Appendix 14.6

Report on the Geophysical Investigation

AGL16077_01

Report on the Geophysical Investigation For The Marine Outfall Pipeline, Arklow Waste Water Treatment Plant For Byrne Looby Arup

05th May 2017

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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.

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AUTHOR	**CHECKED**	**REPORT STATUS**	**DATE**
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CONTENTS

1. EXECUTIVE SUMMARY

APEX Geoservices Limited was requested by Byrne Looby Arup on behalf of Irish Water to carry out a geophysical investigation as part of a ground investigation for a proposed outfall pipeline for the Arklow Waste Water Treatment Plant.

The marine area under investigation is located offshore Arklow, Co. Wicklow and covers approximately 75Ha. Data was acquired from the shoreline to c. 1.5Km offshore.

The marine investigation consisted of underwater multichannel analysis of surface waves (UMASW), sub bottom profiler single channel seismic reflection and seismic refraction surveys.

The objectives of the investigation were to map the type and thickness of the sediment layers, determine sediment stiffness, map the depth to bedrock, map variation in bedrock 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 area under investigation is generally characterised by unconsolidated sediments over glacial till of variable thickness overlying undulating bedrock.

Three sediment layers were defined by the geophysical datasets with layers 1 and 2 consisting of very soft / very loose to firm / medium dense non consolidated sediments overlying firm – very stiff / medium dense – very dense sediment of layer 3. Layer 3 is interpreted as a glacial till unit.

These sediment layers have thickness ranges of < 0.5m to c. 5.5m, c. 1 – 3.5m and c. 1.5m - > 10m respectively.

The depth to the base of sediment / top of bedrock varies across the survey area from c. 7.0m - > 12.5m. The sediment thickness / depth to bedrock undulates from west to east with both ridges and channels present in the top of rock. These features are in general alignment with the regional fault pattern shown on the GSI database.

Recommendations are given for confirmatory boreholes across the site. Proposed borehole locations are given in Irish National Grid (ING) coordinates.

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

2. INTRODUCTION

APEX Geoservices Limited was requested by Byrne Looby Arup on behalf of Irish Water to carry out a geophysical investigation as part of a ground investigation for a proposed outfall pipeline for the Arklow Waste Water Treatment Plant (WwTP). The investigation consisted of sub bottom profiler single channel seismic reflection, underwater multichannel analysis of surface waves (UMASW) and seismic refraction surveys.

The investigation involved the acquisition of data over an area covering the client area of interest of c. 10.6 Ha and an additional fringe to the south, east and north to give a total coverage of c. 75 Ha.

During the initial period of data acquisition the client area of interest was altered due to the presence of a power cable in the southern part of the area.

2.1 Survey Objectives

The objectives of the investigation were to:

- 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

2.2 Site Background

The survey area is located to the north of the north pier in Arklow port. The area of interest has a shoreline frontage of c. 250m immediately east of a derelict factory near the pier. The client supplied location of the proposed diffuser head lies c. 900m offshore.

The location of the geophysical investigation area is shown in Figs. 2.1 and 2.2. Figure 2.2 shows the survey profile layout referenced to local chainages used for the project. The survey layout referenced to chainage and Irish National Grid (ING) is shown in more detail in **Appendix A: Drawings**.

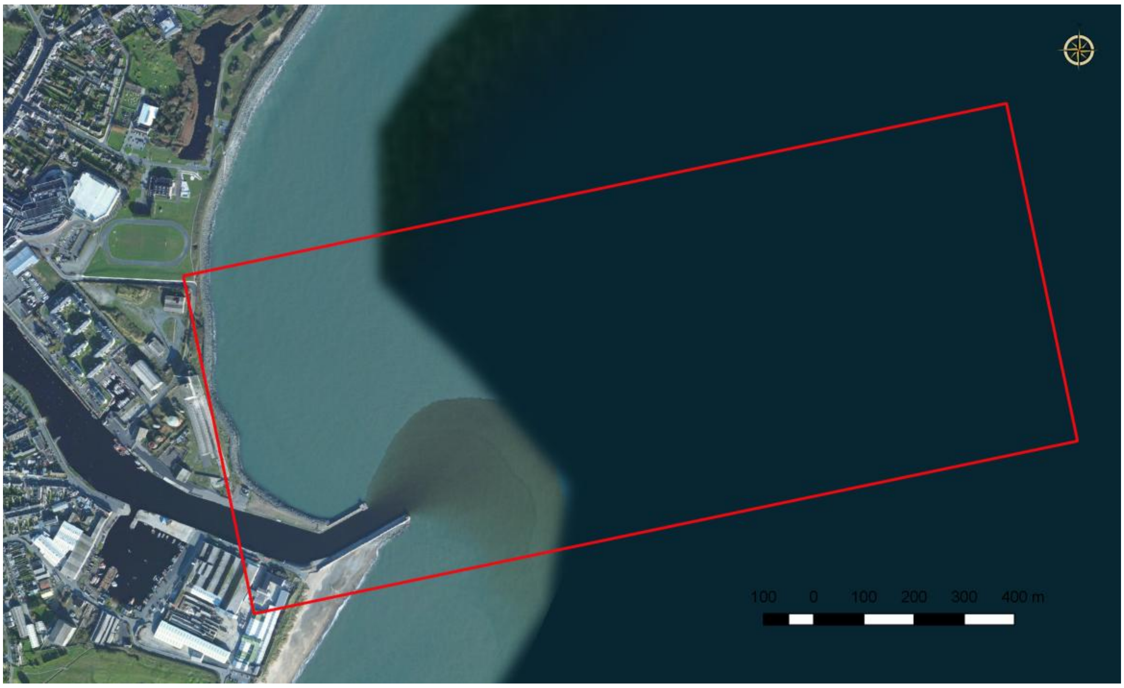

Fig 2.1: Location map showing generalised survey area outlined in red.

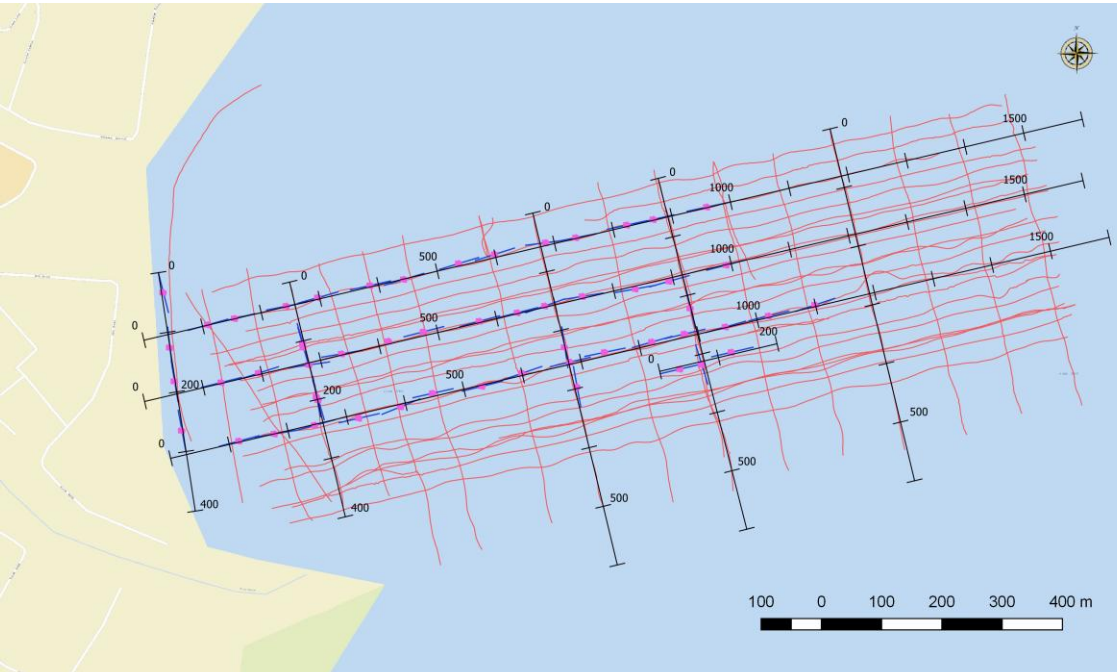

Fig 2.2: Location map showing acquired survey profiles in red, blue and magenta with chainage.

2.2.1 Geology

The GSI terrestrial bedrock geology map (Fig. 2.3) shows the area around the town of Arklow and close to the port is underlain by two formations of Ordovician lithologies of the Paleozoic. The town centre, including areas along the north and south banks of the Avoca River are dominated by the Kilmacrea Formation which consists of dark grey slate, shale, minor pale sandstone and some tuffaceous horizons. Close to the mouth of the river and on the north and south banks the bedrock map shows the Maulin Formation is present. This is described as blue – grey slate, phyllite with siltsone laminae and schist.

The contact between the Kilmacrea and Maulin Formations is unconformable and is shown on the map as a northeast – southwest faulted contact. This fault is shown as continuing offshore to the north. A north- south oriented fault is shown to lie east of the mouth of the river and numerous northeast – southwest oriented faults are shown in the country to the south of Arklow.

The GSI marine bedrock geology map (Fig. 2.4) shows the survey area is underlain by Lower Paleozoic metasedimentary lithologies.

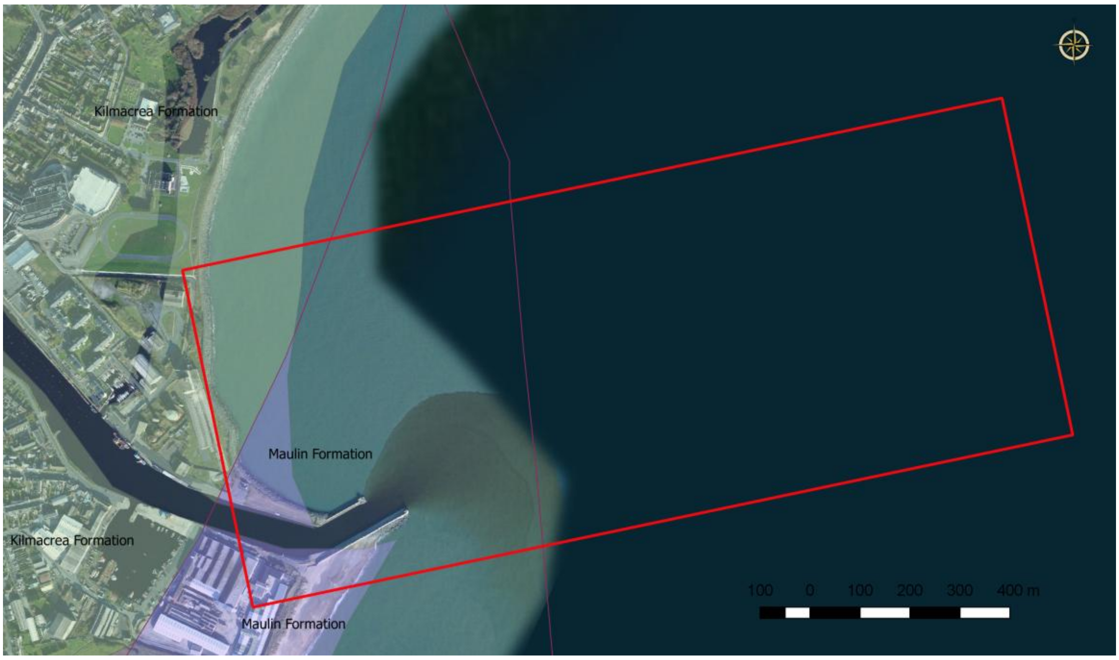

Fig. 2.3: The GSI bedrock map for the Arklow area with faults shown by purple lines.

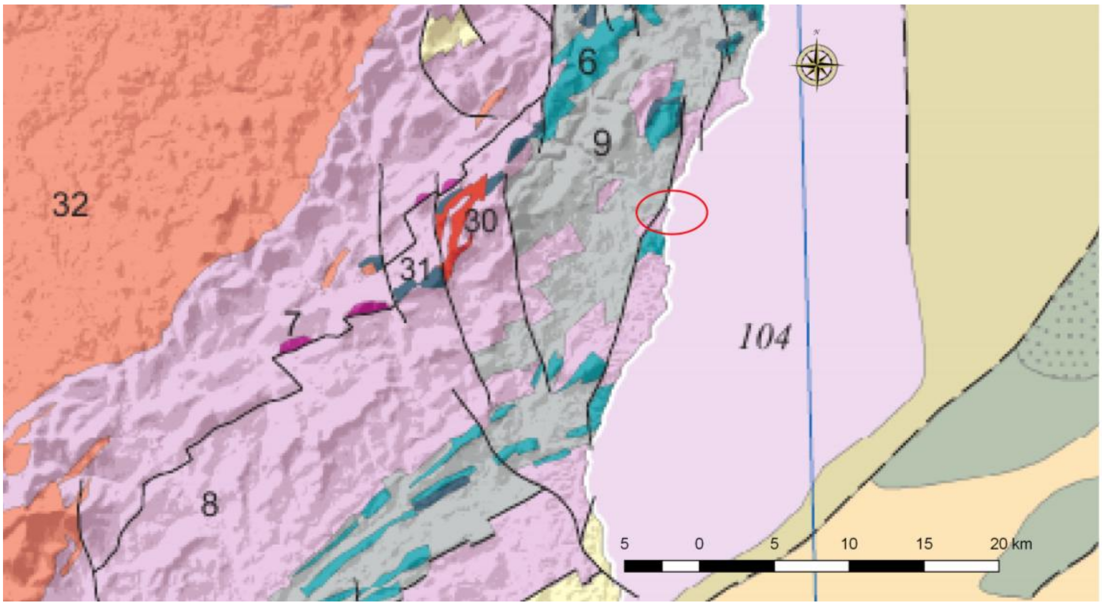

Fig. 2.4: The GSI Marine geology map (survey area highlighted in red). Bedrock type 104, described as metasedimentary rocks, underlies the area.

2.2.2 Quaternary

The GSI Quaternary map for the Arklow area (Fig. 2.5) describes 'urban sediment' across the town with alluvium further west to the north and south of the river. To the north Irish Sea Till derived from Lower Palaeozoic sandstone and shales is described with southerly and southwesterly oriented meltwater channels also shown.

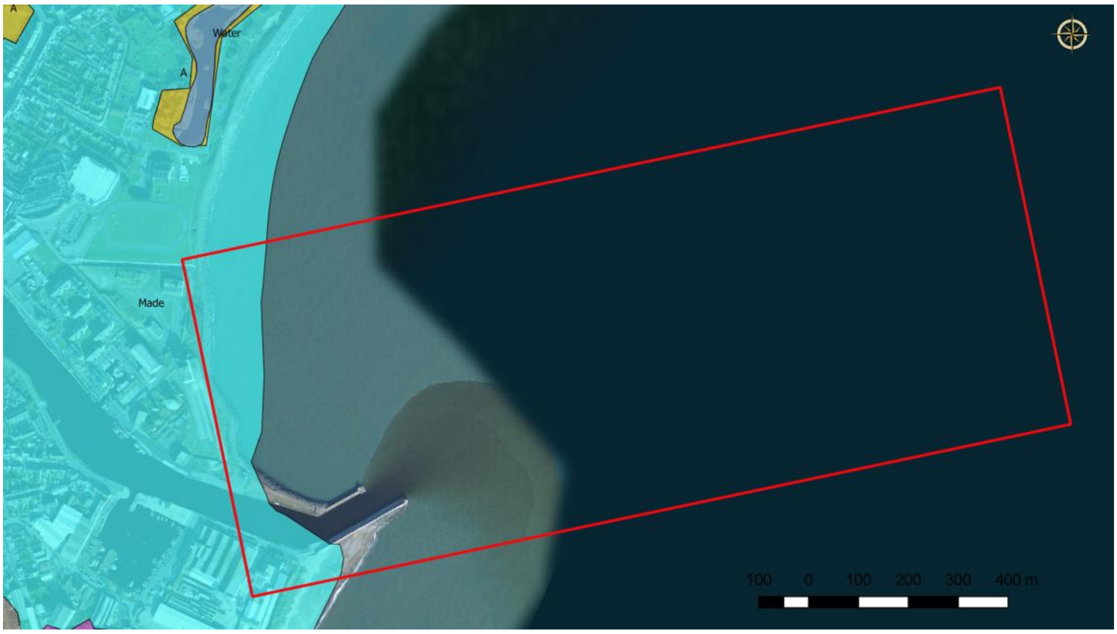

Fig 2.5: The GSI Quaternary map for the Arklow area.

2.2.3 Direct Investigation Data

No direct investigation data was supplied by the client for this investigation.

2.3 Survey Rationale

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

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 **UMASW** method is used to estimate shear-wave (S-wave) velocities in the sediment material. These velocities are derived from analysis of Scholte wave dispersion curves. The UMASW 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). The data may also give an indication of depth to top of weathered rock.

Seismic Refraction Profiling in the marine environment measures the velocity of refracted seismic P-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.

3. RESULTS

The marine geophysical investigation was carried out over a number of work sessions between the 06th and the 16th March 2017 and involved the acquisition of sub bottom profiler data, Underwater Multi-Channel Analysis of Surface Wave (UMASW) and seismic refraction.

The results of the investigation are displayed in **Appendix A: Drawings**. Data is displayed referenced to local chainage and Irish National Grid (ING).

In the sub bottom profiler investigation a total of fifty eight datasets were acquired along sixteen inlines, which were generally acquired with a southwest to northeast orientation, and eighteen crosslines generally acquired with a northwest to southeast orientation. The inlines were generally acquired to within c. 120 – 170m of the shore due to shallow water conditions, the turning circle of the survey vessel and the length of the source and hydrophone receiver array. It was practical to sail crosslines to within c. 50m of the shoreline.

A total of fifty five seismic refraction spreads and 1D UMASW soundings were acquired across the area under investigation. These were generally positioned on four of the sub bottom profiler inlines and on four of the crosslines. These were located to give good spatial coverage and to tie in with the expected positions of the diffuser head and future client specified borehole locations. While the spacing of the spreads was generally regular there is some variation in the gaps or areas of overlap between adjacent spreads. This was due to slight movement of anchor blocks and the hydrophone cable while deploying from the deck of the survey vessels in fast tidal conditions. In one part of the survey area four tightly spaced overlapping spreads were recorded over two work sessions as a quality control and data repeatability check. Spreads were acquired to within c. 30m of the shoreline. Acquisition closer to the shoreline was not possible due to shallow water, strong currents and a rocky bottom associated with the sea defences.

No UMASW or seismic refraction data was acquired across an exclusion zone, centred on the cable route close to the north pier wall.

3.1 Sub Bottom Profiler

In the sub bottom profiler investigation the sixteen inlines had a nominal line spacing of c. 25m while the eighteen crosslines were generally acquired with a line spacing of 100m. The data acquisition rate along each profile was generally 0.5 seconds, equating to data points every c. 1.15m. Other acquisition rates were trialled during pre production parameterisation testing. Data acquisition was to 100mS, which resulted in a maximum depth of c. 88m below the seabed. The vessel speed during acquisition was generally 2 - 3 knots. The profiles extended to c. 1.5km from the shoreline to give additional background information beyond the area of the proposed diffuser head.

The overall sub bottom profiler data quality was good with some reduction in primary data imaging in shallow water close to the shoreline where a strong seabed multiple was present in the data. A multiple occurs when the seismic signal reverberates or bounces between the seabed and the surface.

In shallow water it has the effect of masking real reflections from beneath the seabed. This effect was minimised by acquiring multiple datasets during high and low tide. On one of the northwest – southeast oriented shoreline sideswipe data from the sea defences obscured the likely top of rock boundary imaging.

The data results show a number of defined layers within the sediment units and the likely top of rock. Up to six distinctive layers were interpreted within the uppermost 30ms of the data where a high reflectivity contrast across a layer boundary indicates a change in the material properties. The two shallowest layers, layers 1 and 2, were interpreted as non consolidated sediments with some internal layering visible in the data. Layer 3 was interpreted as likely glacial till. The deepest layer interpreted across the survey area represents the base of till / likely top of rock. The sub bottom profiler single channel seismic reflection data does not yield intra bedrock imaging.

Examples of four sub bottom profiler sections and the interpreted layer boundaries are shown in **Appendix A: Drawing No.s AGL15077_03 – 06.**

3.2 UMASW

Each marine spread was c. 67.85m in length with 24 hydrophones and a hydrophone spacing of 2.95m. Each spread resulted in the acquisition of a 1D UMASW sounding situated at the centre of the refraction spread. The overall data quality was good.

The spread and 1D sounding locations are shown in **Appendix A: Drawing No. AGL15077_01**.

The shear wave (S-wave) velocities ranged from 94m/s – 582m/s over a depth range of 0 – 15m. Values > 428m/s were generally recorded at the top of rock. Data for the sediment layers has been generally interpreted on the following basis:

Layer	***S-Wave Seismic Velocity (m/s)***	***Interpretation***	***Stiffness/Rock Quality***
1	94 - 125	unconsolidated sediments	Very Soft /Very Loose
2	125 - 175	unconsolidated sediments	Soft /Loose
3	175 - 250	unconsolidated sediments / Till	Firm / Medium Dense
4	250 - 300	Sediments / Till	Dense
5	250 - 350	Sediments / Till	Stiff
6	350 - 428	Sediments / Till	Very Stiff / Very Dense

The following table shows shear wave velocity (m/s) and related material type for cohesive and granular sediments / soils. The table also shows typical velocities for weathered – fresh bedrock. The data for offshore Arklow showed top of completely – highly weathered bedrock velocities in the range274 – 582m/s. No values are returned beneath top of weathered rock.

The results of the UMASW investigation are shown in more detail in **Appendix B: Tabular Data with Engineering Parameters.**

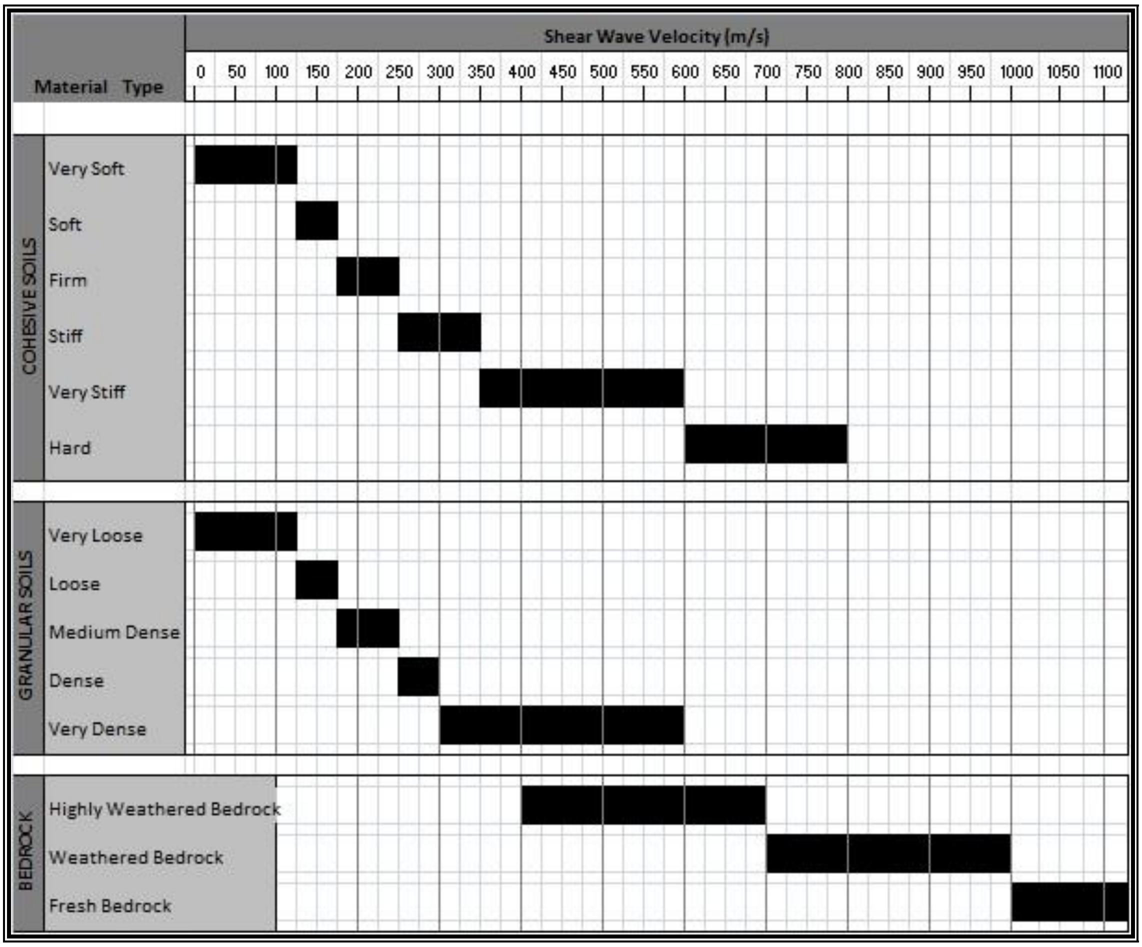

Fig.3.1. Shear-wave velocity and corresponding sediment cohesion.

3.3 Seismic Refraction Profiling

The locations of the P-wave (Vp) seismic refraction spreads are shown in **Appendix A: Drawing No. AGL15077_01**. The overall data quality was good.

The results of the seismic refraction survey were used to determine bedrock information. The bedrock velocities vary across the site from 2283 – 6587m/s with the majority of velocities ranging 2738 - 5729 The interpolated bedrock velocity model is displayed in **Appendix A Drawing No.s AGL16077_03 -06**. The data is displayed to 2m below the top of rock. The Vp velocity data for bedrock has generally been interpreted on the following basis using a calculated RQD based on a laboratory bedrock velocity of 6,000m/s (see **Appendix B**):

Layer	*P-Wave Seismic Velocity (m/s)*	*Interpretation*	*Rock Quality*	*Excavatibility*
1	2283 - 4242	Metasediment Bedrock	Very Poor - Fair	Break / Blast
2	4243 - 5692	Metasediment Bedrock	Fair - Good	Break / Blast
3	>5692	Metasediment Bedrock	Excellent	Break / Blast

Weathered rock, as indicated by reduced Vp values and by shear wave velocities, may be present at the top of the bedrock layer.

The results of the seismic refraction investigation are shown in more detail in **Appendix B: Tabular Data with Engineering Parameters.**

4. DISCUSSION

The area under investigation offshore Arklow is generally characterised by unconsolidated sediments over glacial till of variable thickness overlying undulating bedrock.

4.1 Sedimentary Layers

Three sediment layers were defined by the geophysical datsets with layers 1 and 2 consisting of nonsolidated sediments with low shear wave velocities. These two layers have shear wave velocities in the range 94 – 250m/s and are interpreted as very soft / very loose to firm / medium dense.

Layer 1 is present from the coastline to c. 1km offshore and ranges in thickness from < 0.5m to c. 5.5m. The sub bottom profiler indicates some lamination at the base of this layer at the contact with the underlying layer 2.

Layer 2 is present across the surveyed area and thickens to the east. It is c. 1 – 3.5m thick within 1km of the shore but increases to > 6.5m thick to the east, where layer 1 is not present.

Layer 3, with shear wave velocities in the range 175 – 428m/s, is the deepest sediment layer and is interpreted as glacial till. This is a firm – very stiff / medium dense – very dense layer ranging in thickness from c. 1.5m - > 10m. The data indicates this unit is thinnest in the west and east with a thicker zone, oriented northwest – southeast, present across the central part of the site. Channel features cut into the top of this unit are interpreted from the sub bottom profiler data and are seen in **Appendix A: Drawing No. AGL16077_03 – 06.**

Thickness plots for the three individual sediment units are displayed in **Appendix A: Drawing No. AGL16077_02** and the combined thickness of the units is displayed in **Appendix A: Drawing No. AGL16077_01.**

4.2 Bedrock

The depth to the top of bedrock (see **Appendix A: Drawing No. AGL16077_01)** varies across the survey area from c. 7.0m - > 12.5m. The sediment thickness / depth to bedrock map shows the top of rock is undulating from west to east with both shallow and deep rock present on the southern boundary of the client zone of interest. The data indicates a series of southeast – northwest oriented ridges and channels in the top of rock.

The channels in the top of rock are coincident with thicker sediment infill but may also relate to the regional faulting. The GSI database shows northeast - southwest and northwest – southeast faults in area (see Figs. 2.4 and 2.5 above).

The seismic velocities for the bedrock range from 2283 – 6585m/s and indicate bedrock quality ranges from very poor – excellent. Bedrock velocities are also shown in map view in **Appendix A: Drawing No. AGL16077_02** and correlate well with the bedrock channels and ridges and localised variation in sediment shear wave velocity.

Elevation maps for seabed and bedrock, referenced to Lowest Astronomical Tide (LAT), are displayed in **Appendix A: Drawing No. AGL16077_01.** These maps were generated using interpolation between the acquired data points and show interpolated bedrock elevation varies from c. -13m in the west to -22m in the east.

NOTE: Elevation maps were produced following a time to depth conversion of the sub bottom profiler data. No Bathymetric survey was undertaken across the full extent of the sub bottom profiler investigation.

Variation in bedrock should be investigated further by borehole drilling.

5. RECOMMDATIONS

A number of boreholes are recommended across the site to investigate variations in the overburden and confirm bedrock depth and type.

Proposed Borehole	*ING Easting*	*IING Northing*	*Target Depth*
PBH1	325399	173302	15m
PBH2	325742	173430	10m
PBH3	326424	173489	10m
PBH4	325786	173234	10m
PBH5	325939	173309	15m
PBH6	326127	173314	10m
PBH7	326284	173352	10m
PBH8	326026	173177	15m

The findings of the geophysical investigation should be reviewed upon completion of intrusive ground investigations.

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7. APPENDIX A: DRAWINGS

The information derived from the geophysical investigation is presented in the following drawings:

AGL15077_01

Fig.1	Geophysical Investigation Location Map	Scale 1:5000 @ A1
Fig.2	Seabed Elevation Map in Lowest Astronomical Tide (LAT)	Scale 1:5000 @ A1
Fig.3	Total Sediment Thickness Map	Scale 1:5000 @ A1
Fig.4	Bedrock Elevation Map (LAT)	Scale 1:5000 @ A1

AGL15060_02

Fig.1	Geophysical Investigation Location Map	Scale 1:5000 @ A1
Fig.2	Thickness of Nonconsolidated Sediment – Layer 1	Scale 1:5000 @ A1
Fig.3	Thickness of Nonconsolidated Sediment – Layer 2	Scale 1:5000 @ A1
Fig.4	Thickness of Overburden / Till – Layer 3	Scale 1:5000 @ A1

AGL15060_03

Fig.1	Bedrock Vp Velocity Map	Scale 1:5000 @ A1
Fig.2	Line 33 Cross Section – Sub Bottom Profiler & Structural Interp.	Scale 1:5000 @ A1
Fig.3	Line 33 Cross Section – Sediment Vs Velocity	Scale 1:5000 @ A1
Fig.4	Line 33 Cross Section – Bedrock Vp Velocity	Scale 1:5000 @ A1
Fig.5	Line 33 Cross Section - Interpretation	Scale 1:5000 @ A1

AGL15060_04

Fig.1	Bedrock Vp Velocity Map	Scale 1:5000 @ A1
Fig.2	Line 03B Cross Section – Sub Bottom Profiler & Structural Interp.	Scale 1:5000 @ A1
Fig.3	Line 03B Cross Section – Sediment Vs Velocity	Scale 1:5000 @ A1
Fig.4	Line 03B Cross Section – Bedrock Vp Velocity	Scale 1:5000 @ A1
Fig.5	Line 03B Cross Section - Interpretation	Scale 1:5000 @ A1

AGL15060_05

Fig.1	Bedrock Vp Velocity Map	Scale 1:5000 @ A1
Fig.2	Line 07 Cross Section – Sub Bottom Profiler & Structural Interp.	Scale 1:5000 @ A1
Fig.3	Line 07 Cross Section – Sediment Vs Velocity	Scale 1:5000 @ A1
Fig.4	Line 07 Cross Section – Bedrock Vp Velocity	Scale 1:5000 @ A1
Fig.5	Line 07 Cross Section - Interpretation	Scale 1:5000 @ A1

AGL15060_06

Fig.1	Bedrock Vp Velocity Map	Scale 1:5000 @ A1
Fig.2	Line 36B Cross Section – Sub Bottom Profiler & Structural Interp.	Scale 1:5000 @ A1
Fig.3	Line 36B Cross Section – Sediment Vs Velocity	Scale 1:5000 @ A1
Fig.4	Line 36B Cross Section – Bedrock Vp Velocity	Scale 1:5000 @ A1
Fig.5	Line 36B Cross Section - Interpretation	Scale 1:5000 @ A1

FIGURE 1: Geophysical Investigation Location Map
Scale 1:5000

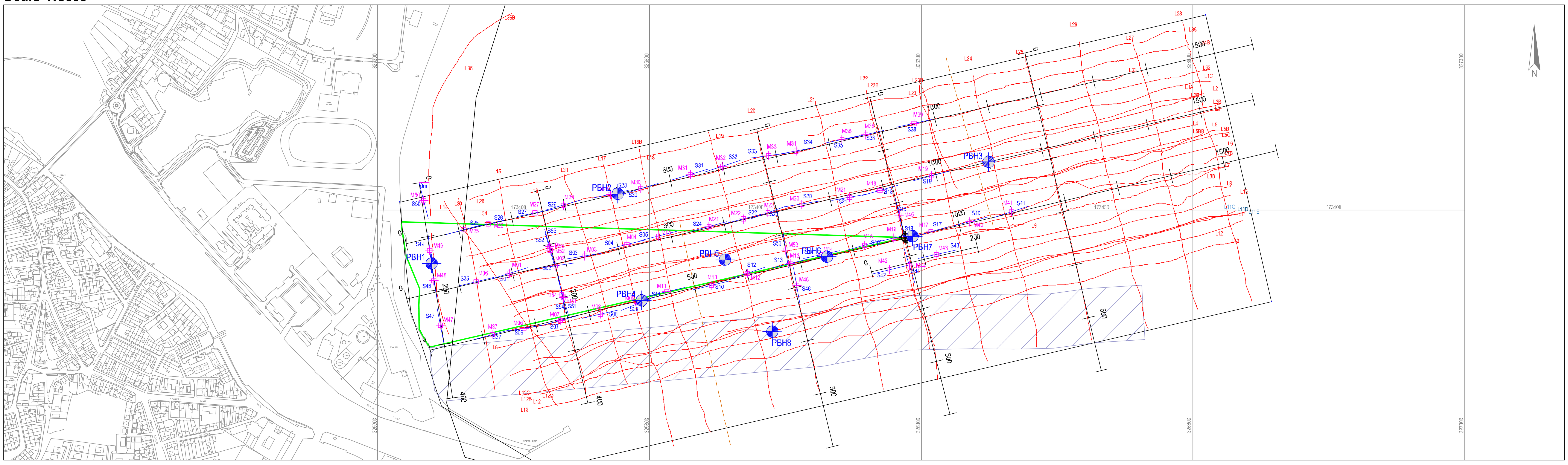


FIGURE 2: Seabed Elevation Map in Lowest Astronomical Tide (LAT)
Scale 1:5000

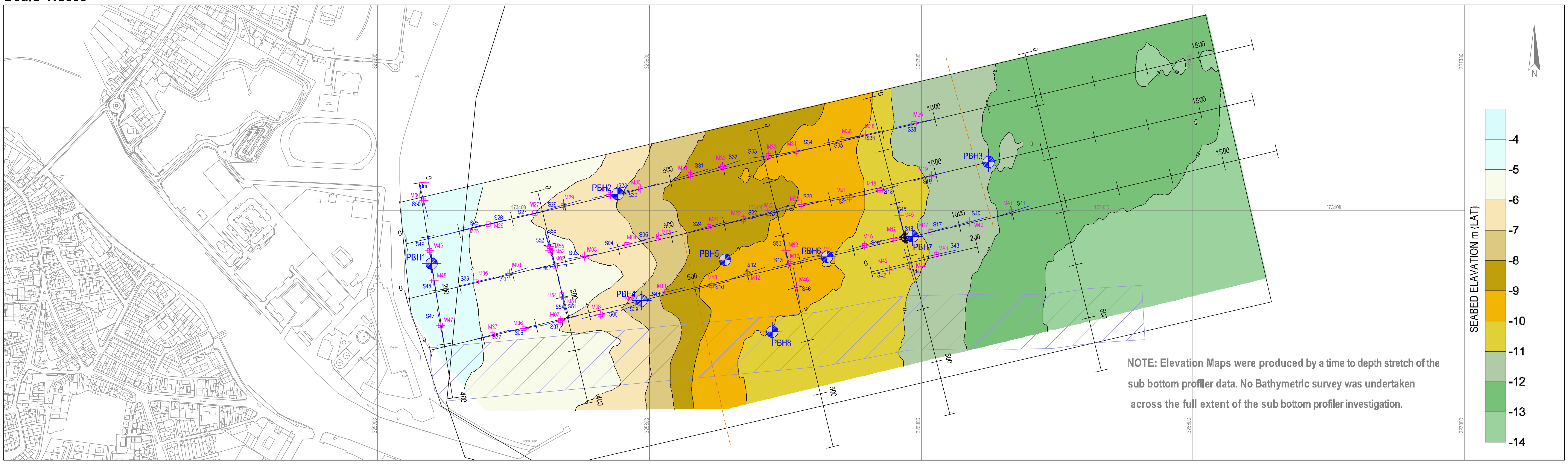


FIGURE 3: Total Sediment Thickness Map
Scale 1:5000

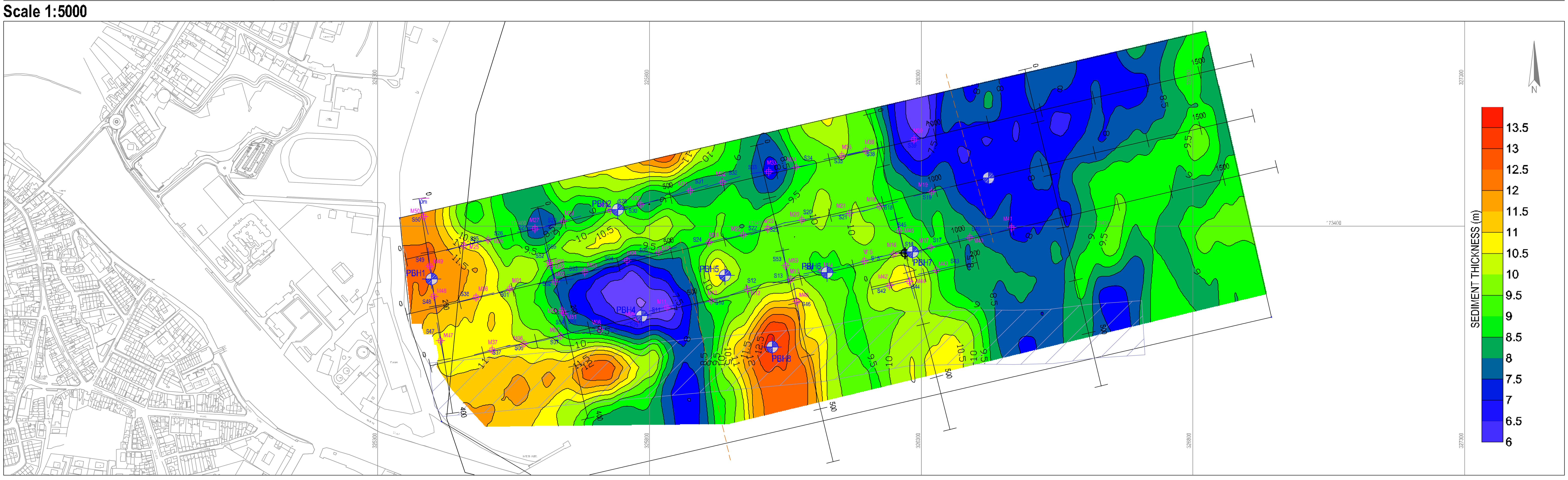
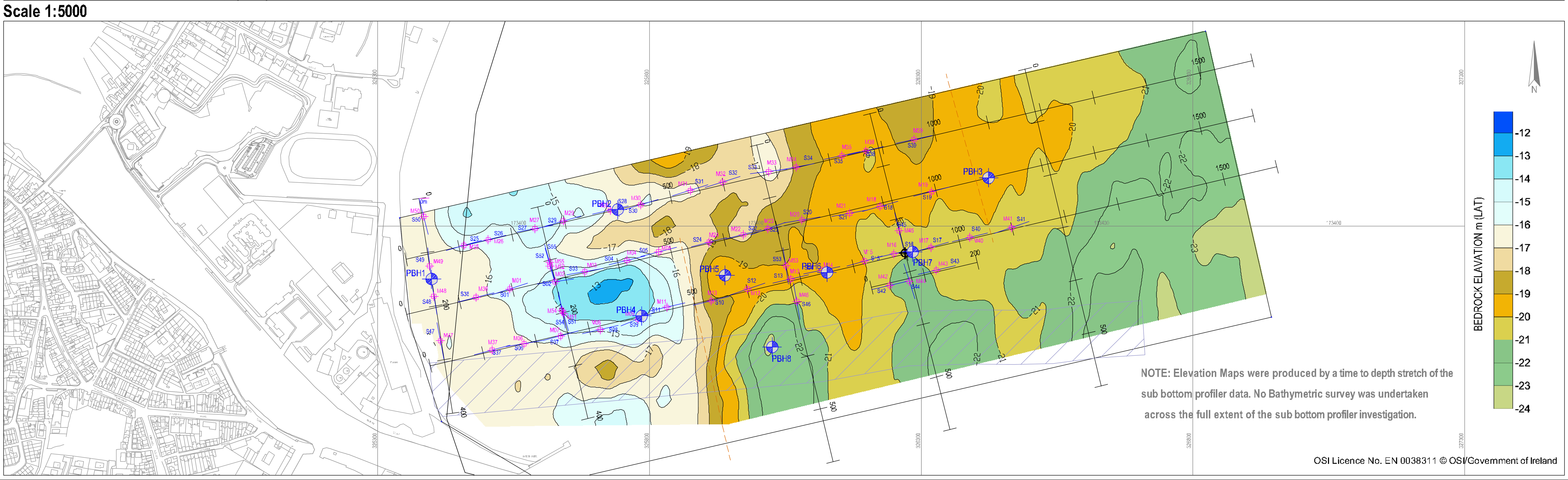
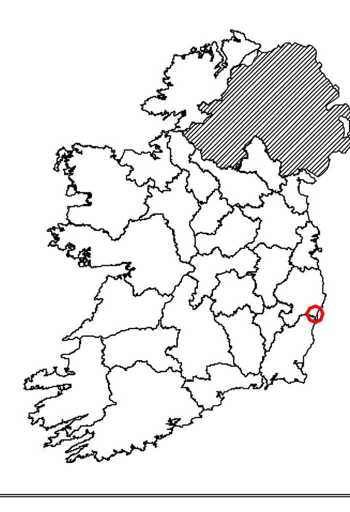


FIGURE 4: Bedrock Elevation Map (LAT)
Scale 1:5000



INDEX MAP:



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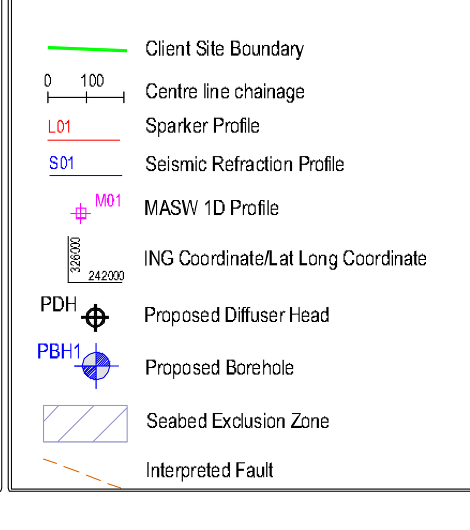

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CLIENT:	BYRNE LOOBY ARUP
DRAWING NUMBER:	AGL16077_01
SCALE:	1:5000 @ A1
DATE:	05/05/2017
NOTES:	The information displayed here is to be used in conjunction with Report AGL16077 Report on the Geophysical Investigation at the Marine Outfall Pipeline, Arklow WwTP for Byrne Looby Arup. APEX Geoservices Ltd. 05th May 2017.
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FIGURE 1: Geophysical Investigation Location Map

Scale 1:5000

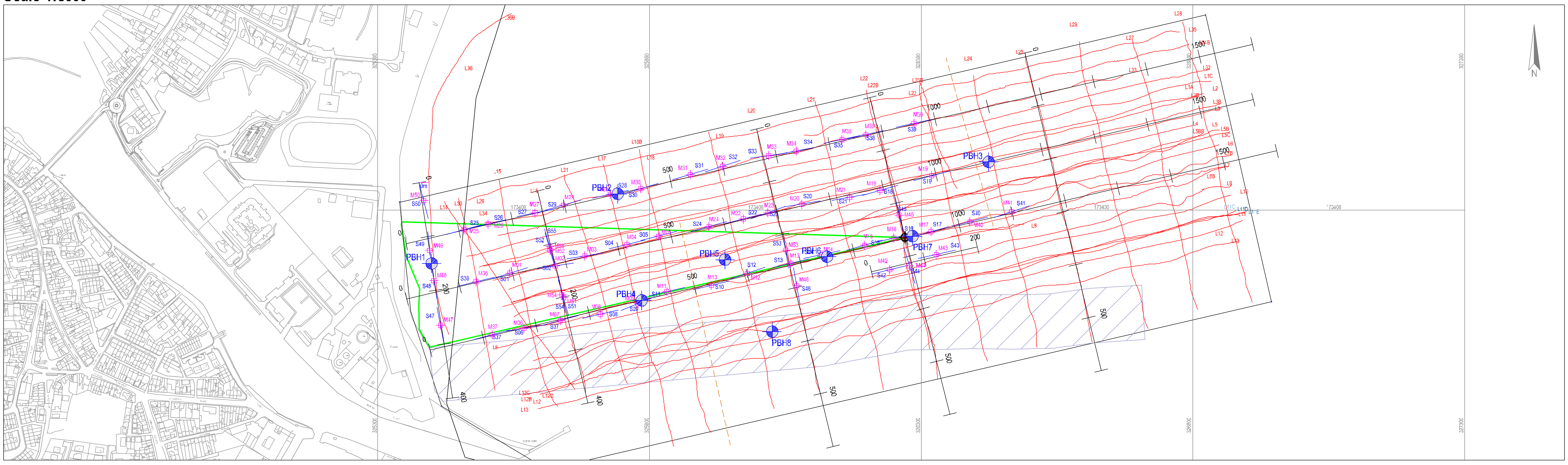


FIGURE 2: Thickness of Noncosolidated Sediment - Layer 1

Scale 1:5000

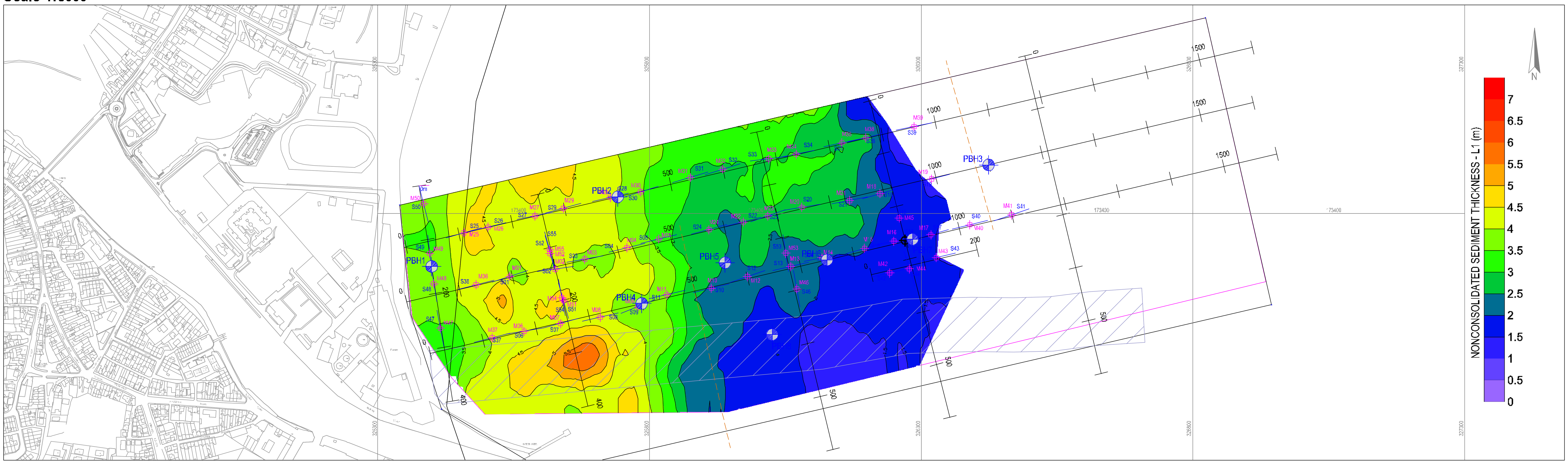


FIGURE 3: Thickness of Noncosolidated Sediment- Layer 2

Scale 1:5000

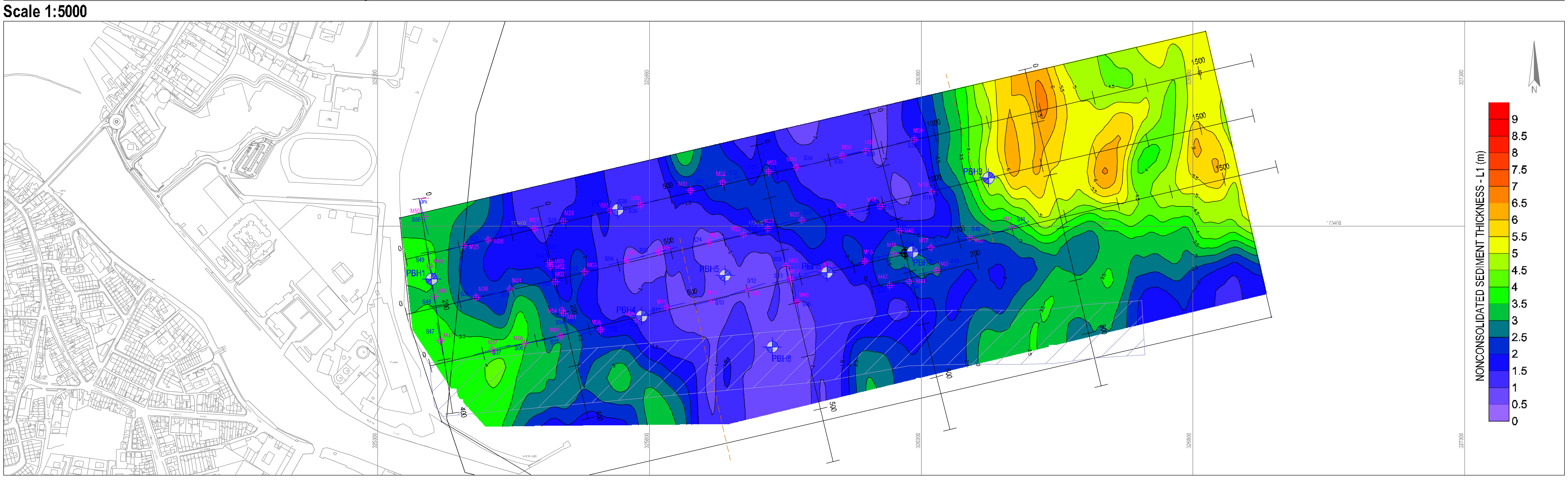
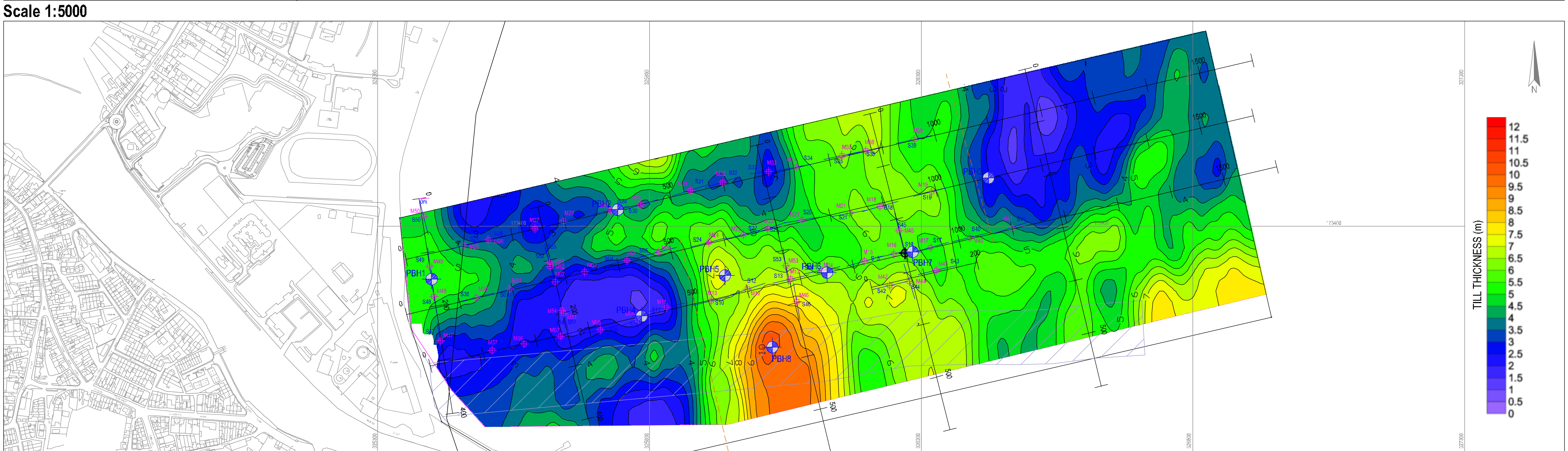
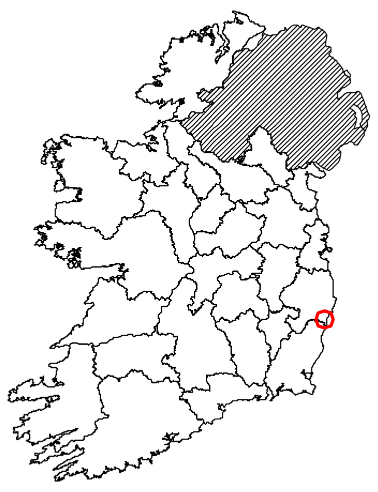


FIGURE 4: Thickness of Sediment / Till - Layer 3

Scale 1:5000



INDEX MAP:



LEGEND:

- Client Site Boundary
- 0 100 Centre line chainage
- L01 Sparker Profile
- S01 Seismic Refraction Profile
- M01 MASW 1D Profile
- 326000 242000 ING Coordinate/Lat Long Coordinate
- PDH Proposed Diffuser Head
- PBH1 Proposed Borehole
- Seabed Exclusion Zone
- Interpreted Fault

PROJECT: MARINE OUTFALL PIPELINE, ARKLOW WwTP GEOPHYSICAL INVESTIGATION

CLIENT: BYRNE LOOBY ARUP

DRAWING NUMBER: AGL16077_02

SCALE: 1:5000 @ A1

DATE: 05/05/2017

NOTES:
The information displayed here is to be used in conjunction with Report AGL16077 Report on the Geophysical Investigation at the Marine Outfall Pipeline, Arklow WwTP for Byrne Looby Arup. APEX Geoservices Ltd. 05th May 2017.

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FIGURE 1: Bedrock Vp Velocity Map, Scale 1:5000

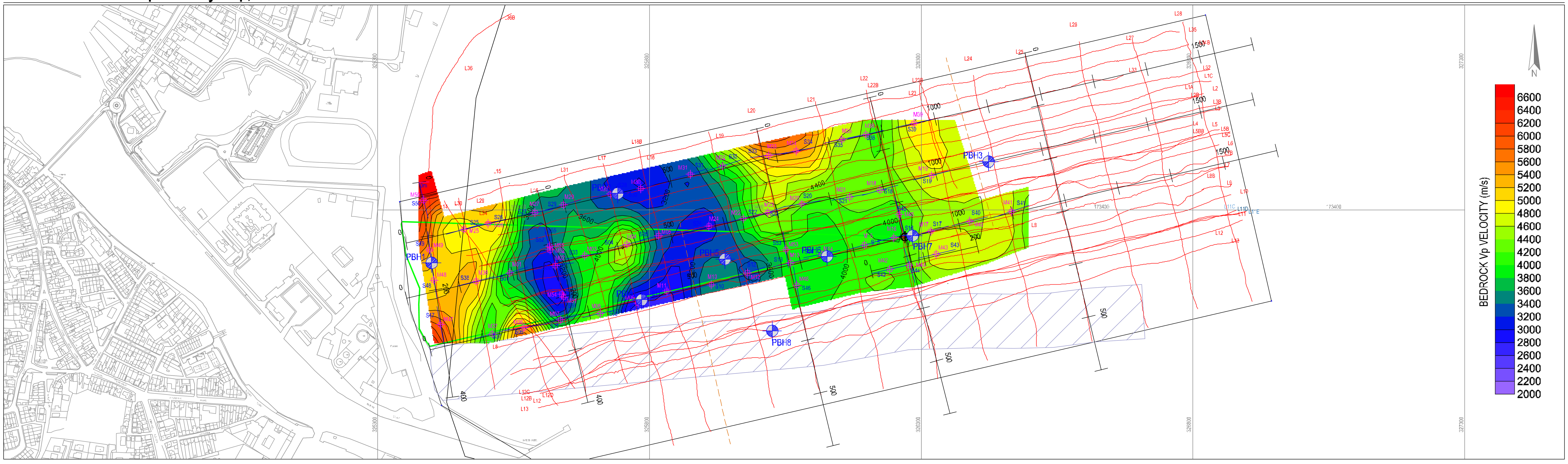


FIGURE 2: Line 33 Cross Section - Sub Bottom Profiler & Structural Interpretation, Scale 1:5000

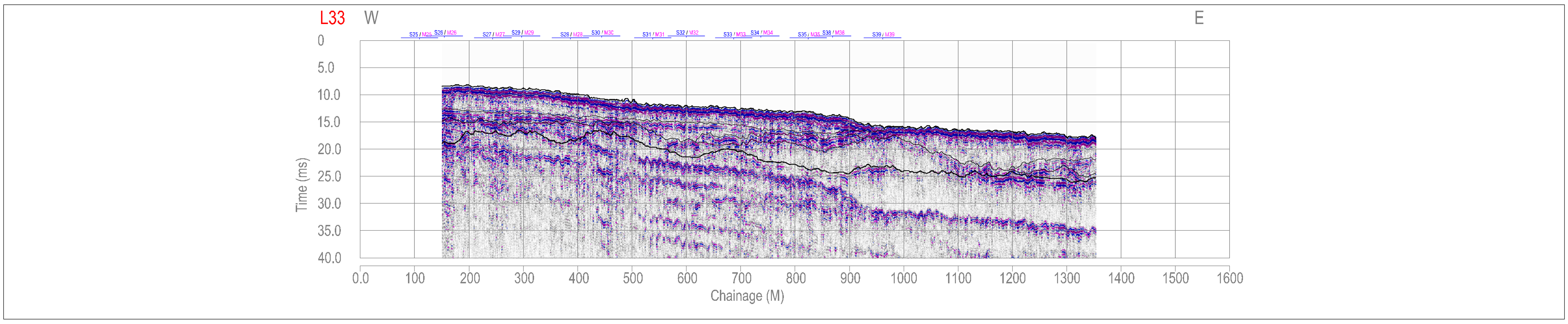


FIGURE 3: Line 33 Cross Section - Overburden Vs Velocity, Scale 1:5000

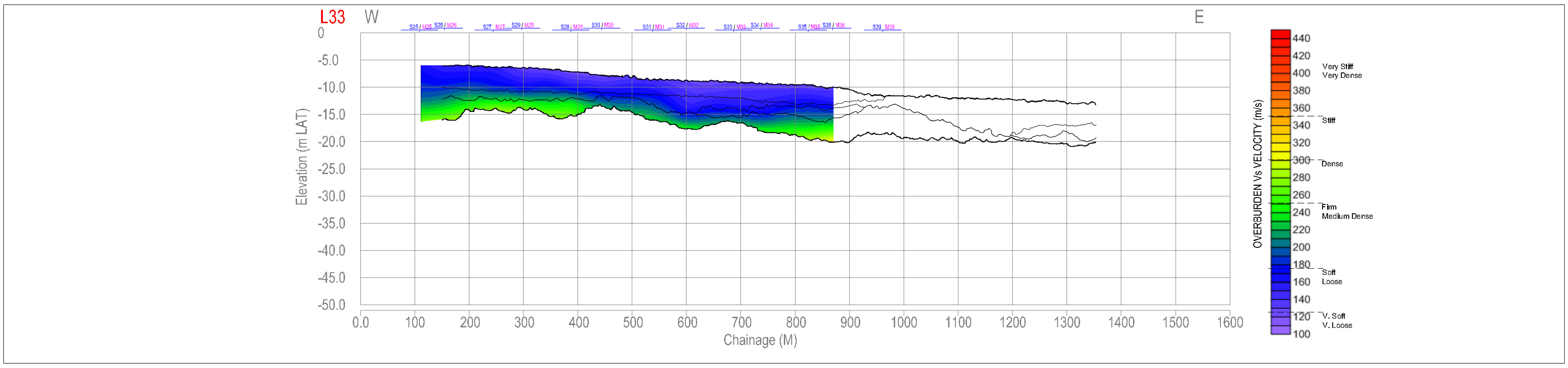


FIGURE 4: Line 33 Cross Section - Bedrock Vp Velocity, Scale 1:5000

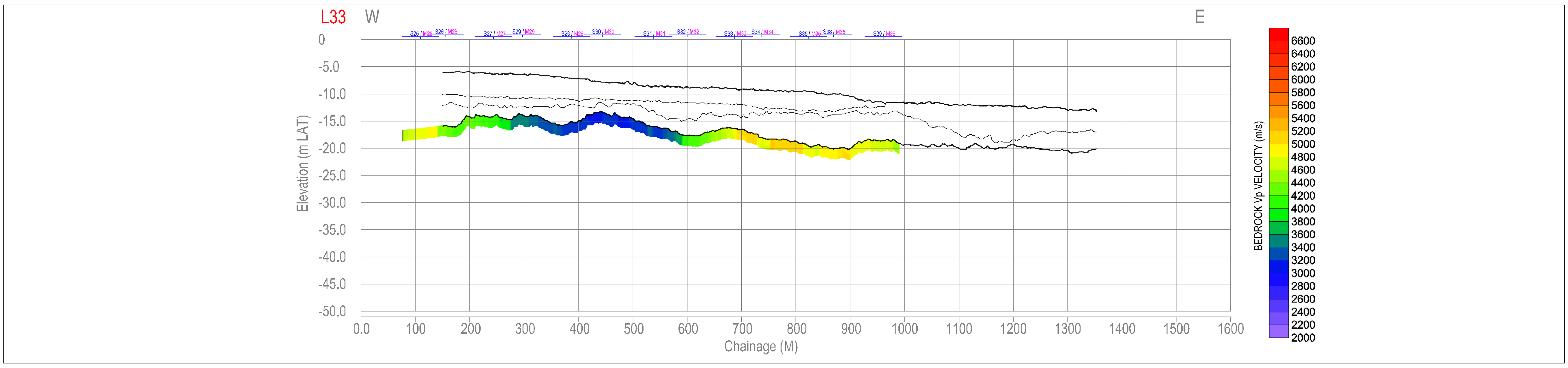
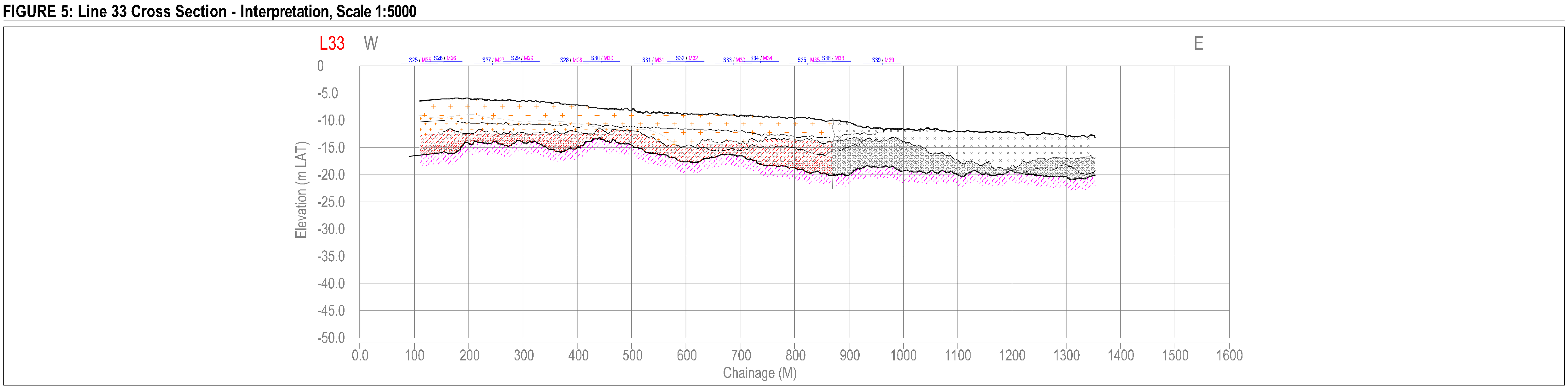
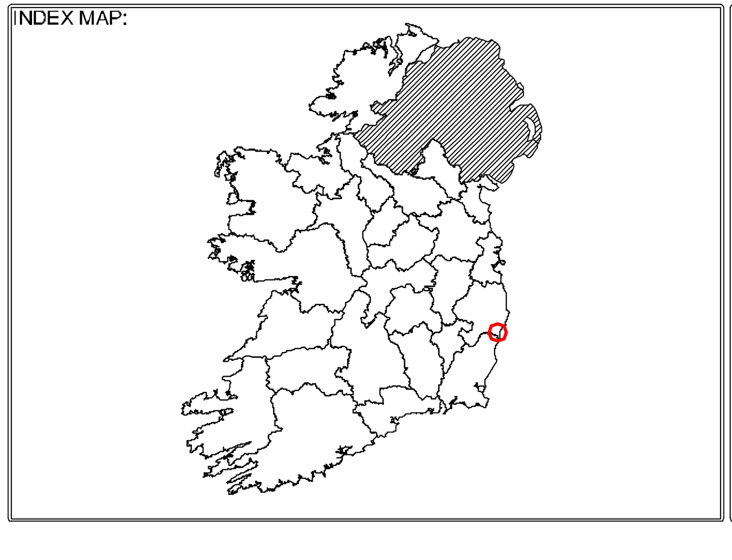


FIGURE 5: Line 33 Cross Section - Interpretation, Scale 1:5000



INDEX MAP:



LEGEND:

- Client Site Boundary
- Chainage
- L01 Sparker Profile
- S01 Seismic Refraction Profile
- M01 MASW 1D Profile
- ING Coordinate/ Lat Long Coordinate
- PDH Proposed Diffuser Head
- PBH1 Proposed Borehole
- Seabed Exclusion Zone
- Interpreted Fault
- Seabed
- Internal Overburden Layer Boundary
- Top of Bedrock
- Change in Layer Stiffness
- V.soft - Soft/V. Loose - Loose Nonconsolidated Overburden
- Firm - Stiff/Medium Dense - Dense Nonconsolidated Overburden
- Stiff/Dense Nonconsolidated Overburden
- V.soft - Soft/V. Loose - Loose Overburden/Till
- Firm /Medium dense Overburden/Till
- Stiff /Dense Overburden/Till
- Very Stiff / Very Dense Overburden/Till
- Unconsolidated Overburden
- Overburden/Till
- Metasediment Bedrock

PROJECT: MARINE OUTFALL PIPELINE, ARKLOW WwTP GEOPHYSICAL INVESTIGATION

CLIENT: BYRNE LOOBY ARUP

DRAWING NUMBER: AGL16077_03

SCALE: 1:5000 @ A1

DATE: 05/05/2017

NOTES: The information displayed here is to be used in conjunction with Report AGL16077 Report on the Geophysical Investigation at the Marine Outfall Pipeline, Arklow WwTP for Byrne Looby Arup. APEX Geoservices Ltd. 05th May 2017.

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FIGURE 1: Bedrock Vp Velocity Map, Scale 1:5000

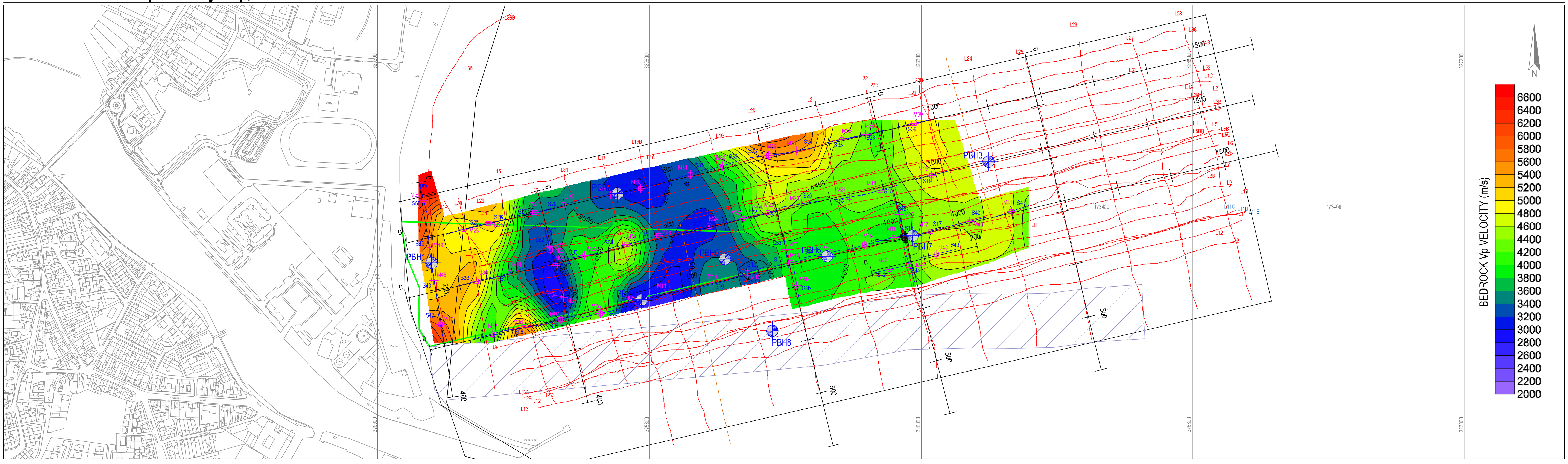


FIGURE 2: Line 03B Cross Section - Sub Bottom Profiler & Structural Interpretation, Scale 1:5000

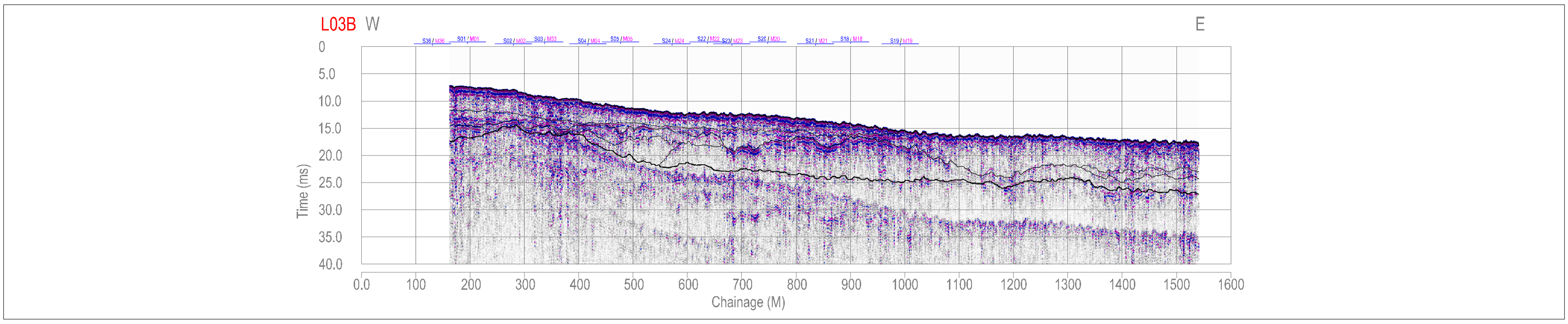


FIGURE 3: Line 03B Cross Section - Overburden Vs Velocity, Scale 1:5000

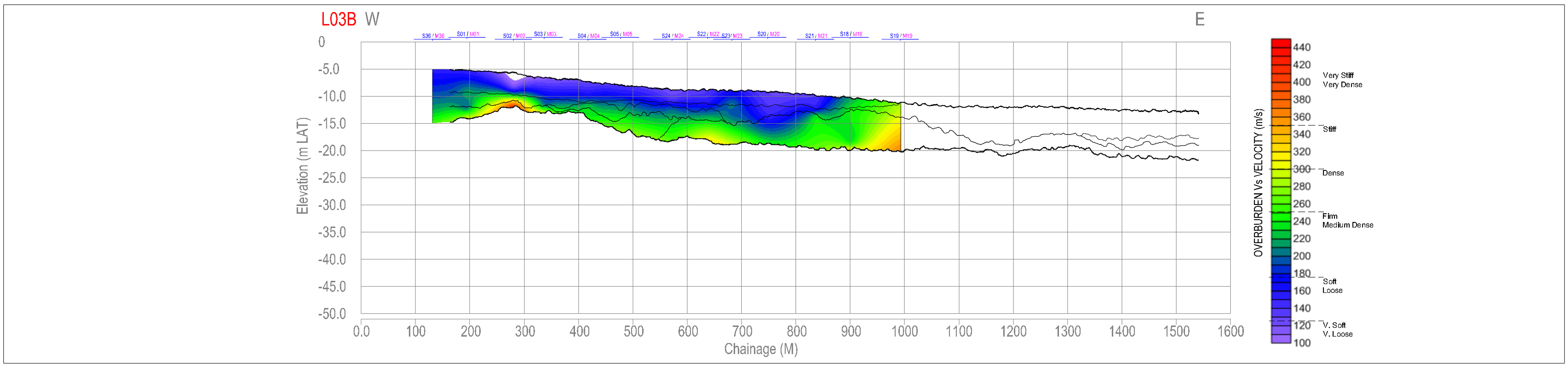


FIGURE 4: Line 03B Cross Section - Bedrock Vp Velocity, Scale 1:5000

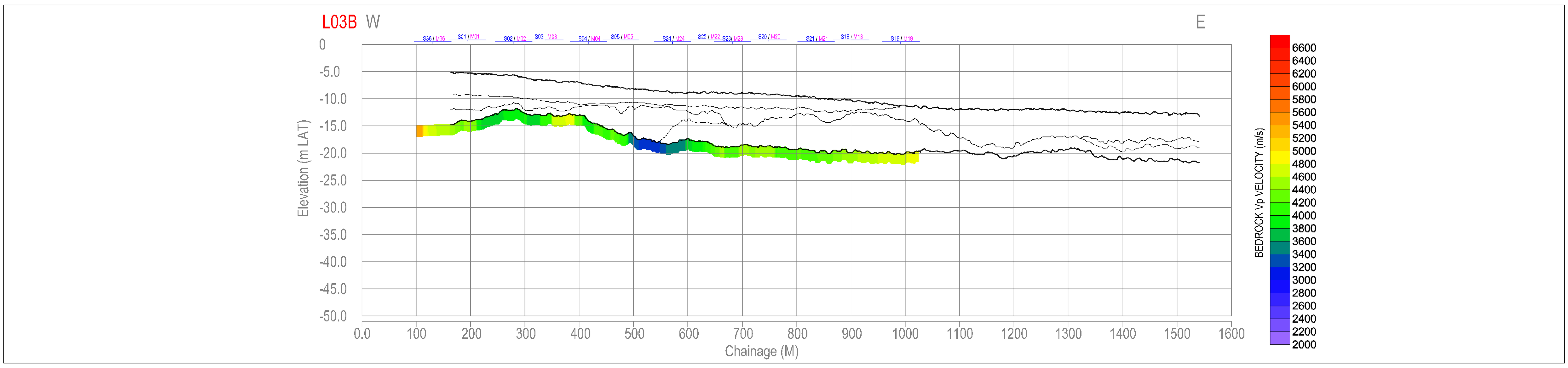
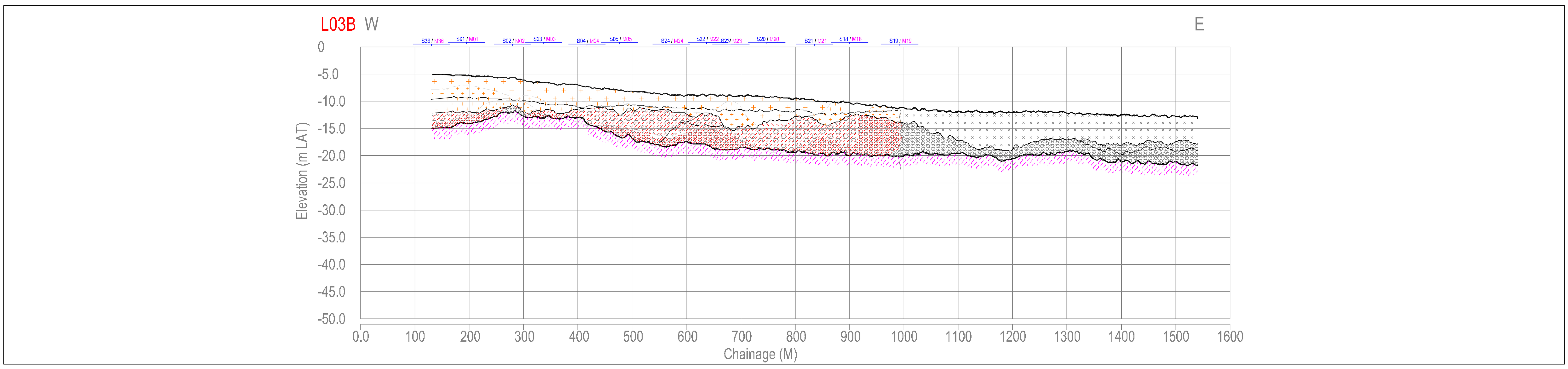
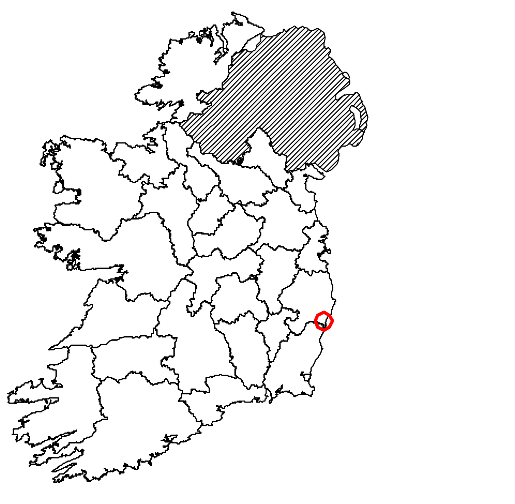


FIGURE 5: Line 03B Cross Section - Interpretation, Scale 1:5000



INDEX MAP:



LEGEND:

- Client Site Boundary
- Chainage (0 100)
- L01 Sparker Profile
- S01 Seismic Refraction Profile
- M01 MASW 1D Profile
- ING Coordinate/ Lat Long Coordinate (326000, 242000)
- PDH Proposed Diffuser Head
- PBH1 Proposed Borehole
- Seabed Exclusion Zone
- Interpreted Fault
- Seabed
- Internal Overburden Layer Boundary
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- Change in Layer Stiffness
- V.soft - Soft/V. Loose - Loose Nonconsolidated Overburden
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- Unconsolidated Overburden
- Overburden/Till
- Metasediment Bedrock

PROJECT:
MARINE OUTFALL PIPELINE, ARKLOW WwTP
GEOPHYSICAL INVESTIGATION

CLIENT:
BYRNE LOOBY ARUP

DRAWING NUMBER:
AGL16077_04

SCALE:
1:5000 @ A1

DATE: 05/05/2017

NOTES:
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FIGURE 1: Bedrock Vp Velocity Map, Scale 1:5000

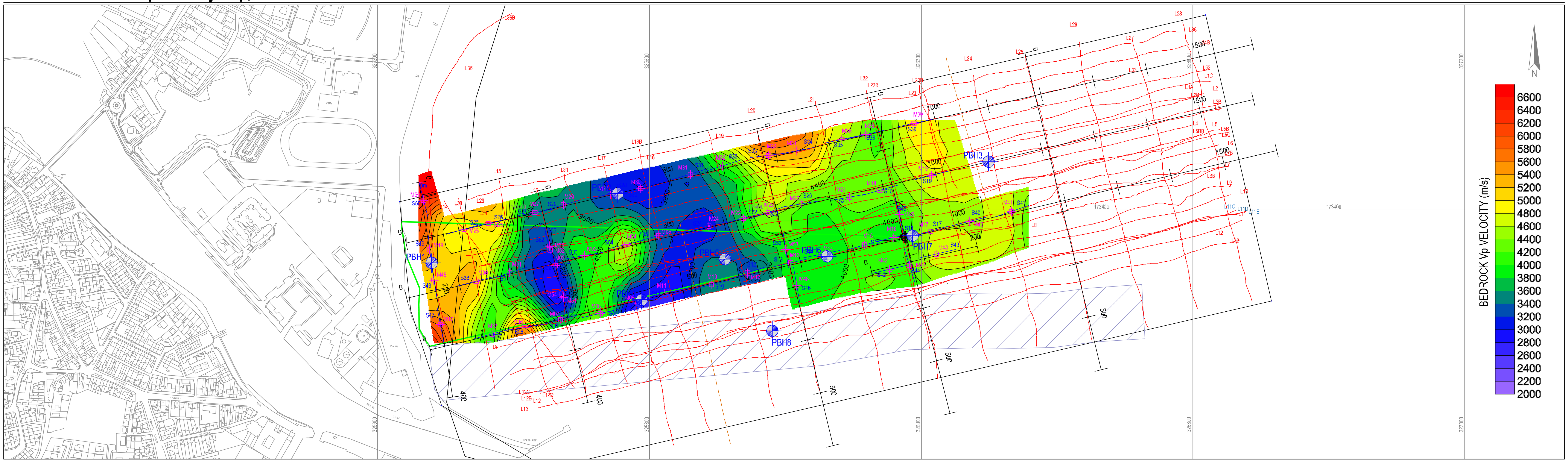


FIGURE 2: Line 07 Cross Section - Sub Bottom Profiler & Structural Interpretation, Scale 1:5000

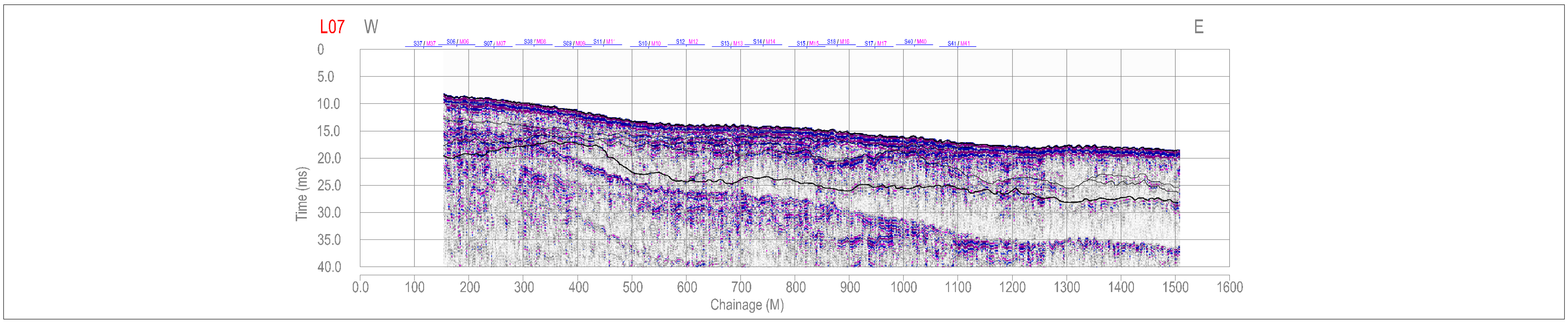


FIGURE 3: Line 07 Cross Section - Overburden Vs Velocity, Scale 1:5000

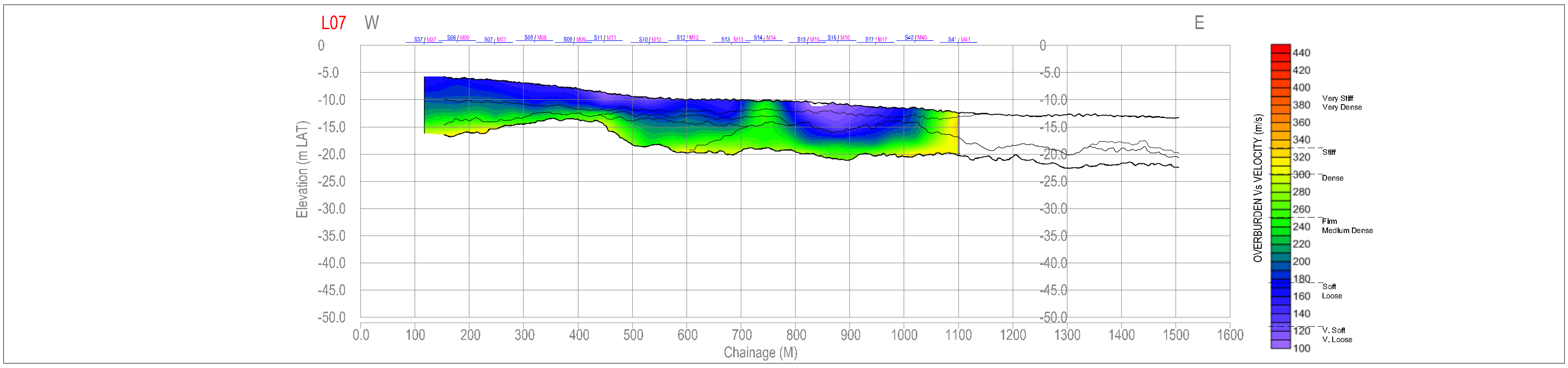


FIGURE 4: Line 07 Cross Section - Bedrock Vp Velocity, Scale 1:5000

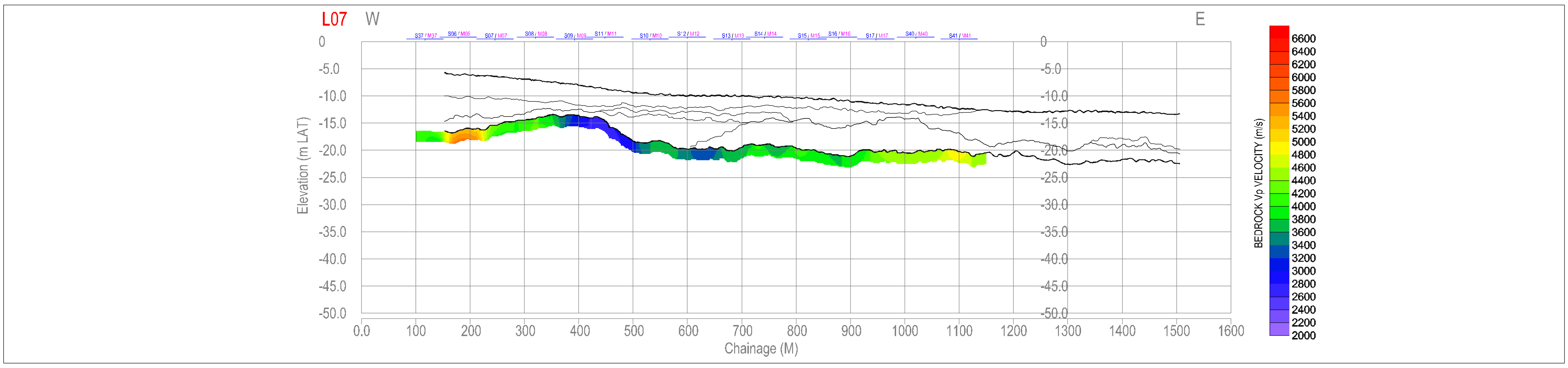
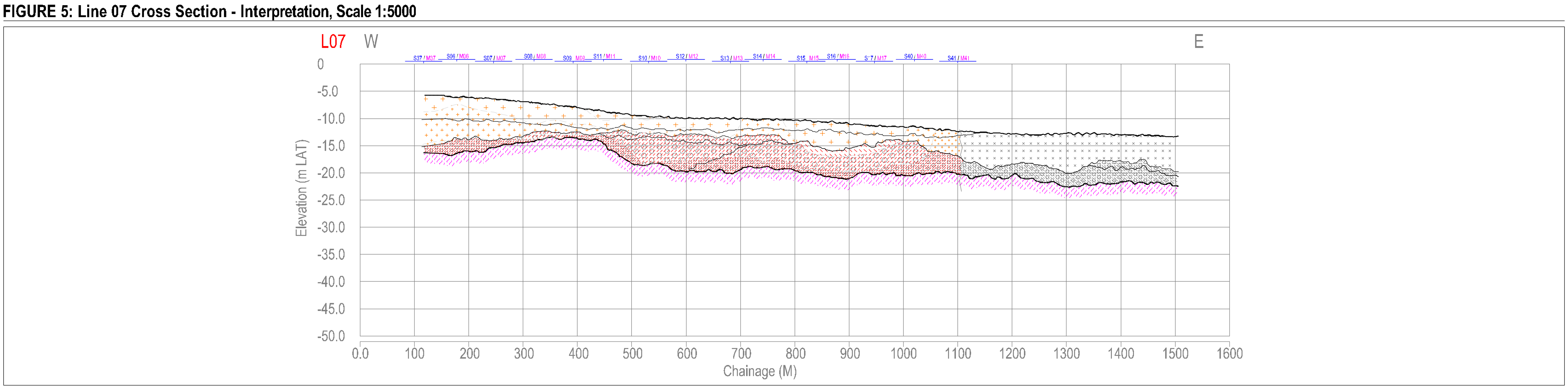
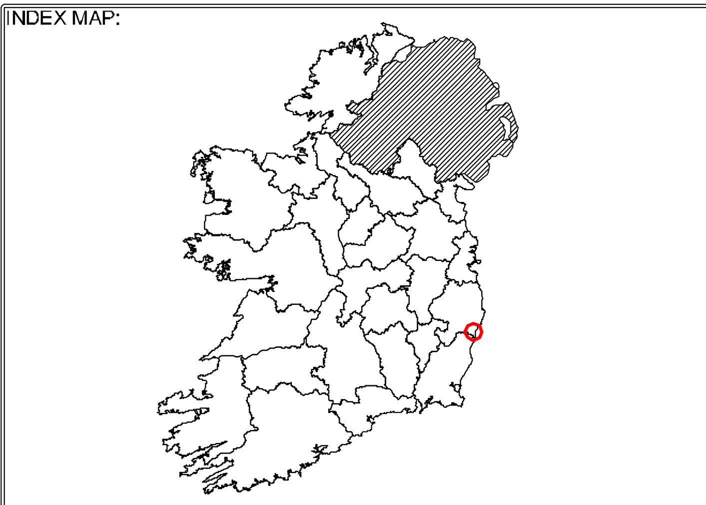


FIGURE 5: Line 07 Cross Section - Interpretation, Scale 1:5000



INDEX MAP:



LEGEND:

- Client Site Boundary
- Chainage
- L01 Sparker Profile
- S01 Seismic Refraction Profile
- M01 MASW 1D Profile
- ING Coordinate/ Lat Long Coordinate
- PDH Proposed Diffuser Head
- PBH1 Proposed Borehole
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- Very Stiff / Very Dense Overburden/Till
- Unconsolidated Overburden
- Overburden/Till
- Metasediment Bedrock

PROJECT: MARINE OUTFALL PIPELINE, ARKLOW WwTP GEOPHYSICAL INVESTIGATION

CLIENT: BYRNE LOOBY ARUP

DRAWING NUMBER: AGL16077_05

SCALE: 1:5000 @ A1

DATE: 05/05/2017

NOTES: The information displayed here is to be used in conjunction with Report AGL16077 Report on the Geophysical Investigation at the Marine Outfall Pipeline, Arklow WwTP for Byrne Looby Arup. APEX Geoservices Ltd. 05th May 2017.

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FIGURE 1: Bedrock Vp Velocity Map, Scale 1:5000

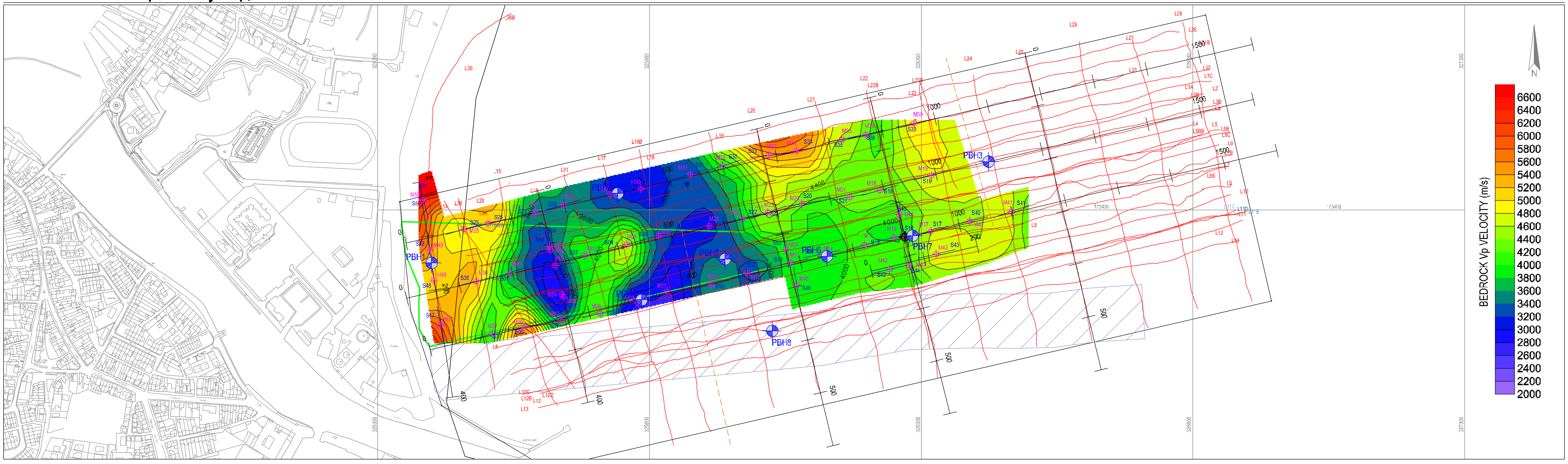


FIGURE 2: Line 36B Cross Section - Sub Bottom Profiler & Structural Interpretation, Scale 1:5000

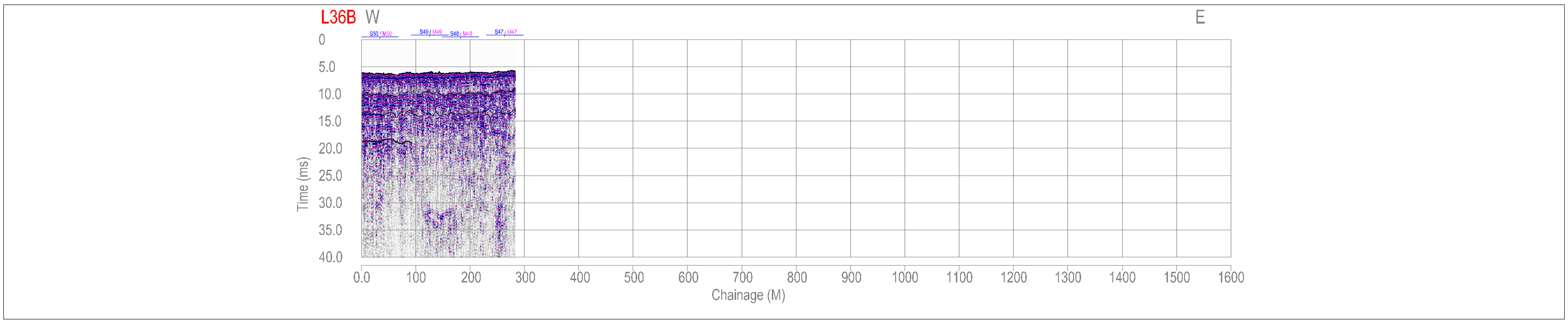


FIGURE 3: Line 36B Cross Section - Overburden Vs Velocity, Scale 1:5000

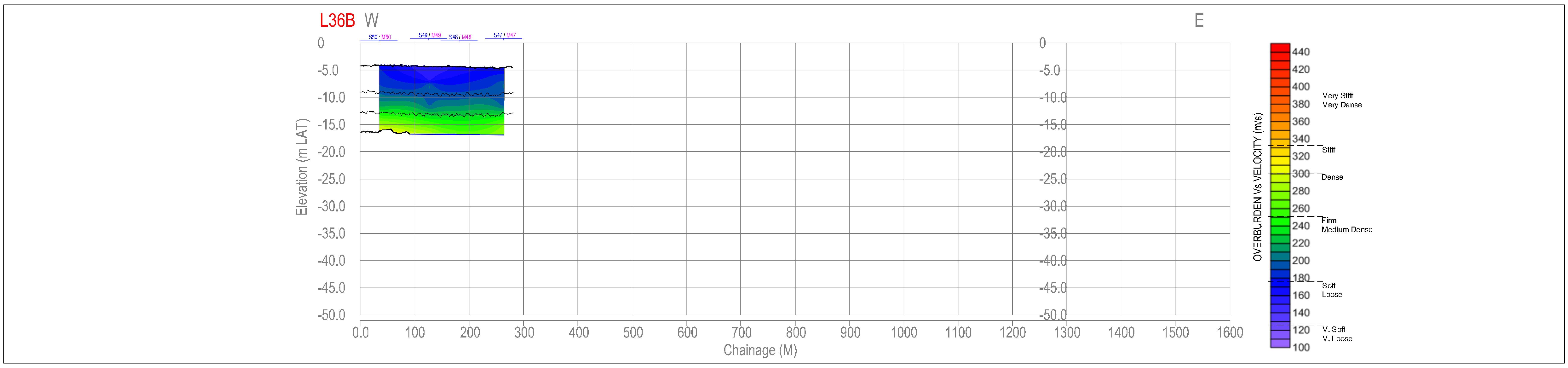


FIGURE 4: Line 36B Cross Section - Bedrock Vp Velocity, Scale 1:5000

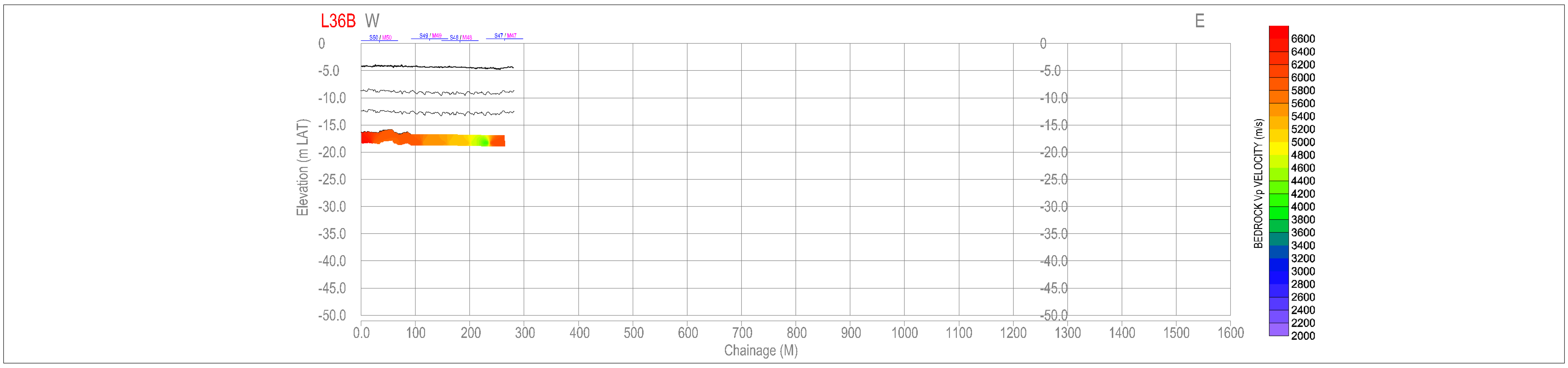
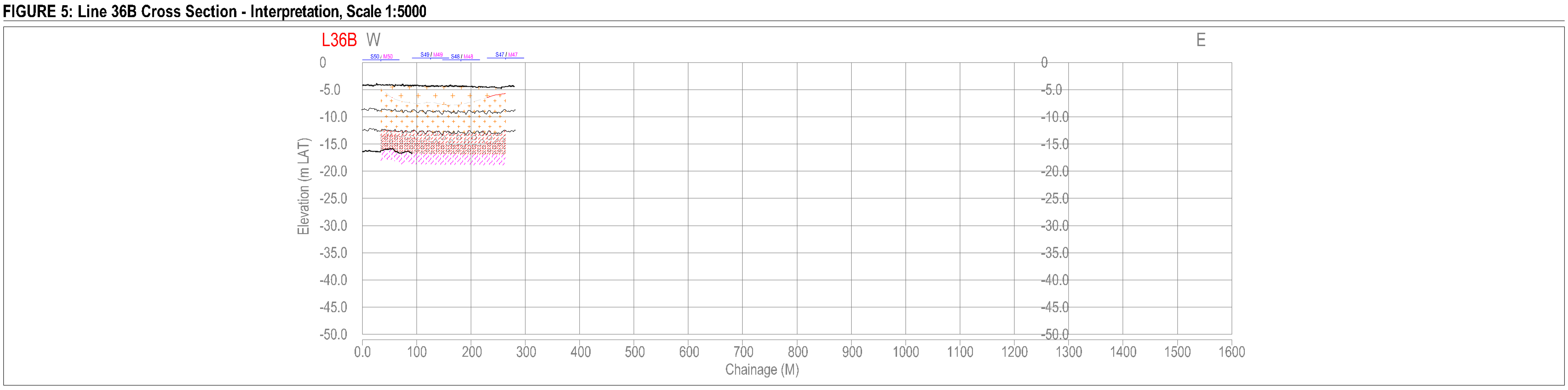
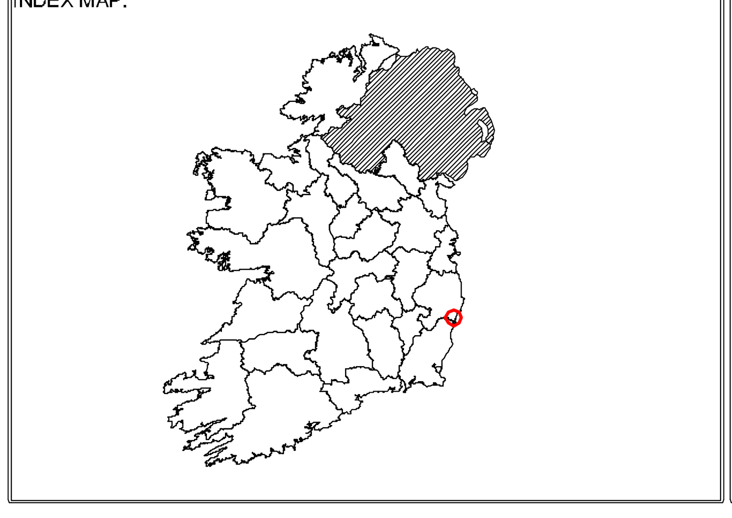


FIGURE 5: Line 36B Cross Section - Interpretation, Scale 1:5000



INDEX MAP:



LEGEND:

- Client Site Boundary
- Chainage (0 100)
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- Firm /Medium dense Overburden/Till
- Stiff /Dense Overburden/Till
- Very Stiff / Very Dense Overburden/Till
- Unconsolidated Overburden
- Overburden/Till
- Metasediment Bedrock

PROJECT: MARINE OUTFALL PIPELINE, ARKLOW WwTP GEOPHYSICAL INVESTIGATION

CLIENT: BYRNE LOOBY ARUP

DRAWING NUMBER: AGL16077_06

SCALE: 1:5000 @ A1

DATE: 05/05/2017

NOTES: **The information displayed here is to be used in conjunction with Report AGL16077 Report on the Geophysical Investigation at the Marine Outfall Pipeline, Arklow WwTP for Byrne Looby Arup. APEX Geoservices Ltd. 05th May 2017.**

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8. 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 locations of the 1D soundings in relation to the sub bottom profiler Sparker data and the seismic refraction spreads is shown in **Appendix A**: Drawings. The data is presented from north to south and east to west along sub bottom profiler survey lines L33, L03B, L07, L36B, L16, L09, L20 and L22.

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

- For the overburden / 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;

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

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

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

  $$SPT = 0.0011 * Vs^2 – 0.1665 * Vs + 7.1017 \text{ (Granular)}$$
  $$SPT = 0.2061 * Vs – 23.076 \text{ (cohesive)}$$

- The depth below seabed values displayed in the tables for the overburden / sediment layers and the bedrock layer are based on a time to depth stretch of the time domain layering from the sub bottom profiler data using a conversion velocity of 1900m/s. The conversion velocity was chosen following analysis of the finalised velocity regimes from the seismic refraction and 1D MSASW datasets in conjuction with the time domain layer boundary picks from the sub bottom profiler data.

- For the bedrock data the relative R.Q.D. values displayed in the tables were calculated based on an assumed laboratory velocity (V lab) of 6,000m/s. Typical published Vp values for sandstones range 1,400m/s to 4,500m/s and for shales range 2,000m/s to 4,100m/s limestone (Press, 1966 & Reynolds, 1997).

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

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

	M25								
	Chainage (m)	109							
	Easting ING	325458.6		LAT	N 52 47.822777				
	Northing ING	173364.1		LONG	W 06 8.444364				
Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	1.976	180.023	58	FIRM	MEDIUM DENSE	14 N	12 N
	Unconsolidated Overburden	1.98	4	181.638	59	FIRM	MEDIUM DENSE	14 N	13 N
	Unconsolidated Overburden	4.00	6	196.945	70	FIRM	MEDIUM DENSE	17 N	16 N
	Overburden	6.00	9.7	260.235	135	STIFF	DENSE	30 N	38 N
		9.70		377.403					
Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	9.70		4594	59	FAIR			

M26								
Chainage (m)	155							
Easting ING	325503.3		LAT	N 52 47.827814				
Northing ING	173374.6		LONG	W 06 8.404418				
Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
Unconsolidated Overburden	0.00	1.593	161.348	42	SOFT	LOOSE	10 N	8 N
Unconsolidated Overburden	1.59	4	183.8	61	FIRM	MEDIUM DENSE	14 N	13 N
Unconsolidated Overburden	4.00	6	207.969	78	FIRM	MEDIUM DENSE	19 N	20 N
Overburden	6.00	9.8	269.68	145	STIFF	DENSE	32 N	42 N
	9.80		375.193					
Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
METASEDIMENT	9.80		5174	74	FAIR			

	M27								
	Chainage (m)	244							
	Easting ING	325589.1		LAT	N 52 47.837667				
	Northing ING	173395.1		LONG	W 06 8.327629				
Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	1.779	174.676	49	SOFT to FIRM	LOOSE to MEDIUM DENSE	12 N	11 N
	Unconsolidated Overburden	1.78	4.2	170.643	47	SOFT to FIRM	LOOSE to MEDIUM DENSE	12 N	10 n
	Unconsolidated Overburden	4.20	5.8	228.407	94	FIRM	MEDIUM DENSE	23 N	26 N
	Overburden	5.80	7.7	295.083	174	STIFF	DENSE to VERY DENSE	37 N	>50 N
		7.70		326.185					
Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	7.70		3163	28	POOR			

M29								
Chainage (m)	297							
Easting ING	325641.4		LAT	N 52 47.844553				
Northing ING	173409.3		LONG	W 06 8.280870				
Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
Unconsolidated Overburden	0.00	1.837	148.935	35	SOFT	LOOSE	7 N	6 N
Unconsolidated Overburden	1.84	4.2	172.687	48	SOFT to FIRM	LOOSE to MEDIUM DENSE	12 N	11 N
Unconsolidated Overburden	4.20	5.8	221.173	88	FIRM	MEDIUM DENSE	22 N	24 N
Overburden	5.80	7.5	292.015	171	STIFF	DENSE to VERY DENSE	37 N	>50 N
	7.50		320.532					
Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
METASEDIMENT	7.50		3540	35	POOR			

	M28								
	Chainage (m)	387							
	Easting ING	325728.2		LAT	N 52 47.854141				
	Northing ING	173429.3		LONG	W 06 8.203220				
Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	1.835	142.804	33	SOFT	LOOSE	6 N	5 N
	Unconsolidated Overburden	1.84	3.8	169.899	46	SOFT to FIRM	LOOSE to MEDIUM DENSE	11 N	10 N
	Unconsolidated Overburden	3.80	4.8	243.276	107	FIRM to STIFF	LOOSE to MEDIUM DENSE	27 N	31 N
	Overburden	4.80	8	266.827	142	STIFF	DENSE	31 N	40 N
		8.00		331.204					
Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	8.00		2952	24	VERY POOR			

M30								
Chainage (m)	444							
Easting ING	325784		LAT	N 52 47.858804				
Northing ING	173439.4		LONG	W 06 8.153365				
Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
Unconsolidated Overburden	0.00	2.8	155.881	39	SOFT	LOOSE	9 N	7 N
Unconsolidated Overburden	2.80	4	188.992	64	FIRM	MEDIUM DENSE	15 N	14 N
Overburden	4.00	6	227.937	94	FIRM	MEDIUM DENSE	23 N	26 N
	6.00		274.203					
Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
METASEDIMENT	6.00		2738	21	VERY POOR			

	M31								
	Chainage (m)	538							
	Easting ING	325875.1		LAT	N 52 47.871711				
	Northing ING	173465.7		LONG	W 06 8.071718				
Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	2.5	169.962	46	SOFT to FIRM	LOOSE to MEDIUM DENSE	11 N	10 N
	Unconsolidated Overburden	2.50	4.5	198.183	71	FIRM	MEDIUM DENSE	17 N	17 N
	Overburden	4.50	7.32	229.931	95	FIRM	MEDIUM DENSE	24 N	26 N
		7.32		301.055					
Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	7.32		2930	24	VERY POOR			

M32								
Chainage (m)	600							
Easting ING	325934.7		LAT	N 52 47.879081				
Northing ING	173480.9		LONG	W 06 8.018398				
Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
Unconsolidated Overburden	0.00	1.833	141.621	32	SOFT	LOOSE	6 N	5 N
Unconsolidated Overburden	1.83	3	146.765	34	SOFT	LOOSE	7 N	6 N
Unconsolidated Overburden	3.00	6	148.776	35	SOFT	LOOSE	7 N	6 N
Overburden	6.00	9	260.294	136	STIFF	DENSE	30 N	38 N
	9.00		333.276					
Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
METASEDIMENT	9.00		3831	41	POOR			

	M33								
	Chainage (m)	687							
	Easting ING	326019.4		LAT	N 52 47.888294				
	Northing ING	173500.2		LONG	W 06 7.942691				
Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	3	155.722	39	SOFT	LOOSE	9 N	7 N
	Unconsolidated Overburden	3.00	5.003	149.451	36	SOFT	LOOSE	7 N	6 N
	Overburden	5.00	7.5	230.682	96	FIRM	MEDIUM DENSE	24 N	27 N
		7.50		314.147					
Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	7.50		5493	84	GOOD			

	M34								
	Chainage (m)	737							
	Easting ING	326069.8		LAT	N 52 47.892090				
	Northing ING	173508.6		LONG	W 06 7.897713				
	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	3	157.241	40	SOFT	LOOSE	9 N	8 N
	Unconsolidated Overburden	3.00	4.5	145.983	34	SOFT	LOOSE	7 N	6 N
	Overburden	4.50	8.7	244.436	108	FIRM to STIFF	MEDIUM DENSE to DENSE	27 N	32 N
		8.70		334.509					
	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	8.70		5513	84	GOOD			

	M35								
	Chainage (m)	824							
	Easting ING	326154.2		LAT	N 52 47.902200				
	Northing ING	173529.6		LONG	W 06 7.822126				
Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	3	163.993	43	SOFT	LOOSE	10 N	9 N
	Unconsolidated Overburden	3.00	4	188.513	64	FIRM	MEDIUM DENSE	15 N	14 N
	Overburden	4.00	7.565	218.441	86	FIRM	MEDIUM DENSE	21 N	23 N
	Overburden	7.57	10	302.339	183	STIFF	DENSE to VERY DENSE	39 N	>50 N
		10.00		375.816					
Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	10.00		4614	59	FAIR			

	M38								
	Chainage (m)	869							
	Easting ING	326198.2		LAT	N 52 47.906533				
	Northing ING	173538.7		LONG	W 06 7.782826				
	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	3	154.364	38	SOFT	LOOSE	8 N	7 N
	Unconsolidated Overburden	3.00	4	187.088	63	FIRM	MEDIUM DENSE	15 N	14 N
	Overburden	4.00	7.388	233.517	98	FIRM	MEDIUM DENSE	25 N	28 N
	Overburden	7.39	10	324.878	211	STIFF to VERY STIFF	VERY DENSE	43 N	>50 N
		10.00		389.116					
	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	10.00		3909	42	POOR			

	M36								
	Chainage (m)	131							
	Easting ING	325481		**LAT**	N 52 47.770959				
	Northing ING	173268.5		**LONG**	W 06 8.426689				
Sediment	**Type**	**Depth Below Seabed (m)**	**To**	**Vs (m/s)**	**Gmax (Mpa)**	**Stiffness Cohesive**	**Stiffness Granular**	**SPT* Cohesive**	**SPT* Granular**
	Unconsolidated Overburden	0.00	3.7	189.711	65	FIRM	MEDIUM DENSE	16 N	15 N
	Unconsolidated Overburden	3.70	6.5	211.683	81	FIRM	MEDIUM DENSE	20 N	21 N
	Overburden	6.50	8.8	243.763	107	FIRM to STIFF	MEDIUM DENSE to DENSE	27 N	31 N
		8.80		311.232					
Bedrock	**Type**	**Depth Below Seabed (m)**		**Vp (m/s)**	**RQD****	**Quality**			
	METASEDIMENT	8.80		5518	85	GOOD			

	M01								
	Chainage (m)	195							
	Easting ING	325543		**LAT**	N 52 47.778454				
	Northing ING	173284.1		**LONG**	W 06 8.371196				
Sediment	**Type**	**Depth Below Seabed (m)**	**To**	**Vs (m/s)**	**Gmax (Mpa)**	**Stiffness Cohesive**	**Stiffness Granular**	**SPT* Cohesive**	**SPT* Granular**
	Unconsolidated Overburden	0.00	4	222.384	89	FIRM	MEDIUM DENSE	22 N	24 N
	Unconsolidated Overburden	4.00	6.7	191.748	66	FIRM	MEDIUM DENSE	16 N	15 N
	Overburden	6.70	8.8	311.914	195	STIFF	VERY DENSE	41 N	>50 N
		8.80		400.929					
Bedrock	**Type**	**Depth Below Seabed (m)**		**Vp (m/s)**	**RQD****	**Quality**			
	METASEDIMENT	8.80		3504	34	POOR			

	M02								
	Chainage (m)	280							
	Easting ING	325626.7		**LAT**	N 52 47.784603				
	Northing ING	173297.6		**LONG**	W 06 8.296504				
Sediment	**Type**	**Depth Below Seabed (m)**	**To**	**Vs (m/s)**	**Gmax (Mpa)**	**Stiffness Cohesive**	**Stiffness Granular**	**SPT* Cohesive**	**SPT* Granular**
	Unconsolidated Overburden	0.00	2.574	113.177	20	VERY SOFT	VERY LOOSE	0 N	2 N
	Unconsolidated Overburden	2.57	4.1	232.049	97	FIRM	MEDIUM DENSE	24 N	27 N
	Unconsolidated Overburden	4.10	5	322.216	208	STIFF to VERY STIFF	VERY DENSE	43 N	>50 N
	Overburden	5.00	6.3	428.794	368	VERY STIFF	VERY DENSE	>50 N	>50 N
		6.30		434.109					
Bedrock	**Type**	**Depth Below Seabed (m)**		**Vp (m/s)**	**RQD****	**Quality**			
	METASEDIMENT	6.30		3861	41	POOR			

	M03								
	Chainage (m)	337							
	Easting ING	325680.9		**LAT**	N 52 47.793756				
	Northing ING	173316		**LONG**	W 06 8.247866				
Sediment	**Type**	**Depth Below Seabed (m)**	**To**	**Vs (m/s)**	**Gmax (Mpa)**	**Stiffness Cohesive**	**Stiffness Granular**	**SPT* Cohesive**	**SPT* Granular**
	Unconsolidated Overburden	0.00	3.7	191.132	66	FIRM	MEDIUM DENSE	16 N	15 N
	Unconsolidated Overburden	3.70	5.1	199.519	72	FIRM	MEDIUM DENSE	18 N	17 N
	Overburden	5.10	6.5	319.52	204	STIFF	VERY DENSE	42 N	>50 N
		6.50		351.331					
Bedrock	**Type**	**Depth Below Seabed (m)**		**Vp (m/s)**	**RQD****	**Quality**			
	METASEDIMENT	6.50		4218	49	POOR			

	M04								
	Chainage (m)	417							
	Easting ING	325758.5		**LAT**	N 52 47.803892				
	Northing ING	173336.8		**LONG**	W 06 8.178418				
Sediment	**Type**	**Depth Below Seabed (m)**	**To**	**Vs (m/s)**	**Gmax (Mpa)**	**Stiffness Cohesive**	**Stiffness Granular**	**SPT* Cohesive**	**SPT* Granular**
	Unconsolidated Overburden	0.00	2.5	165.354	44	SOFT to FIRM	LOOSE to MEDIUM DENSE	11 N	9 N
	Unconsolidated Overburden	2.50	4	224.806	91	FIRM	MEDIUM DENSE	23 N	25 N
	Overburden	4.00	6.9	244.346	107	FIRM to STIFF	MEDIUM DENSE to DENSE	27 N	32 N
		6.90		361.288					
Bedrock	**Type**	**Depth Below Seabed (m)**		**Vp (m/s)**	**RQD****	**Quality**			
	METASEDIMENT	6.90		5487	84	GOOD			

	M05								
	Chainage (m)	477							
	Easting ING	325816.8		**LAT**	N 52 47.811594				
	Northing ING	173352.6		**LONG**	W 06 8.126206				
Sediment	**Type**	**Depth Below Seabed (m)**	**To**	**Vs (m/s)**	**Gmax (Mpa)**	**Stiffness Cohesive**	**Stiffness Granular**	**SPT* Cohesive**	**SPT* Granular**
	Unconsolidated Overburden	0.00	1.75	165.157	44	SOFT to FIRM	LOOSE to MEDIUM DENSE	10 N	9 N
	Unconsolidated Overburden	1.75	2.7	195.307	69	FIRM	MEDIUM DENSE	17 N	16 N
	Overburden	2.70	4.7	222.461	89	FIRM	MEDIUM DENSE	22 N	24 N
	Overburden	4.70	8.6	279.791	157	STIFF	DENSE	34 N	46 N
		8.60		377.376					
Bedrock	**Type**	**Depth Below Seabed (m)**		**Vp (m/s)**	**RQD****	**Quality**			
	METASEDIMENT	8.60		3332	31	POOR			

	M24								
	Chainage (m)	572							
	Easting ING	325909.6		**LAT**	N 52 47.819682				
	Northing ING	173370.1		**LONG**	W 06 8.043317				
Sediment	**Type**	**Depth Below Seabed (m)**	**To**	**Vs (m/s)**	**Gmax (Mpa)**	**Stiffness Cohesive**	**Stiffness Granular**	**SPT* Cohesive**	**SPT* Granular**
	Unconsolidated Overburden	0.00	2	141.566	32	SOFT	LOOSE	6 N	5 N
	Unconsolidated Overburden	2.00	3	197.987	71	FIRM	MEDIUM DENSE	17 N	17 N
	Overburden	3.00	9.2	261.722	137	STIFF	DENSE	30 N	38 N
		9.20		354.568					
Bedrock	**Type**	**Depth Below Seabed (m)**		**Vp (m/s)**	**RQD****	**Quality**			
	METASEDIMENT	9.20		2997	25	VERY POOR			

	M22								
	Chainage (m)	637							
	Easting ING	325972.6		**LAT**	N 52 47.826389				
	Northing ING	173384.1		**LONG**	W 06 7.986969				
Sediment	**Type**	**Depth Below Seabed (m)**	**To**	**Vs (m/s)**	**Gmax (Mpa)**	**Stiffness Cohesive**	**Stiffness Granular**	**SPT* Cohesive**	**SPT* Granular**
	Unconsolidated Overburden	0.00	2.4	160.302	41	SOFT	LOOSE	9 N	8 N
	Unconsolidated Overburden	2.40	3.4	189.733	65	FIRM	MEDIUM DENSE	16 N	15 N
	Unconsolidated Overburden	3.40	6.514	260.312	136	STIFF	DENSE	30 N	38 N
	Overburden	6.51	9	318.641	203	STIFF	VERY DENSE	42 N	>50 N
		9.00		374.477					
Bedrock	**Type**	**Depth Below Seabed (m)**		**Vp (m/s)**	**RQD****	**Quality**			
	METASEDIMENT	9.00		3801	40	POOR			

	M23								
	Chainage (m)	682							
	Easting ING	326018		LAT	N 52 47.831808				
	Northing ING	173395.4		LONG	W 06 7.946379				
Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	2.5	211.459	80	FIRM	MEDIUM DENSE	20 N	21 N
	Unconsolidated Overburden	2.50	3.9	190.524	65	FIRM	MEDIUM DENSE	16 N	15 N
	Overburden	3.90	6.3	226.819	93	FIRM	MEDIUM DENSE	23 N	25 N
	Overburden	6.30	9.9	301.32	182	STIFF	DENSE to VERY DENSE	39 N	>50 N
		9.90		421.773					
Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	9.90		5027	70	FAIR			

	M20								
	Chainage (m)	195							
	Easting ING	326080.5		LAT	N 52 47.839474				
	Northing ING	173411.2		LONG	W 06 7.890420				
	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	2.6	140.599	32	SOFT	LOOSE	5 N	5 N
	Unconsolidated Overburden	2.60	4.6	154.014	38	SOFT	LOOSE	8 N	7 N
	Overburden	4.60	9.4	240.618	104	FIRM to STIFF	MEDIUM DENSE to DENSE	26 N	30 N
	Overburden	9.40		309.003					
	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	9.40		4058	46	POOR			

	M21								
	Chainage (m)	836							
	Easting ING	326168.3		LAT	N 52 47.844915				
	Northing ING	173423.6		LONG	W 06 7.812114				
Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	2.4	151.647	37	SOFT	LOOSE	8 N	7 N
	Unconsolidated Overburden	2.40	3.5	242.131	106	FIRM to STIFF	MEDIUM DENSE to DENSE	26 N	31 N
	Overburden	3.50	10	269.553	145	STIFF	DENSE	32 N	42 N
		10.00		419.054					
Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	10.00		4392	54	FAIR			

	M18								
	Chainage (m)	900							
	Easting ING	326224.2		LAT	N 52 47.850984				
	Northing ING	173436.3		LONG	W 06 7.762038				
	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	1.8	235.708	100	FIRM	MEDIUM DENSE	25 N	28 N
	Unconsolidated Overburden	1.80	2.2	244.871	108	FIRM to STIFF	MEDIUM DENSE to DENSE	27 N	32 N
	Overburden	2.20	8	223.946	90	FIRM	MEDIUM DENSE	23 N	24 N
	Overburden	8.00	9.7	330.5	218	STIFF to VERY STIFF	VERY DENSE	45 N	>50 N
		9.70		359.283					
	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	9.70		4390	54	FAIR			

	M19								
	Chainage (m)	992							
	Easting ING	326319.1		LAT	N 52 47.864096				
	Northing ING	173463.1		LONG	W 06 7.677053				
Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	0.7	291.097	169	STIFF	DENSE to VERY DENSE	36 N	>50 N
	Unconsolidated Overburden	0.70	1.5	292.816	171	STIFF	DENSE to VERY DENSE	37 N	>50 N
	Overburden	1.50	3	309.779	192	STIFF	VERY DENSE	40 N	>50 N
	Overburden	3.00	9	367.457	270	STIFF to VERY STIFF	VERY DENSE	>50 N	>50 N
		9.00		422.328					
Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	9.00		4808	64	FAIR			

M37

Chainage (m)	117		
Easting ING	325510	LAT	N 52 47.717993
Northing ING	173171	LONG	W 06 8.403127

Sediment Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
Unconsolidated Overburden	0.00	2.137	170.078	46	SOFT to FIRM	LOOSE - MEDIUM DENSE	11 N	10 N
Unconsolidated Overburden	2.14	4.3	203.16	74	FIRM	MEDIUM DENSE	18 N	18 N
Unconsolidated Overburden	4.30	7.5	217.114	85	FIRM	MEDIUM DENSE	21 N	22 N
Overburden	7.50	10.3	308.566	190	STIFF	VERY DENSE	40 N	>50 N
	10.30		397.307					

Bedrock Type	Depth Below Seabed (m)	Vp (m/s)	RQD**	Quality
METASEDIMENT	10.30	3700	38	POOR

M06

Chainage (m)	178		
Easting ING	325569	LAT	N 52 47.723636
Northing ING	173183	LONG	W 06 8.350401

Sediment Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
Unconsolidated Overburden	0.00	1.924	189.032	64	FIRM	MEDIUM DENSE	15 N	14 N
Unconsolidated Overburden	1.92	4.329	190.52	65	FIRM	MEDIUM DENSE	16 N	16 N
Unconsolidated Overburden	4.33	7.335	228.672	94	FIRM	MEDIUM DENSE	24 N	26 N
Overburden	7.34	10.3	313.651	197	STIFF	VERY DENSE	41 N	>50N
	10.30		429.699	369	VERY DENSE		>50 N	>50 N

Bedrock Type	Depth Below Seabed (m)	Vp (m/s)	RQD**	Quality
METASEDIMENT	10.30	5723	91	EXCELLENT

M07

Chainage (m)	246		
Easting ING	325636	LAT	N 52 47.730784
Northing ING	173198	LONG	W 06 8.290493

Sediment Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
Unconsolidated Overburden	0.00	2.048	175.284	55	SOFT to FIRM	LOOSE - MEDIUM DENSE	13 N	11 N
Unconsolidated Overburden	2.05	4.3	201.547	73	FIRM	MEDIUM DENSE	18 N	18 N
Unconsolidated Overburden	4.30	7.6	220.613	88	FIRM	MEDIUM DENSE	22 N	23 N
Overburden	7.60	9	335.173	225	STIFF to VERY STIFF	VERY DENSE	46 N	>50 N
	9.00		400.177					

Bedrock Type	Depth Below Seabed (m)	Vp (m/s)	RQD**	Quality
METASEDIMENT	9.00	3745	39	POOR

M08

Chainage (m)	320		
Easting ING	325709	LAT	N 52 47.735693
Northing ING	173209	LONG	W 06 8.225344

Sediment Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
Unconsolidated Overburden	0.00	1.917	165.029	44	SOFT to FIRM	LOOSE - MEDIUM DENSE	10 N	9 N
Unconsolidated Overburden	1.92	4	173.557	48	SOFT to FIRM	LOOSE - MEDIUM DENSE	12 N	11 N
Unconsolidated Overburden	4.00	5.5	199.414	72	FIRM	MEDIUM DENSE	18 N	17 N
Overburden	5.50	7.2	272.453	148	STIFF	DENSE	33 N	43 N
	7.20		327.211	214			>50 N	.50 N

Bedrock Type	Depth Below Seabed (m)	Vp (m/s)	RQD**	Quality
METASEDIMENT	7.20	4373	53	FAIR

M09

Chainage (m)	392		
Easting ING	325779	LAT	N 52 47.744954
Northing ING	173228	LONG	W 06 8.162677

Sediment Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
Unconsolidated Overburden	0.00	1.537	170.261	46	LOOSE to MEDIUM DENSE	LOOSE - MEDIUM DENSE	10 N	10 N
Unconsolidated Overburden	1.54	3.9	167.677	45	LOOSE to MEDIUM DENSE	LOOSE - MEDIUM DENSE	10 N	10 N
Unconsolidated Overburden	3.90	4.7	232.111	97	MEDIUM DENSE	MEDIUM DENSE	27 N	22 N
Overburden	4.70	5.7	288.69	167	DENSE	DENSE	50 N	>50 N
	5.70		294.658					

Bedrock Type	Depth Below Seabed (m)	Vp (m/s)	RQD**	Quality
METASEDIMENT	5.70	2535	18	VERY POOR

M11

Chainage (m)	448		
Easting ING	325832	LAT	N 52 47.756607
Northing ING	173251	LONG	W 06 8.115030

Sediment Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
Unconsolidated Overburden	0.00	1.63	111.632	20	VERY SOFT	VERY LOOSE	-1 N	2 N
Unconsolidated Overburden	1.63	3.2	161.424	42	SOFT	LOOSE	10 N	8 N
Unconsolidated Overburden	3.20	4	261.573	137	STIFF	DENSE	30 N	38 N
Overburden	4.00	6	307.513	189	STIFF	VERY DENSE	40 N	>50 N
	6.00		345.874				>50 N	>50 N

Bedrock Type	Depth Below Seabed (m)	Vp (m/s)	RQD**	Quality
METASEDIMENT	6.00	2684	20	VERY POOR

M10

Chainage (m)	531		
Easting ING	325914	LAT	N 52 47.761388
Northing ING	173262	LONG	W 06 8.041878

Sediment Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
Unconsolidated Overburden	0.00	1.481	134.276	29	VERY SOFT to SOFT	VERY LOOSE - LOOSE	4 N	4 N
Unconsolidated Overburden	1.48	2.2	154.026	38	SOFT	LOOSE	8 N	7 N
Unconsolidated Overburden	2.20	3.2	194.163	68	FIRM	MEDIUM DENSE	16 N	16 N
Overburden	3.20	8.9	230.16	95	FIRM	MEDIUM DENSE	24 N	27 N
	8.90		352.606					

Bedrock Type	Depth Below Seabed (m)	Vp (m/s)	RQD**	Quality
METASEDIMENT	8.90	3778	40	POOR

M12

Chainage (m)	600		
Easting ING	325980	LAT	N 52 47.772319
Northing ING	173284	LONG	W 06 7.982697

Sediment Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
Unconsolidated Overburden	0.00	1.955	187.034	63	FIRM	MEDIUM DENSE	15 N	14 N
Unconsolidated Overburden	1.96	3	203.392	74	FIRM	MEDIUM DENSE	18 N	18 N
Overburden	3.00	7.452	225.871	92	FIRM	MEDIUM DENSE	23 N	25 N
Overburden	7.45	9.8	331.18	219	STIFF to VERY STIFF	VERY DENSE	45 N	>50 N
	9.80		386.88					

Bedrock Type	Depth Below Seabed (m)	Vp (m/s)	RQD**	Quality
METASEDIMENT	9.80	3232	29	POOR

M13

Chainage (m)	682		
Easting ING	326060	LAT	N 52 47.780899
Northing ING	173302	LONG	W 06 7.911161

Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	1.89	153.34	38	SOFT	LOOSE	8 N	7 N
	Unconsolidated Overburden	1.89	3.4	175.892	56	SOFT to FIRM	LOOSE - MEDIUM DENSE	13 N	11 N
	Overburden	3.40	7.204	249.453	112	FIRM to STIFF	MEDIUM DENSE - DENSE	28 N	34 N
	Overburden	7.20	10.895	317.108	201	STIFF	VERY DENSE	42 N	>50 N
		10.90		393.974					

Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality
	METASEDIMENT	10.90		3757	39	POOR

M14

Chainage (m)	742		
Easting ING	326117	LAT	N 52 47.788723
Northing ING	173318	LONG	W 06 7.860118

Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	1.233	259.524	135	STIFF	DENSE	30 N	37 N
	Unconsolidated Overburden	1.23	2.774	259.909	135	STIFF	DENSE	30 N	38 N
	Overburden	2.77	4.701	252.542	128	FIRM to STIFF	MEDIUM DENSE - DENSE	28 N	35 N
	Overburden	4.70	9	246.07	109	FIRM to STIFF	MEDIUM DENSE - DENSE	27 N	32 N
		9.00		336.608	227				

Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality
	METASEDIMENT	9.00		3747	39	POOR

M15

Chainage (m)	822		
Easting ING	326196	LAT	N 52 47.797315
Northing ING	173336	LONG	W 06 7.789470

Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	1.5	94.2167	14	VERY SOFT	VERY LOOSE	0 N	1 N
	Unconsolidated Overburden	1.50	3.7	165.299	44	SOFT to FIRM	LOOSE - MEDIUM DENSE	10 N	9 N
	Overburden	3.70	8	201.731	73	FIRM	MEDIUM DENSE	18 N	18 N
	Overburden	8.00	9.8	319.396	204	STIFF	VERY DENSE	42 N	>50 N
		9.80	19.258	373.793					

Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality
	METASEDIMENT	9.80		3869	42	POOR

M16

Chainage (m)	878		
Easting ING	326250	LAT	N 52 47.803563
Northing ING	173349	LONG	W 06 7.741163

Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	1.6	115.407	21	VERY SOFT	VERY LOOSE to LOOSE	0 N	2 N
	Unconsolidated Overburden	1.60	4.9	126.08	25	VERY SOFT to SOFT	VERY LOOSE - LOOSE	2 N	3 N
	Overburden	4.90	7.058	227.341	93	FIRM	MEDIUM DENSE	23 N	26 N
	Overburden	7.06	10	268.333	144	STIFF	DENSE	32 N	41 N
		10.00	15.193	324.254	210				

Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality
	METASEDIMENT	10.00		3994	44	POOR

M17

Chainage (m)	947		
Easting ING	326318	LAT	N 52 47.809076
Northing ING	173361	LONG	W 06 7.680433

Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	1.6	143.529	33	SOFT	LOOSE	6 N	5 N
	Unconsolidated Overburden	1.60	4	173.911	48	SOFT to FIRM	LOOSE to MEDIUM DENSE	12 N	10 N
	Overburden	4.00	7.295	204.053	75	FIRM	MEDIUM DENSE	18 N	27 N
	Overburden	7.30	9	305.259	186	STIFF	VERY DENSE	39 N	50 N
		9.00	15.703	416.522					

Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality
	METASEDIMENT	9.00		4517	57	FAIR

M40

Chainage (m)	1020		
Easting ING	326390	LAT	N 52 47.817764
Northing ING	173379	LONG	W 06 7.616007

Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	1.573	198.274	71	FIRM	MEDIUM DENSE	17 N	17 N
	Unconsolidated Overburden	1.57	2.8	197.69	70	FIRM	MEDIUM DENSE	17 N	17 N
	Overburden	2.80	5.998	212.061	81	FIRM	MEDIUM DENSE	20 N	21 N
	Overburden	6.00	8.9	329.259	217	STIFF to VERY STIFF	VERY DENSE	44 N	>50 N
		8.90	12.912	441.431				>50 N	>50 N

Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality
	METASEDIMENT	8.90		4514	57	FAIR

M41

Chainage (m)	1100		
Easting ING	326466	LAT	N 52 47.826397
Northing ING	173397	LONG	W 06 7.548025

Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	2.086	339.801	231	STIFF to VERY STIFF	VERY DENSE	46 N	>50 N
	Unconsolidated Overburden	2.09	4.5	325.167	211	STIFF to VERY STIFF	VERY DENSE	43 N	>50 N
	Overburden	4.50	7.8	300.834	181	STIFF	DENSE to VERY DENSE	38 N	>50 N
		7.80		397.703					

Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality
	METASEDIMENT	7.80		4641	60	FAIR

	M50								
	Chainage (m)	34							
	Easting ING	325384.5		**LAT**	N 52 47.852608				
	Northing ING	173417.6		**LONG**	W 06 8.509031				
Sediment	**Type**	**Depth Below Seabed (m)**	**To**	**Vs (m/s)**	**Gmax (Mpa)**	**Stiffness Cohesive**	**Stiffness Granular**	**SPT* Cohesive**	**SPT* Granular**
	Unconsolidated Overburden	0.00	1.89	187.068	63	FIRM	MEDIUM DENSE	15 N	14 N
	Unconsolidated Overburden	1.89	3.5	190.335	65	FIRM	MEDIUM DENSE	16 N	15 N
	Unconsolidated Overburden	3.50	7.206	217.021	85	FIRM	MEDIUM DENSE	21 N	22 N
	Overburden	7.21	12	311.902	195	STIFF	VERY DENSE	41 N	>50 N
		12.00		400.328					
Bedrock	**Type**	**Depth Below Seabed (m)**		**Vp (m/s)**	**RQD****	**Quality**			
	METASEDIMENT	12.00		5788	93	EXCELLENT			

	M49								
	Chainage (m)	126							
	Easting ING	325395.5		**LAT**	N 52 47.803274				
	Northing ING	173326.3		**LONG**	W 06 8.501371				
	Type	**Depth Below Seabed (m)**	**To**	**Vs (m/s)**	**Gmax (Mpa)**	**Stiffness Cohesive**	**Stiffness Granular**	**SPT* Cohesive**	**SPT* Granular**
	Unconsolidated Overburden	0.00	2.518	155.757	39	SOFT	LOOSE	9 N	7 N
	Unconsolidated Overburden	2.52	3.4	201.244	73	FIRM	MEDIUM DENSE	18 N	18 N
	Unconsolidated Overburden	3.40	7.1	198.095	71	FIRM	MEDIUM DENSE	17 N	17 N
	Overburden	7.10	12	281.567	159	STIFF	DENSE	34 N	47 N
		12.00		355.371					
	Type	**Depth Below Seabed (m)**		**Vp (m/s)**	**RQD****	**Quality**			
	METASEDIMENT	12.00		5411	81	GOOD			

	M48								
	Chainage (m)	182							
	Easting ING	325403.1		**LAT**	N 52 47.773073				
	Northing ING	173270.5		**LONG**	W 06 8.495857				
Sediment	**Type**	**Depth Below Seabed (m)**	**To**	**Vs (m/s)**	**Gmax (Mpa)**	**Stiffness Cohesive**	**Stiffness Granular**	**SPT* Cohesive**	**SPT* Granular**
	Unconsolidated Overburden	0.00	2.216	174.619	49	SOFT to FIRM	LOOSE to MEDIUM DENSE	12 N	11 N
	Unconsolidated Overburden	2.22	3.5	181.743	59	FIRM	MEDIUM DENSE	14 N	13 N
	Unconsolidated Overburden	3.50	7	208.505	78	FIRM	MEDIUM DENSE	19 N	20 N
	Overburden	7.00	12.775	269.528	145	STIFF	DENSE	32 N	42 N
		12.78		307.824					
Bedrock	**Type**	**Depth Below Seabed (m)**		**Vp (m/s)**	**RQD****	**Quality**			
	METASEDIMENT	12.78		5152	74	FAIR			

	M47								
	Chainage (m)	264							
	Easting ING	325415.3		**LAT**	N 52 47.728836				
	Northing ING	173188.7		**LONG**	W 06 8.486881				
	Type	**Depth Below Seabed (m)**	**To**	**Vs (m/s)**	**Gmax (Mpa)**	**Stiffness Cohesive**	**Stiffness Granular**	**SPT* Cohesive**	**SPT* Granular**
	Unconsolidated Overburden	0.00	2.446	184.106	61	FIRM	MEDIUM DENSE	14 N	13 N
	Unconsolidated Overburden	2.45	3.5	202.921	74	FIRM	MEDIUM DENSE	18 N	18 N
	Unconsolidated Overburden	3.50	7	191.768	66	FIRM	MEDIUM DENSE	16 N	15 N
	Overburden	7.00	11	272.449	148	STIFF	DENSE	33 N	43 N
		11.00		302.392					
	Type	**Depth Below Seabed (m)**		**Vp (m/s)**	**RQD****	**Quality**			
	METASEDIMENT	11.00		5989	100	EXCELLENT			

	M55								
	Chainage (m)	104							
	Easting ING	325616.4		LAT	N 52 47.803951				
	Northing ING	173333.3		LONG	W 06 8.304842				
Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	2.283	203.331	74	FIRM	MEDIUM DENSE	18 N	18 N
	Unconsolidated Overburden	2.28	5.137	179.767	58	SOFT to FIRM	LOOSE to MEDIUM DENSE	13 N	12 N
	Overburden	5.14	9.7	331.813	220	STIFF to VERY STIFF	VERY DENSE	45 N	>50 N
		9.70		381.482					
Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	9.70		2836	22	VERY POOR			

	M54								
	Chainage (m)	195							
	Easting ING	325638.8		LAT	N 52 47.756035				
	Northing ING	173244.9		LONG	W 06 8.286892				
	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	2.612	212.027	81	FIRM	MEDIUM DENSE	20 N	21 N
	Unconsolidated Overburden	2.61	5.877	190.602	65	FIRM	MEDIUM DENSE	16 N	15 N
	Overburden	5.88	8.599	335.366	225	STIFF to VERY STIFF	VERY DENSE	46 N	>50 N
		8.60		389.933					
	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	8.60		2337	15	VERY POOR			

	M52								
	Chainage (m)	111							
	Easting ING	325617.1		LAT	N 52 47.800231				
	Northing ING	173326.4		LONG	W 06 8.304325				
Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	2.092	203.521	75	FIRM	MEDIUM DENSE	18 N	18 N
	Unconsolidated Overburden	2.09	4.707	175.287	55	SOFT to FIRM	LOOSE to MEDIUM DENSE	13 N	11 N
	Unconsolidated Overburden	4.71	9.601	302.982	184	STIFF	DENSE to VERY DENSE	39 N	>50 N
	Overburden	9.60	12.061	389.853	304	VERY STIFF	VERY DENSE	>50 N	>50 N
		12.06	17.168	492.363					
Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	9.60		2836	22	VERY POOR			

	M51								
	Chainage (m)	201							
	Easting ING	325641.9		LAT	N 52 47.752988				
	Northing ING	173239.4		LONG	W 06 8.284257				
	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	2.676	209.849	79	FIRM	MEDIUM DENSE	20 N	20 N
	Unconsolidated Overburden	2.68	6.021	197.993	71	FIRM	MEDIUM DENSE	17 N	17 N
	Unconsolidated Overburden	6.02	8.6	318.887	203	STIFF	VERY DENSE	42 N	>50 N
	Overburden	8.60	15.429	409.946	336	VERY STIFF	VERY DENSE	>50 N	>50 N
		15.43	21.962	531.794					
	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	8.60		2337	15	VERY POOR			

	M42								
	Chainage (m)	684							
	Easting ING	326242.2		LAT	N 52 47.772240				
	Northing ING	173290.7		LONG	W 06 7.749476				
Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	1.6	145.857	34	SOFT	LOOSE	6 N	6 N
	Unconsolidated Overburden	1.60	4.8	166.674	44	SOFT to FIRM	LOOSE to MEDIUM DENSE	11 N	9 N
	Unconsolidated Overburden	4.80	9	247.591	110	FIRM to STIFF	MEDIUM DENSE to DENSE	27 N	33 N
	Overburden	9.00	11.25	340.48	232	STIFF to VERY STIFF	VERY DENSE	47 N	>50 N
		11.25		368.037					
Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	11.25		4428	54	FAIR			

	M43								
	Chainage (m)	775							
	Easting ING	326327.8		LAT	N 52 47.786121				
	Northing ING	173318.7		LONG	W 06 7.672697				
	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	1.3	164.528	43	SOFT	LOOSE	10 N	9 N
	Unconsolidated Overburden	1.30	2.6	188.409	64	FIRM	MEDIUM DENSE	15 N	14 N
	Overburden	2.60	6	167.513	45	SOFT to FIRM	LOOSE to MEDIUM DENSE	11 N	10 N
	Overburden	6.00	9.2	222.721	89	FIRM	MEDIUM DENSE	22 N	24 N
		9.20		331.37					
	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	9.20		4904	67	FAIR			

	M53								
	Chainage (m)	229							
	Easting ING	326050.8		LAT	N 52 47.794384				
	Northing ING	173326.8		LONG	W 06 7.918763				
Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	2.483	230.996	96	FIRM	MEDIUM DENSE to DENSE	24 N	27 N
	Unconsolidated Overburden	2.48	5.586	213.612	82	FIRM	LOOSE to MEDIUM DENSE	20 N	21 N
	Overburden	5.59	9.8	324.908	211	STIFF to VERY STIFF	VERY DENSE	43 N	>50 N
		9.80		410.522					
Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	9.80		3863	41	POOR			

	M46								
	Chainage (m)	297							
	Easting ING	326071.1		LAT	N 52 47.758804				
	Northing ING	173261.3		LONG	W 06 7.902196				
	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	1.926	202.436	74	FIRM	MEDIUM DENSE	18 N	18 N
	Unconsolidated Overburden	1.93	4.333	184.268	61	FIRM	MEDIUM DENSE	14 N	13 N
	Overburden	4.33	7.342	264.451	140	STIFF	DENSE	31 N	39 N
	Overburden	7.34	11.6	344.054	237	STIFF to VERY STIFF	VERY DENSE	47 N	>50 N
		11.60		405.798					
	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	11.60		4070	46	POOR			

	M45								
	Chainage (m)	222							
	Easting ING	326259.3		LAT	N 52 47.826243				
	Northing ING	173391.3		LONG	W 06 7.731920				
Sediment	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	2.508	110.456	20	VERY SOFT	VERY LOOSE	0 N	2 N
	Unconsolidated Overburden	2.51	5.643	156.679	39	SOFT	LOOSE	9 N	8 N
	Unconsolidated Overburden	5.64	9.4	253.651	129	FIRM to STIFF	MEDIUM DENSE to DENSE	29 N	35 N
	Overburden	9.40		348.387					
Bedrock	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	9.40		4084	46	POOR			

	M44								
	Chainage (m)	317							
	Easting ING	326278		LAT	N 52 47.775738				
	Northing ING	173298.1		LONG	W 06 7.717435				
	Type	Depth Below Seabed (m)	To	Vs (m/s)	Gmax (Mpa)	Stiffness Cohesive	Stiffness Granular	SPT* Cohesive	SPT* Granular
	Unconsolidated Overburden	0.00	1.813	122.099	24	VERY SOFT to SOFT	VERY LOOSE to LOOSE	2 N	3 N
	Unconsolidated Overburden	1.81	4.08	131.297	28	VERY SOFT to SOFT	VERY LOOSE to LOOSE	3 N	4 N
	Overburden	4.08	6.913	215.386	84	FIRM	MEDIUM DENSE to DENSE	21 N	22 N
	Overburden	6.91	10.6	254.221	129	FIRM to STIFF	MEDIUM DENSE to DENSE	29 N	35 N
		10.60		327.68					
	Type	Depth Below Seabed (m)		Vp (m/s)	RQD**	Quality			
	METASEDIMENT	10.60		3942	43	POOR			

9. APPENDIX C: DETAILED METHODOLOGY

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

9.1 Multichannel Analysis of Surface Waves (MASW)

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

9.1.1 Principles

The Multi-channel Analysis of Surface Waves (MASW) (Park et al., 1998, 1999) utilises surface waves (Rayleigh waves in the terrestrial environment) 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.

In the terrestrial environment the type of Surface wave which is measured is generally the Rayleigh wave, which travels along the earth – air boundary. In the marine environment at the interface between water and solid material the surface wave behaviour is different and it is the Scholte wave which is measured. While similar to the Rayleigh wave it propagates with a velocity in the range of 88% - 99% of the Rayleigh wave. This range of variation depends on the frequency content of the wave and the water column thickness (Kaufmann et al., 2005).

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.

9.1.2 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 with 2.95m hydrophone spacing. The hydrophone cable remains stationary on the seabed during data acquisition and the airgun discharges slightly off the seabed. Once data acquisition is complete on one spread the cable is lifted from the seabed and recovered to the deck of the survey vessel.

9.1.3 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 Scholte 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) Following application of a Scholte wave to Rayleigh wave conversion ratio the shear wave velocities were then used to calculate 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)

9.1.4 Relocation

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

9.2 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.

9.2.1 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.

9.2.2 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 (generally set to 300 Joules), a high voltage cable connecting to the 200 tip sparker unit. Prior to commencement of acquisition of production data acquisition parameterisation and energy level testing was undertaken. 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.

9.2.3 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 navigation positions)
- ✓ Surface related multiple suppression
- ✓ Time cut
- ✓ Spherical divergence compensation
- ✓ Bandpass Butterworth filter

- ✓ Seabed Mute application
- ✓ Display optimisation
- ✓ Interpretation of sediment and bedrock layers using automated negative phase tracker
- ✓ Stretch of picked data to depth domain based on conversion velocity of 1900m/s
- ✓ Application of spatially varying time specific tidal correction computed from high resolution UKCS model (CS20-15HC) to reduce the data to Lowest Astronomical Tide (LAT)

The interpreted layer boundaries were stretched to the depth domain based on a conversion velocity of 1900m/s. The conversion velocity was chosen following analysis of the finalised velocity regimes from the seismic refraction and 1D MSASW datasets in conjunction with the time domain layer boundary picks from the sub bottom profiler data.

9.2.4 Relocation

The sub bottom profiler data was acquired using a combination of a system integrated with the ships on board dGPS navigation system and a GEO7X VRS system. The data was saved in Irish National Grid coordinates.

9.3 Seismic refraction profiling

9.3.1 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 can be 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 hydrophones connected via multi-core cable to a seismograph.

9.3.2 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.

9.3.3 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).

9.3.4 Relocation

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

10. APPENDIX D: MARINE MAMMAL OBSERVER REPORT

Marine mammal observer report

Arklow Waste Water Treatment Plant

Project Name:

Arklow Waste Water Treatment Plant – Marine Outfall Geophysical Investigation

Client:

Byrne Looby Arup

Date: March 2017

Marine mammal observer: Anthony Irwin,
Elly, Clogher,
Belmullet, Co. Mayo
Ireland

Marine Geophysical Investigation: Apex Geoservices Ltd.
6 Knockmullen Business Park,
Gorey,
Co. Wexford
Ireland

Summary

As part of the ground investigation works for a proposed marine outfall pipeline for the Arklow Waste Water Treatment Plant Apex Geoservices Ltd undertook a geophysical investigation over a number of sessions between the 6th and 16th of March 2017. The investigation consisted of single channel seismic reflection sub bottom profiler, seismic refraction profiling and multichannel analysis of surface waves (MASW) surveying.

Location

The area under investigation was situated offshore Arklow, immediately north of the mouth of the Avoca River, and extended from the coastline to c. 1.5km offshore. Data acquisition was conducted along a series of southwest – northeast oriented profiles at c. 25m spacing and on northwest – southeast oriented profiles at c. 100m spacing. The generalised survey location is shown in Figure 1.

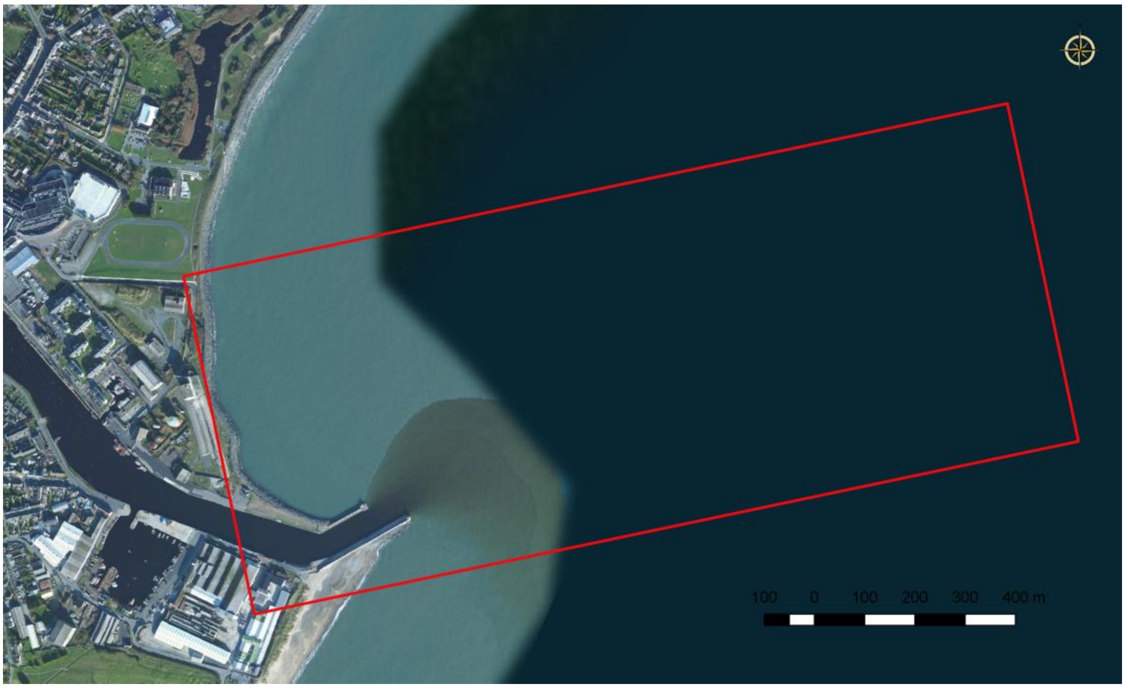


Figure 1. LOCATION MAP SHOWING GENERALISED SURVEY AREA OUTLINED IN RED.

Methods

The survey was conducted aboard the vessel *Dulra na Mara*, a 12.5 meter twin engine multipurpose research vessel and Fionn *mac cumhaill an 11m twin engine, cabin RIB.*

Equipment

The equipment for the single channel seismic reflection sub bottom profiler investigation was a marine Sparker system. The equipment consisted of a pulsed power supply, a high voltage cable, a 200 tip Sparker unit with frequency content 250Hz – 3.5KHz and an eight element single channel hydrophone receiver.

The equipment for the seismic refraction and MASW surveys consisted of a 12-cu. in. Mini G Gun energy source under control of a MG-SCU Source Controller. In response to a trigger source the Source Controller produces a high voltage pulse of 15ms duration for firing the Air Gun solenoid. The amplitude of the pulse is adjustable between 125 and 100V. The receiver for the survey was a 24 channel Bay Cable hydrophone.

A Marine Mammal Observer (MMO) was aboard the survey vessel for the whole duration of the survey work. In accordance with the code of practise for marine survey (NPWS 2007), the MMO conducted a 30-minute survey before starting survey operations.

The marine mammal observer conducted a continuous survey before survey operations (Table 1). Binoculars (Steiner pro navigator 7x50) and a hand-held compass were used to survey the area surrounding the vessel, assist with the species identification and direction of travel of animals recorded.

Environmental conditions were recorded at the start of each observation period, and at the start of survey operations. Sea state ranged between 2 and 4 during the survey work, with only small to medium waves present during the survey (Table 1).

Results

A total of 10.5 hours of visual survey effort was conducted (Table 1). All visual effort was conducted in suitable weather conditions sea state <4 (Fig. 2). One marine mammal sighting was recorded.

One marine mammal sighting of a single Harbour porpoise (*Phocoena phocoena*) was recorded on March 8 2017 (Fig. 2). The sighting was recorded during survey operation with the vessel on line and conducting a sparker survey.

Figure 2. DATA FORM FOR COASTAL/MARINE WORKS - MARINE MAMMAL SIGHTING RECORDS

Operation/Activity (please tick)	**Dredging**	**Drilling**	**Pile Driving**	**Blasting**	**Other** Sparker Survey MASW

Date 08/03/2017	**Time 10:28**	**Time** 10:28	**Sighting Record no.** 001

How did this sighting occur? (please tick) Other (please specify) Details:..Spotted While on line during sparker survey...

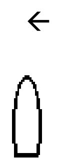
Platform type & name 12.5 meter survey vessel Dulra Na mara	**Observer's name** Anthony irwin

Observer's position 52°48'.027N 006°07'.605W	**Water depth** 8.2 Meters

Species recorded **Harbour Porpoise**	**Certainty of identification** *Definite*

Total number of animals 01	**No. of adults** **01**	**No. of juveniles** **0**	**No. of calves** **0**

Maximum number 01	**Minimum number** 01

Description (include features such as overall size; shape of head; position, shape and size of dorsal fin; colour and patterning; height, direction, shape of blow)	**Photograph or video taken** *No* **Direction of travel of animals in relation to platform/vessel** (draw arrow) 
Behaviour Travelling north to South	**Direction of travel of animals** (compass points or degrees) Approx 180°

Activity of platform/vessel Sparker survey in progress	**Operation/activity under way** (when animals first seen) *Yes*	**Closest distance of animals from platform/vessel** (metres) (Record even if not operating) 60 Meters

Table 1. DATA FORM FOR COASTAL/MARINE WORKS - RECORD OF OPERATION/ACTIVITY

Platform name: Dulra Na mara Platform type: 12.5M Survey vessel Client: Irish Water Contractor: APEX GEO Services   MMO: Anthony Irwin

Complete this form every time the sound-producing operation or activity (e.g., drilling, pile driving, blasting) occurs including overnight, whether for testing, full operation or any other purpose.

		Sound-producing operation or activity			Pre-Start Monitoring effort for marine mammals					Action necessary		
Type of operation or activity Dredging, Drilling, Pile driving, Blasting, other	**Date** (dd/mm/yyyy)	Time when ramp-up/soft-start began [if any] (GMT/UTC)	Time when equipment reached full power (GMT/UTC)	Time when equipment stopped or shut down (GMT/UTC)	Who carried out the monitoring for marine mammals? (Job Title)	Start time of monitoring for marine mammals [Pre-start-up] (GMT/UTC)	End time of monitoring for marine mammals (GMT/UTC)	Reason for non-detection of marine mammals? (e.g. sea state, swell, glare, poor light, fog, rain, etc.)	Were hydro-phones used? (Yes/No)	Were marine mammals present in the 30/60 mins before start-up? (Yes/No)	If Yes, give time when marine mammals were last seen (GMT/UTC)	If marine mammals were present, what action was taken? (e.g., delay ramp-up/soft start, delay full start-up)
Sparker Survey	06/03/17	16:20	16:35	18:50	Anthony Irwin	15:50	16:20	None present	no	no	n/a	n/a
Sparker Survey	07/03/17	09:30	09:15	12:10	Anthony Irwin	09:00	09:30	None present	no	no	n/a	n/a
Sparker Survey	08/03/17	09:30	09:45	18:00	Anthony Irwin	09:00	09:30	None present	no	no	n/a	n/a
Sparker Survey	09/03/17	11:30	11:50	19;00	Anthony Irwin	11:00	11:30	None present	no	no	n/a	n/a
MASW	10/03/17	11:15	11:30	17:00	Anthony irwin	10:45	11:15	None present	no	no	n/a	n/a
MASW	11/03/17	09:35	09:50	17:27	Anthony Irwin	08:05	09:35	None present	no	no	n/a	n/a
MASW	12/03/17	09:00	09:30	16:55	Anthony Irwin	08:30	09:00	None present	no	no	n/a	n/a
MASW	13/03/17	09:00	09:15	17:20	Anthony Irwin	08:30	09:00	None present	no	no	n/a	n/a
MASW	14/03/17	09:00	09:15	18:10	Anthony irwin	08:30	09:00	None present	no	no	n/a	n/a

MASW	15/03/17	09:10	09:25	17:20	Anthony Irwin	08:30	09:00	None present	no	no	n/a	n/a
MASW	16/03/17	09:15	09:25	16:40	Anthony Irwin	08:30	09:00	None present	no	no	n/a	n/a
MASW	17/03/17	DEMOB	DEMOB	DEMOB	Anthony irwin	DEMOB	DEMOB	None present	no	no	n/a	n/a

Table 2. DATA FORM FOR COASTAL/MARINE WORKS – RECORD OF MONITORING EFFORT

Location Arklow Co Wicklow Platform name: Dulra na mara Platform 12.5 m Surver Vessel type: 5m platform Client: Irish Water MMO(s): Anthony Irwin

Please record the following information every day (as many lines per day as you wish), even if no marine mammals are seen.

Type of operation or activity Dredging, Drilling, Pile driving, Blasting, other	**Date** (dd/mm/yyyy)	**Marine Mammal Observer** (name/initials)		Time you stopped monitoring for marine mammals (GMT/UTC)	Duration of monitoring watch (minutes)	Duration of the sound-producing operation/activity while you were monitoring for marine mammals (minutes)	Start Lat/Long position (if static/moving)	End Lat/Long position (if moving)	Wind direction & Beaufort wind force (e.g., SW 2)	Sea State (WMO) (0 to 9)	Swell height Choose from: 0 = no Swell L = 0-1 m M = 1-2 m H = 2+ m	Visibility Choose from: P = < 1 km M = 1-5 km G = 5-10 km H = >10 km
Sparker Survey	06/03/17	Anthony Irwin	15:50	16:20	30	<1	Daily pre start watch position 52°47'.884N 006°07'.145W.	n/a	W/F4	1	No Swell	10km
Sparker Survey	07/03/17	Anthony Irwin	09:00	09:30	30	<1	Daily pre start watch position 52°47'.884N 006°07'.145W	n/a	W/F4/5/6	3	1/2M	5/10km
Sparker Survey	08/03/17	Anthony Irwin	09:00	09:30	30	<1	Daily pre start watch position 52°47'.884N 006*07'.145W	n/a	SW/F3	1	0.5M	5-1010km
Sparker Survey	09/03/17	Anthony Irwin	11:00	11:30	30	<1	Daily pre start watch position 52°47'.884N 006°07'.145W	n/a	S/F4/5	3	1M	5-10km
MASW	10/03/17	Anthony Irwin	10:45	11;15	30	<1	Daily pre start watch position 52°47'.884N 006°07'.145W	n/a	SSW/4/6	4	1.5M	1-5km

MASW	11/03/17	Anthony Irwin	08:05	09:35	30	<1	Daily pre start watch position 52°47'.884N 006°07'.145W	n/a	W/F1/3	1	0.5M	1.5km
MASW	12/03/17	Anthony Irwin	08:30	09:00	30	<1	Daily pre start watch position 52°47'.884N 006°07'.145W	n/a	WNW/F4/5	3	0.5	>10km
MASW	13/03/17	Anthony Irwin	08:30	09:00	30	<1	Daily pre start watch position 52°47'.884N 006°07'.145W	n/a	Wsw/F1	2	0.5	>10km
MASW	14/03/17	Anthony Irwin	08:30	09:00	30	<1	Daily pre start watch position 52°47'.884N 006°07'.145W	n/a	W/SWF3	2	0.5	>10km
MASW	15/03/17	Anthony Irwin	08:30	09:00	30	<1	Daily pre start watch position 52°47'.884N 006°07'.145W	n/a	S/SWF2	2	0.5	>10km
MASW	16/03/17	Anthony Irwin	08:30	09:00	30	<1	Daily pre start watch position 52°47'.884N 006°07'.145W	n/a	SWF3	2	0.5	>10km