSE to DENSE	34 N
Sandy Gravelly	CLAY	4.30	8.52	253.21	128	FIRM to STIFF	29 N
		8.52					

S47 – Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
Argillaceous LSTN	-24.36	3074	26	26	POOR

S43 – Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Sandy	GRAVEL	0.00	1.94	228.93	94	MEDIUM DENSE	26 N
Sandy	GRAVEL	1.94	3.39	232.17	97	MEDIUM DENSE	27 N
Sandy Gravelly	CLAY	3.39	3.70	232.17	97	FIRM	24 N
Sandy Gravelly	CLAY	3.70	5.73	204.14	75	FIRM	18 N
Sandy Gravelly	CLAY	5.73	7.55	236.71	101	FIRM	25 N
		7.55					

S43 – Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
MUDST	-21.86	5402	100	81	EXCELLENT

	S46	S29
Chainage (m)	4955	5041
Easting ING	328568	328654
Northing ING	242297	242296
Sea Bed Elevation (MSL)	-17.15	-17.98

S46 – Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Sandy	GRAVEL	0.00	3.30	223.73	90	MEDIUM DENSE	24 N
Sandy	GRAVEL	3.30	4.93	279.76	157	DENSE	46 N
Sandy Gravelly	CLAY	4.93	8.36	271.65	148	STIFF	32 N
		8.36					

S46 – Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
MUDST	-25.51	2320	22	15	VERY POOR

S29 – Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Sandy	GRAVEL	0.00	0.66	279.86	157	DENSE	46 N
Sandy	GRAVEL	0.66	2.62	211.54	81	MEDIUM DENSE	21 N
Sandy	GRAVEL	2.62	2.90	279.37	156	DENSE	46 N
Sandy Gravelly	CLAY	2.90	7.81	327.35	214	STIFF to VERY STIFF	44 N
		7.81					

S29 – Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
MUDST	-25.79	2407	23	16	VERY POOR

	S49	S48
Chainage (m)	5103	5181
Easting ING	328716	328794
Northing ING	242296	242295
Sea Bed Elevation (MSL)	-18.37	-18.78

S49 – Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Sandy	GRAVEL	0.00	2.80	222.51	89	MEDIUM DENSE	24 N
Sandy	GRAVEL	2.80	3.63	275.51	152	DENSE	44 N
Sandy Gravelly	CLAY	3.63	7.23	305.15	186	STIFF	39 N
		7.23					

S49 – Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
MUDST	-25.61	2420	23	16	VERY POOR

S48 – Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Sandy	GRAVEL	0.00	2.90	268.07	144	DENSE	41 N
Sandy	GRAVEL	2.90	4.11	268.34	144	DENSE	41 N
Sandy Gravelly	CLAY	4.11	6.29	230.83	96	FIRM	24 N
		6.29					

S48 – Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
SNDST / SLTST	-25.06	3831	59	41	FAIR

S50

Chainage (m)	5253
Easting ING	328866
Northing ING	242295
Sea Bed Elevation (MSL)	-19.15

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Sandy	GRAVEL	0.00	2.40	168.89	46	LOOSE to MEDIUM DENSE	10 N
Sandy	GRAVEL	2.40	3.32	210.01	79	MEDIUM DENSE	20 N
Sandy Gravelly	CLAY	3.32	6.85	248.59	111	FIRM to STIFF	28 N
		6.85					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
MUDST	-26.00	2703	29	20	POOR

S51

Chainage (m)	5330
Easting ING	328943
Northing ING	242294
Sea Bed Elevation (MSL)	-19.77

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Sandy	GRAVEL	0.00	2.96	226.39	92	MEDIUM DENSE	25 N
Sandy Gravelly	CLAY	2.96	5.75	265.48	141	STIFF	31 N
Sandy Gravelly	CLAY	5.75	7.98	325.17	211	STIFF to VERY STIFF	43 N
		7.98					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
SNDST / SLTST	-27.75	4609	85	59	GOOD

S53

Chainage (m)	5391
Easting ING	329004
Northing ING	242294
Sea Bed Elevation (MSL)	-20.11

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Sandy	GRAVEL	0.00	2.39	251.40	126	MEDIUM DENSE to DENSE	34 N
Sandy	GRAVEL	2.39	3.30	253.16	128	MEDIUM DENSE to DENSE	35 N
Sandy	GRAVEL	3.30	4.52	264.13	140	DENSE	39 N
Sandy Gravelly	CLAY	4.52	5.75	304.26	185	STIFF	39 N
Sandy Gravelly	CLAY	5.75	7.24	327.20	214	STIFF to VERY STIFF	44 N
		7.24					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
SNDST / SLTST	-27.34	3771	57	39	FAIR

S52

Chainage (m)	5472
Easting ING	329085
Northing ING	242293
Sea Bed Elevation (MSL)	-20.51

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Sandy	GRAVEL	0.00	1.26	250.12	125	MEDIUM DENSE to DENSE	34 N
Sandy	GRAVEL	1.26	3.86	250.09	125	MEDIUM DENSE to DENSE	34 N
Sandy Gravelly	CLAY	3.86	5.25	238.94	103	FIRM	26 N
Sandy Gravelly	CLAY	5.25	6.91	239.59	103	FIRM	26 N
		6.91					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
SNDST / SLTST	-27.42	3706	55	38	FAIR

S56

Chainage (m)	5546
Easting ING	329158
Northing ING	242293
Sea Bed Elevation (MSL)	-20.98

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Sandy	GRAVEL	0.00	2.04	172.93	48	LOOSE to MEDIUM DENSE	11 N
Sandy	GRAVEL	2.04	6.00	268.96	145	DENSE	41 N
Sandy Gravelly	CLAY	6.00	7.91	259.07	134	STIFF	30 N
		7.91					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
SNDST / SLTST	-28.89	3501	49	34	POOR

S57

Chainage (m)	5624
Easting ING	329236
Northing ING	242292
Sea Bed Elevation (MSL)	-21.37

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Sandy	GRAVEL	0.00	2.46	200.41	72	MEDIUM DENSE	17 N
Sandy	GRAVEL	2.46	6.75	268.80	145	DENSE	41 N
Sandy Gravelly	CLAY	6.75	9.50	269.44	145	STIFF	32 N
Sandy Gravelly	CLAY	9.50	12.59	253.47	128	FIRM to STIFF	29 N
		12.59					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
MUDST	-33.96	3122	39	27	POOR

S54

Chainage (m)	5693
Easting ING	329305
Northing ING	242292
Sea Bed Elevation (MSL)	-21.72

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Sandy	GRAVEL	0.00	1.44	260.50	136	DENSE	38 N
Sandy	GRAVEL	1.44	3.86	271.46	147	DENSE	42 N
Sandy Gravelly	CLAY	3.86	7.99	263.74	139	STIFF	31 N
		7.99					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
MUDST	-29.71	3184	41	28	POOR

S55

Chainage (m)	5772
Easting ING	329384
Northing ING	242291
Sea Bed Elevation (MSL)	-22.14

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness	SPT*
Sandy	GRAVEL	0.00	2.30	180.45	59	MEDIUM DENSE	12 N
Sandy	GRAVEL	2.30	3.43	199.03	71	MEDIUM DENSE	17 N
Sandy Gravelly	CLAY	3.43	6.00	265.78	141	STIFF	31 N
Sandy Gravelly	CLAY	6.00	8.77	324.75	211	STIFF to VERY STIFF	43 N
		8.77					

Bedrock

Type	Elevation MSL	Vp (m/s)	Litho RQD**	Relative RQD**	Quality
SNDST / SLTST	-30.90	3515	49	34	POOR

Chainage (m)	S44	5842
Easting ING		329454
Northing ING		242291
Sea Bed Elevation (MSL)		-22.50

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Sandy	GRAVEL	0.00	2.30	180.25	58		MEDIUM DENSE	12 N
Sandy	GRAVEL	2.30	3.89	192.58	67		MEDIUM DENSE	15 N
Silty	CLAY	3.89	7.07	323.63	209		STIFF to VERY STIFF	43 N
Sandy Gravelly	CLAY	7.07	9.82	323.63	209		STIFF to VERY STIFF	43 N
		9.82						

Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
SNDST / SLTST		-32.31		3779	57	40	FAIR	

Chainage (m)	S45	5919
Easting ING		329531
Northing ING		242290
Sea Bed Elevation (MSL)		-22.86

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Sandy	GRAVEL	0.00	2.90	216.85	85		MEDIUM DENSE	22 N
Sandy	GRAVEL	2.90	3.92	217.40	85		MEDIUM DENSE	22 N
Silty	CLAY	3.92	6.18	248.70	111		FIRM to STIFF	28 N
Silty	CLAY	6.18	7.86	287.12	165		STIFF	36 N
Sandy Gravelly	CLAY	7.86	12.08	279.88	157		STIFF	34 N
		12.08						

Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
SNDST / SLTST		-34.94		3693	55	38	FAIR	

Chainage (m)	S41	5957
Easting ING		329569
Northing ING		242290
Sea Bed Elevation (MSL)		-23.00

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Sandy	GRAVEL	0.00	1.12	250.10	125		MEDIUM DENSE to DENSE	34 N
Sandy	GRAVEL	1.12	2.90	237.72	102		MEDIUM DENSE	29 N
Sandy	GRAVEL	2.90	4.07	250.72	126		MEDIUM DENSE to DENSE	34 N
Silty	CLAY	4.07	6.82	261.67	137		STIFF	30 N
Silty	CLAY	6.82	8.80	263.10	138		STIFF	31 N
Sandy Gravelly	CLAY	8.80	11.77	237.94	102		FIRM	25 N
		11.77						

Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
SNDST / SLTST		-34.77		3356	45	31	POOR	

Chainage (m)	S40	6033
Easting ING		329645
Northing ING		242290
Sea Bed Elevation (MSL)		-23.15

Sediment

Type		Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)		Stiffness	SPT*
Sandy	GRAVEL	0.00	3.20	280.53	157		DENSE	46 N
Sandy	GRAVEL	3.20	4.20	285.83	163		DENSE	49 N
Silty	CLAY	4.20	7.37	244.53	108		FIRM to STIFF	27 N
Silty	CLAY	7.37	8.76	247.85	111		FIRM to STIFF	28 N
Sandy Gravelly	CLAY	8.76	10.44	253.58	129		FIRM to STIFF	29 N
		10.44						

Bedrock

Type		Elevation MSL		Vp (m/s)	Litho RQD**	Relative RQD**	Quality	
SNDST / SLTST		-33.59		4046	65	45	FAIR	

8. APPENDIX C: DETAILED METHODOLOGY

A combination of a number of geophysical techniques was used to provide the high quality interpretation and reduce any ambiguities, which may otherwise exist.

8.1 Multichannel Analysis of Surface Waves (MASW)

MASW profiling was carried out to provide information on overburden material stiffness or density.

8.1.1 Principles

The Multi-channel Analysis of Surface Waves (MASW) (Park et al., 1998, 1999) utilizes Surface waves (Rayleigh waves) to determine the elastic properties of the shallow subsurface (<15m). Surface waves carry up to two/thirds of the seismic energy but are usually considered as noise in conventional body wave reflection and refraction seismic surveys.

The penetration depth of surface waves changes with wavelength, i.e. longer wavelengths penetrate deeper. When the elastic properties of near surface materials vary with depth, surface waves then become dispersive, i.e. propagation velocity changes with frequency. The propagation (or phase) velocity is determined by the average elastic property of the medium within the penetration depth. Therefore the dispersive nature of surface waves may be used to investigate changes in elastic properties of the shallow subsurface.

The MASW method employs the multi-channel recording and processing techniques (Sheriff and Geldart, 1982) that have similarities to those used in a seismic reflection survey and which allow better waveform analysis and noise elimination. To produce a shear wave velocity (Vs) profile and a stiffness profile of the subsurface using Surface waves the following basic procedure is followed:

(i)A point source (eg. An airgun) is used to generate vertical ground motions,

(ii)The ground motions are measured using low frequency hydrophones, which are disposed along a straight line directed toward the source,

(iii)The ground motions are recorded using either a conventional seismograph, oscilloscope or spectrum analyzer,

(iv)A dispersion curve is produced from a spectral analysis of the data showing the variation of Surface wave velocity with wavelength,

(v)The dispersion curve is inverted using a modeling and least squares minimization process to produce a subsurface profile of the variation of Surface wave and shear wave velocity with depth.

8.1.2 Data Collection

The recording equipment consisted of a Geode 24 channel digital seismograph, 24 no. hydrophones, an airgun source with radio trigger and a 24 take-out cable.

8.1.3 Data Processing

MASW processing was carried out using the SURFSEIS processing package developed by Kansas Geological Survey (KGS, 2000). SURFSEIS is designed to generate a shear wave (Vs) veolocity profile.

SURFSEIS data processing involves three steps:

(i) Preparation of the acquired multichannel record. This involves converting data file into the processing format.

(ii) Production of a dispersion curve from a spectral analysis of the data showing the variation of Raleigh wave phase velocity with wavelength. Confidence in the dispersion curve can be estimated through a measure of signal to noise ratio (S/N), which is obtained from a coherency analysis. Noise includes both body waves and higher mode surface waves. To obtain an accurate dispersion curve the spectral content and phase velocity characteristics are examined through an overtone analysis of the data.

(iii) Inversion of the dispersion curve is then carried out to produce a subsurface profile of the variation of shear wave velocity with depth.

(iv) The shear wave velocities were then converted into shear modulus values using the formula:

$$G = V_s^2 * \rho / 1000000$$

Where			
	G	=	Shear Modulus (MPa)
	V_s	=	Shear Wave Velocity (m/s)
	ρ	=	Density (kg/m^3)

8.1.4 Relocation

All profiles were surveyed to Irish National Grid using a GEO7X VRS system.

8.2 Sub Bottom Profiler

The sub bottom profiler survey utilised the single channel seismic reflection method to provide information on the stratigraphy of the sedimentary units and to determine the morphology of the bedrock.

8.2.1 Principles

The seismic surveying methodology consists of using a source to generate seismic waves and measuring the time required for the energy to travel from the source to a series of data receivers (geophones or hydrophones). The time taken by the energy to travel to the receivers (travel times) and the velocity of the waves can be used to reconstruct the pathways of the seismic waves and determine structural information of the sub surface lithological boundaries.

The single channel seismic reflection sparker method utilises a single hydrophone group and an electrical source to generate a real time continuous profile of the sub surface. The real time section allows for the imaging, identification and interpretation of sediment layering and the top of bedrock profile. The sparker source uses the discharge of a capacitor to create a spark between electrodes located within the water column. The sparker source and the hydrophone cable are both towed behind, or slightly offset from, the acquisition vessel. The source and receiver are both towed in the water column rather than on the seabed and there is a lateral offset between source and receiver.

8.2.2 Data Collection

The recording equipment used a Geo Marine Survey Systems Geo-Source 200 Light Weight Sparker system. The source equipment consisted of a Geo-Spark pulsed power supply (set to 300 Joules), a high voltage cable connecting to the 200 tip sparker unit. The receiver equipment consisted of a Geo-Sense mini streamer with an 8 element hydrophone array with an active length of 2.8m. The survey was conducted using a Mini-Trace II acquisition system under laptop control. Data was acquired in SEG-Y standard format for later office based processing and analysis.

8.2.3 Data Processing

The processing of the sub bottom profiler data was carried out using proprietary processing software (ReflexW V.6.05)

The following processing was applied to the data:

- ✓ SEG-Y data importation and conversion to internal format
- ✓ Spatial relocation (data merge with surveyed positions)
- ✓ 2D data filtering (running average)
- ✓ Swell and noise attenuation (correct max. Phase, time independent static correction , time dependent dynamic correction)
- ✓ Amplitude recovery gain (time dependant gain)
- ✓ Display optimisation
- ✓ Interpretation of sediment and bedrock layers using automated negative phase tracker
- ✓ Conversion of picked data to depth domain based on conversion velocity of 1700m/s

The interpreted layer boundaries were converted to the depth domain based on a conversion velocity of 1700m/s. This velocity was chosen as it representative of typical sediment layers.

8.2.4 Relocation

The sub bottom profiler data was acquired using a system integrated with the ships on board dGPS navigation system. The data was acquired in latitude / longitude and was later converted to Irish National Grid coordinates for display and visualisation purposes.

8.3 Seismic refraction profiling

8.3.1 Principles

This method measures the velocity of refracted seismic waves through the overburden and rock material and allows an assessment of the thickness and quality of the materials present to be made. Stiffer and stronger materials usually have higher seismic velocities while soft, loose or fractured materials have lower velocities. In the marine environment the sediment velocities are generally not determined as they are masked by water velocity.

Seismic profiling measures the p-wave velocity (Vp) of refracted seismic waves through the overburden and rock material and in the marine environment allows an assessment of the bedrock quality to be made. Readings are taken using hydphones connected via multi-core cable to a seismograph.

8.3.2 Data Collection

A Geode high resolution 24 channel digital seismograph, 24 hydrophones and an airgun source with radio trigger were used to provide first break information, with a 24 take-out cable with a nominal spacing of 2.95m. The source equipment was deployed from a dedicated source vessel and the recording equipment was operated from a larger command boat.

Readings are taken using geophones connected via multi-core cable to a seismograph. The depth of resolution of bedrock boundaries is determined by the length of the seismic spread, typically the depth of resolution is about one third the length of the profile.(eg. 69m profile ~23m depth.

8.3.3 Data Processing

First break picking in digital format was carried out using the FIRSTPIX software program to construct p-wave (Vp) traveltime plots for each spread. Velocity phases were selected from these plots using the GREMIX software program and were used to calculate the thickness of individual velocity units. Material types were assigned to bedrock lithologies.

Approximate errors for Vp velocities are estimated to be +/- 10%. Possible errors due to the "hidden layer" and "velocity inversion" effects may also occur (Soske, 1959).

8.3.4 Relocation

All profiles were surveyed to Irish National Grid using a GEO7X VRS system.