Digby Bridge Attachment D1-Tier 2 Report

Appendix A Geophysical Survey Report

AGL17263_02

REPORT

ON THE

GEOPHYSICAL INVESTIGATION

AT

DIGBY BRIDGE LANDFILL, CO. KILDARE

FOR

CDM SMITH

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03TH MAY 2019

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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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CONTENTS

1. **EXECUTIVE SUMMARY** ... **1**
2. **INTRODUCTION** ... **2**
2.1 Survey Objectives ... 2
2.2 Site Background ... 2
2.3 Geology & Soils ... 2
2.4 Direct Investigation Data ... 4
2.5 Survey Rationale ... 4
3. **RESULTS** ... **5**
3.1 EM Ground Conductivity Mapping ... 5
3.2 Electrical Resistivity Tomography ... 5
3.3 Seismic Refraction Profiling ... 6
3.4 MASW ... 6
3.5 Discussion ... 8
3.5.1 Extent of the waste ... 8
3.5.2 Type of waste ... 8
3.5.3 Thickness of waste and possible leachate ... 8
4. **REFERENCES** ... **10**
5. **APPENDIX A: DETAILED METHODOLOGY** ... **11**
5.1 EM ground conductivity mapping ... 11
5.1.1 Principles ... 11
5.1.2 Data collection ... 11
5.1.3 Data processing ... 11
5.2 Electrical Resistivity Tomography (ERT) ... 11
5.2.1 Principles ... 11
5.2.2 Data Collection ... 11
5.2.3 Data Processing ... 12
5.3 Seismic Refraction Profiling ... 12
5.3.1 Principles ... 12
5.3.2 Data Collection ... 12
5.3.3 Data Processing ... 12
5.4 Multi-channel Analysis of Surface Waves ... 13
5.4.1 Principles ... 13
5.4.2 Data Collection ... 13
5.4.3 Data Processing ... 13
5.5 Spatial relocation ... 14
6. **APPENDIX B: DRAWINGS** ... **15**
7. **APPENDIX C: SEISMIC PLATES** ... **16**
8. **APPENDIX D: MASW DATA** ... **18**

1. EXECUTIVE SUMMARY

APEX Geoservices Limited was requested by CDM Smith to carry out a geophysical survey at a landfill site in Digby Bridge, County Kildare as part of an environmental risk assessment.

Digby Bridge Landfill is located approximately 2.5km north-west of the village of Sallins and is to the south of a local road and the Grand Canal. The site is c. 8.17Ha in extents and consists of open grassland.

The Geological Survey Ireland (GSI) maps for the area indicate the site is underlain by gravels derived from limestones and the bedrock type across the site is the Rickardstown Fomation, which consists of cherty and often dolomitised limestone.

The geophysical investigation consisted of reconnaissance EM ground conductivity mapping with follow-up Electrical Resistivity Tomography, Seismic Refraction and Multi-channel Analysis of Surface Waves (MASW) profiling.

Across the site MADE GROUND/TOPSOIL is c. 0.2 – 1.8m thick with areas of little or no waste present close to the eastern, northern and south-western boundaries of the site.

The geophysical datasets in conjunction with client supplied trial pit and monitoring well logs are interpreted to define the type of waste as MADE GROUND/WASTE (mixed and organic).

MADE GROUND/WASTE (mixed & organic) has been interpreted based on EM conductivity (30 - 148 mS/m) and ERT resistivity values (5 - 60 Ohm-m).

Interpreted thickness of MADE GROUND/WASTE (mixed and organic) ranges from 5.2 – 8.9m with an average of 7.8m.

The main waste body lies across central, southern and western parts of the site and covers approximately 4.7Ha. The volume of waste is estimated as 366,600 cu.m. and tonnage is estimated at 513,240 tonnes.

Low model resistivity values (< 60 Ohm-m) beneath interpreted base of waste indicate possible leachate beneath base of waste.

Minor levels of waste may also be present in soil layers interpreted as predominantly sandy gravelly clay away from the main area of waste. This is confirmed by the client supplied trial pit and monitoring well logs which indicate plastics in these areas.

Depth to interpreted top of limestone bedrock varies from c. 9.8 to 22.4m below ground level across the site.

2. INTRODUCTION

APEX Geoservices Limited was requested by CDM Smith to carry out a geophysical survey at a landfill site in Digby Bridge, County Kildare as part of an environmental risk assessment.

2.1 Survey Objectives

The objective of the investigation is to aid in determination of:

- The extent of the waste body.
- The thickness of the waste body and presence of any anomalous features.
- A volume calculation.

2.2 Site Background

Digby Bridge Landfill is located approximately 2.5km north-west of the village of Sallins and is to the south of a local road and the Grand Canal. The site comprises c. 8.17Ha of open grassland. Topography on the site ranges from 80.5 in the east to 88.2m OD in the south.

The location of the site is shown below in Figure 2.1.

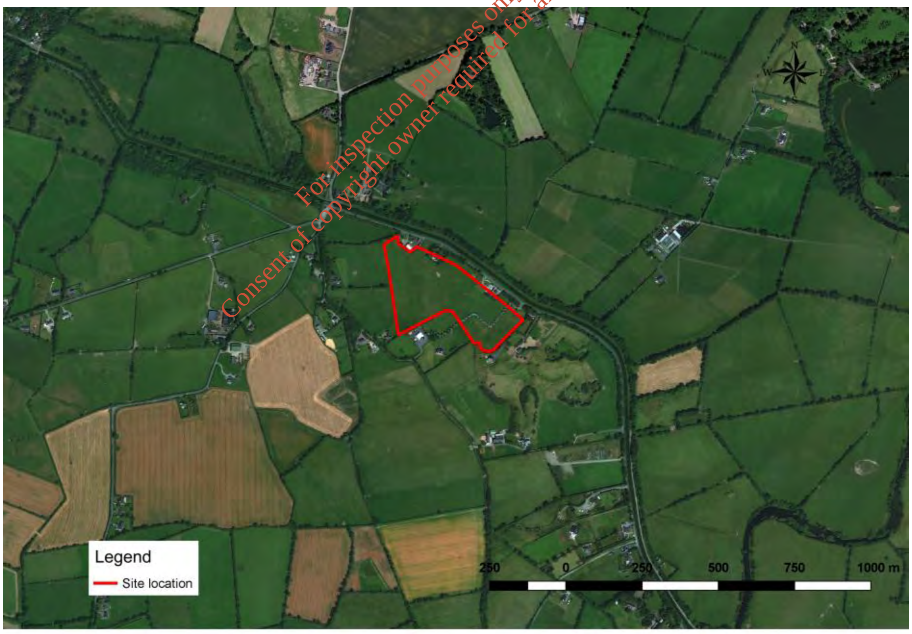

Fig 2.1: Location map (site marked in red).

2.3 Geology & Soils

The Geological Survey Ireland (GSI) soils map for the area (Fig. 2.2) indicates that the site is originally underlain by gravels derived from limestones. Alluvium is shown to the north and northeast of the site.

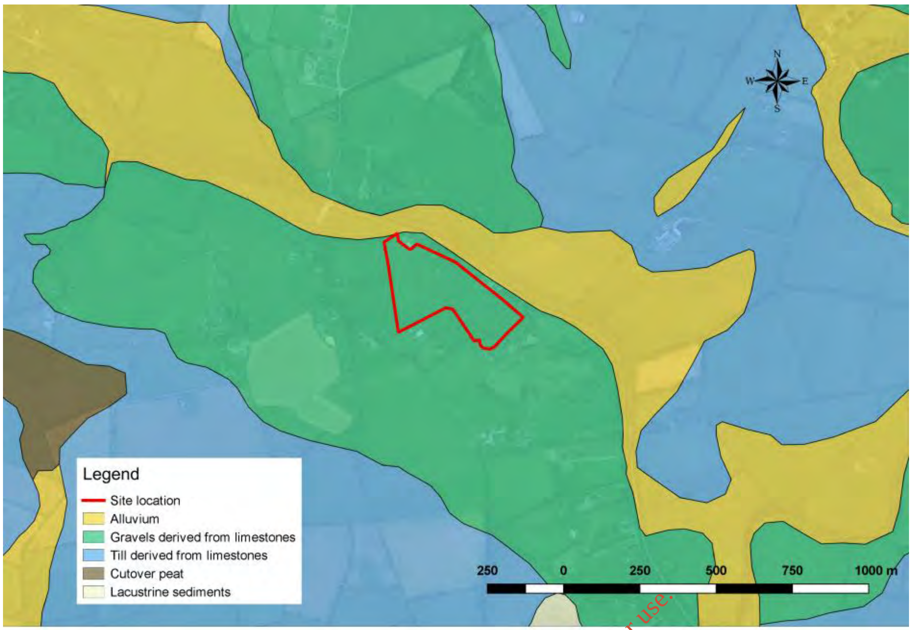

Fig 2.2: The GSI soils map (site outlined in red).

The GSI 1:100,000 Bedrock Geology map for the area (Figure 2.3) indicates that the site is underlain by the Rickardstown Fomation, which consists of cherty and often dolomitised limestone. The map also shows massive unbedded lime-mudstone of the Waulsortian limestones lying to the southeast of the site.

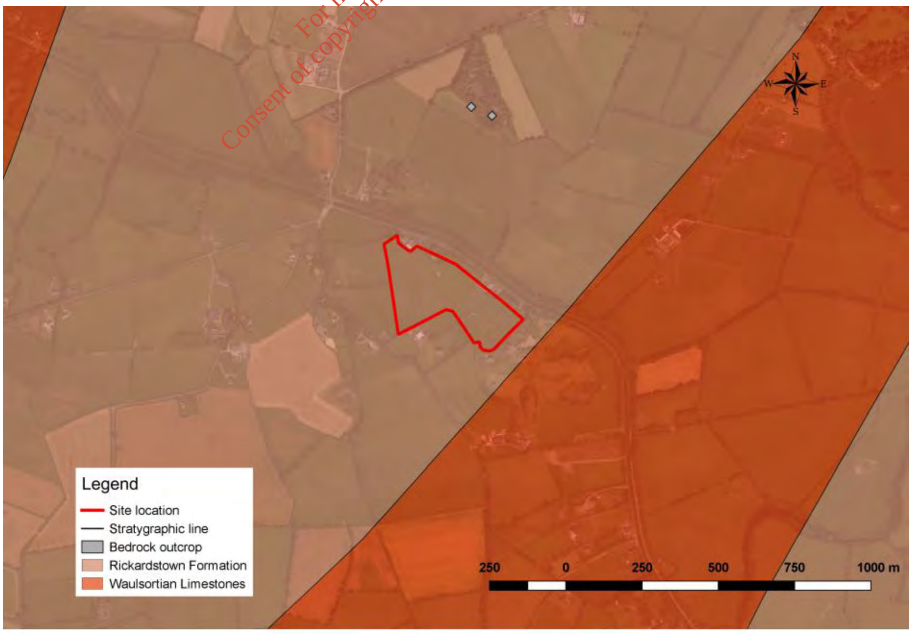

Figure 2.3. Bedrock geological map for the survey area (site marked in red).

2.4 Direct Investigation Data

In 2019 a suite of direct investigation information was supplied by the client for incorporation into this report.

The direct investigation comprises twenty six trial pits and seventeen monitoring wells.

The trial pits show the following general stratigraphy; topsoil (0.2 – 1.5m) over mixed waste material to between 1.8 and 4.8m below ground level (bgl) over dense silty gravelly sand. Thirteen of the pits terminate in waste, six show waste over inert material and seven do not encounter waste.

Thirteen of the monitoring wells show made ground including waste to between 0.5 and 7.9m bgl. The waste overlies sand, silty sandy gravel and sandy gravelly clay to between 4.0 and 16.5m bgl. Possible bedrock is encountered in five of the monitoring wells at depths of 8.3 – 14.8m bgl.

2.5 Survey Rationale

The investigation consisted of reconnaissance Electromagnetic (EM) ground conductivity mapping with follow-up Electrical Resistivity Tomography (ERT), Seismic Refraction profiling and Multi-Channel Analysis of Surface Waves (MASW).

- EM ground conductivity mapping has been carried out across the site in order to map the extent of the fill and variations in the fill, and also to screen for any leachate plumes and obtain background values for the soils and rock.

- Electrical Resistivity Tomography (ERT) has been carried out along selected survey lines to investigate variations in the thickness and extent of the fill material and leachate, as well as to investigate the overburden and bedrock geology.

- Seismic refraction was carried out at selected locations. The results of the seismic survey have been used to outline the fill/soil boundary.

- 1D MASW was carried out on the seismic refraction profiles. The results of the MASW have been used to indicate base of waste material. The MASW method is used to estimate shear-wave (S-wave) velocities in the ground material to indicate possible soft zones. Soil / fill material with an S-wave velocity of <175 m/s is generally classified as soft/loose.

As with all geophysical methods the results are based on indirect readings of the subsurface properties. The effectiveness of the proposed approach will be affected by variations in the ground properties. By combining a number of techniques it is possible to provide a higher quality interpretation and reduce any ambiguities which may otherwise exist. Further information on the detailed methodology of each geophysical method employed in this investigation is given in **APPENDIX A: DETAILED METHODOLOGY**.

3. RESULTS

The survey was carried out on the 01st and 02nd of November 2017 and involved the collection of 1257 EM conductivity data points, 7 no. ERT profiles, 4 no. seismic refraction profiles and associated 1D MASW soundings.

The geophysical investigation locations are indicated on Drawing AGL17263_01 (Appendix B).

3.1 EM Ground Conductivity Mapping

The EM conductivity survey locations are shown on Drawing AGL17263_01 and the recorded values are contoured on Drawing AGL17263_02. The conductivity values range from 1-148 milliSiemens/metre (mS/m). The conductivity values have been generally interpreted as follows:

Conductivity (mS/m)	Interpretation
1 - 10	Thin MADE GROUND/TOPSOIL/CAPPING (< 2m) over natural ground
10 – 30	MADE GROUND/TOPSOIL (>2m) over sandy gravelly CLAY (pos. Minor waste)
30 – 148	MADE GROUND/WASTE (mixed & organic) over sandy gravelly CLAY **with possible LEACHATE**

Note: EM ground conductivity measurements refer to the bulk electrical conductivity of the upper 6m of ground.

3.2 Electrical Resistivity Tomography

Seven Electrical Resistivity Tomography (ERT) Profiles (R1 to R7) were acquired across the site. The locations are shown on Drawing AGL17263_01. Interpreted cross sections were compiled for the profiles and are presented on Drawings AGL17263_04 to 07.

In determining the various types of imported material present from the ERT sections R1-R7 it should be noted that:

a) typical resistivities of Irish soils range from 20 Ohm-m (clays) to around 3000 Ohm-m (dry gravel),

b) the resistivity generally increases as the sand/gravel content increases,

c) silt/clay typically has values in the range 30-50 Ohm-m,

d) silty gravelly clay typically has resistivity values in the range 50-100 Ohm-m,

e) deposits of predominantly organic waste such as those occurring in municipal landfills typically have resistivities in the range 5-30 Ohm-m.

f) leachate saturated soils originating from predominantly organic waste have a similar resistivity range to organic waste, but will be influenced by the resistivities of the host material and the degree of dilution and dispersion of the leachate,

g) inert construction and demolition (C&D) waste such as concrete, brick and mixed rock fill, stone and clay will usually have resistivities similar to gravelly material (50-500 Ohm-m).

The resistivity values recorded at this site ranged from 5-15741 Ohm-m and have been generally interpreted as follows:

Resistivity (Ohm-m)	Interpretation
5 - 60	MADE GROUND/WASTE (mixed & organic) over sandy gravelly CLAY **with possible LEACHATE**
60 - 240	Gravelly sandy CLAY
240 - 480	Clayey GRAVEL
240 - 15741	LIMESTONE

3.3 Seismic Refraction Profiling

Four seismic refraction profiles (S1-S4) were recorded across the site. The locations are shown on Drawing AGL17263_01 and the results of S1 to S3 are included on the interpreted cross sections in Drawings AGP17263_04 to 07 and in Appendix B. The data quality of S4 was poor due to loss of transmission in likely fill material and the results of S4 were not used for interpretation.

The P-wave seismic velocities have been interpreted as follows:

Layer	Velocity (m/s)	Interpretation
1	380-381	Soft/loose MADE GROUND/WASTE
2	506 - 690	Firm/medium dense MADE GROUND/WASTE
3	989 - 1273	Firm – Stiff / Medium Dense – Dense SOILS

3.4 MASW

Four 1D MASW soundings (M1-M4) were recorded across the site at the centre of each seismic refraction profile. Shear wave (S-wave) velocity (Vs) and Gmax values were determined for the made ground/waste and underlying soil material.

The shear wave (Vs) velocity values for the site range from 77-328 m/s, over a depth range of c. 0.5 to19.1m bgl. Shear wave velocities of <175m/s are indicative of soft / loose ground conditions typical of unconsolidated waste deposits. Gmax values range from 12 – 215MPa over the same depth range.

Vs velocities and corresponding soil cohesion ranges are summarised in Figure 3.1.

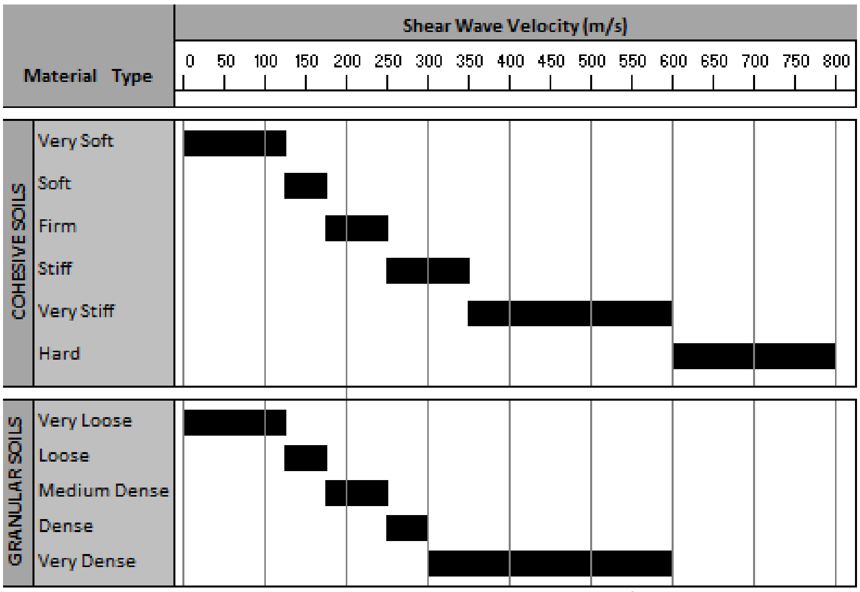

Fig 3.1: Vs velocities and corresponding soil cohesion ranges.

The Vs velocities from this site have been interpreted as follows:

Layer	Velocity (m/s)	Interpretation
1	77 - 175	Soft/Loose MADE GROUND/WASTE
2	175 - 250	Firm/Medium Dense MADE GROUND/WASTE and / or sandy gravelly SILT/CLAY
3	250 - 328	Stiff / Dense – very Dense sandy gravelly SILT/CLAY

The Vs seismic velocities and stiffness ranges are shown below in Figure 3.2.

The Vs values for M1 and M2 indicate soft / loose material to 7.0 and 9.0m bgl over firm / medium dense becoming stiff / dense – very dense material to depths of 15 and 19.1m bgl.

The Vs values for M3 indicate soft / loose material to 10.7m bgl. The values for M4 indicate soft / loose material to 14.0m becoming firm / medium dense to 17.6m bgl.

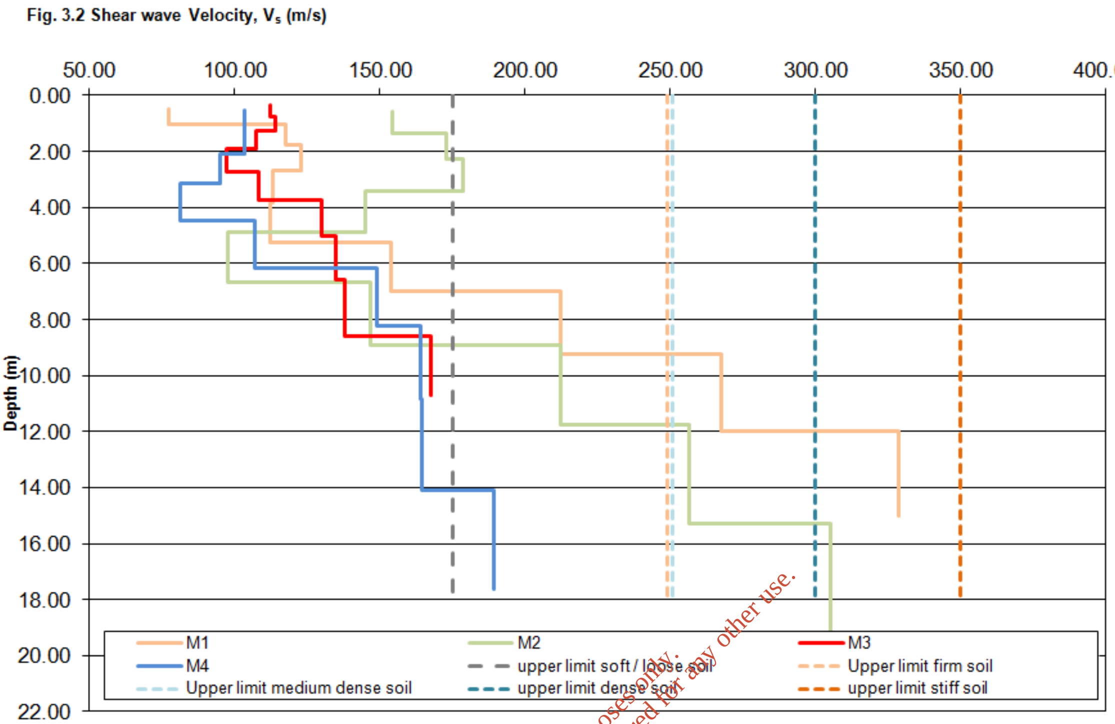

Fig 3.2: Vs velocities across the site (M1 – M4).

3.5 Discussion

The interpretation of the geophysical data is plotted on Drawings AGL17263_03 to AGL17263_07.

3.5.1 Extent of the waste

Client supplied trial pit data and monitoring well logs are combined with areas of elevated EM conductivity readings (30 - 148 mS/m) and reduced electrical resistivity readings (5 - 60 Ohm-m) to indicate areas of waste. The extent of interpreted waste material is shown on Drawing AGL17263_03.

3.5.2 Type of waste

MADE GROUND/WASTE (mixed & organic) has been interpreted based on EM conductivity values of 30 - 148 mS/m) and ERT resistivity values (5 - 60 Ohm-m).

Minor levels of waste may also be present in soil layers interpreted as predominantly sandy gravelly clay away from the main area of waste. This is confirmed by the client supplied trial pit and monitoring well logs.

3.5.3 Thickness of waste and possible leachate

Across the site MADE GROUND/TOPSOIL is c. 0.2 – 1.8m thick with areas of little or no waste present close to the eastern, northern and south-western boundaries of the site.

Electrical contrasts between waste and the underlying sandy gravelly clay are not always sharp. In areas of potentially thick waste the base of the fill may therefore be unclear and possible leachate beneath predominantly organic waste may also obscure the base of waste.

Across the site thick areas of predominantly organic waste are interpreted on all ERT profiles R1 – R7. In these areas base of waste is defined by an increase in stiffness from soft – firm to firm – stiff based on the seismic refraction and MASW datasets and by incorporating base of waste on the nearest trial pits and monitoring wells.

Interpreted thickness of MADE GROUND/WASTE (mixed & organic) ranges from 5.2 – 8.9m with an average of 7.8m.

Low model resistivity values (< 60 Ohm-m) extending to 17m and 19m bgl on ERT profiles R3 and R5 respectively (see Drawing AGL17263_05) in an area of increased material stiffness defined by high Vs velocities on the MASW on R3 (212 – 305m/s) are interpreted as possible leachate beneath base of waste at 8.2 and 9.4m bgl respectively.

3.5.4 Volume Calculation

The volume of waste calculated across the site is as follows;

Extent (Ha.)	Average Thickness (m.)	Volume (cu. m.)	Tonnes (@ 1.4 tonnes/cu.m.)
4.7	7.8	366,600	513,240

3.5.4 Bedrock

The combined geophysical datasets in conjunction with the intrusive data indicate undulating top of bedrock across the site. Depth to interpreted top of bedrock varies from c. 9.8 to 22.4m bgl across the site. The minimum and maximum depth levels are interpreted along ERT profile R3 (see Drawing AGL17263_05). There is generally broad agreement between the areas of deeper rock, areas of interpreted thicker MADE GROUND/WASTE and client supplied information of historic pits at the site. Interpreted bedrock type is limestone based on resistivity values of 240 – 15741 Ohm-m.

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5. APPENDIX A: DETAILED METHODOLOGY

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

5.1 EM ground conductivity mapping

5.1.1 Principles

This is an electromagnetic technique used to investigate lateral variations in overburden material and to assist with the indication of the depth to bedrock. This method operates on the principle of inducing currents in conductive substrata and measuring the resultant secondary electro-magnetic field. The strength of this secondary EM field is calibrated tore give apparent ground conductivity in milliSiemens/metre (mS/m). Readings over material such as organic waste and peat give high conductivity values while readings over dry materials with low clay mineral content such as gravels, limestone or quartzite give low readings. The EM31 survey technique determines the apparent conductivity of the ground material from 0-6m bgl depending on the dipole mode used. Depending on the dipole mode used, the measured conductivity is a function of the different overburden layers and/or rock from 0 to 6m below ground level.

5.1.2 Data collection

The EM equipment used was a GF CMD-4 conductivity meter equipped with data logger. This instrument features a real time graphic display of the previous 20 measurement points to monitor data quality and results. Conductivity and in-phase values were recorded across the site. Local conditions and variations were recorded.

5.1.3 Data processing

The conductivity and in-phase field readings were downloaded, contoured and plotted using the SURFER 12 program (Golden Software, 2015). Data which was affected by metallic objects was removed. Assignation of material types and possible anomaly sources was carried out, with cross-reference to other data.

5.2 Electrical Resistivity Tomography (ERT)

5.2.1 Principles

This surveying technique makes use of the Wenner resistivity array. The 2D-resistivity profiling method records a large number of resistivity readings in order to map lateral and vertical changes in material types. This method involves the use of electrodes connected to a resistivity meter, using computer software to control the process of data collection and storage.

5.2.2 Data Collection

Profiles were recorded using a Tigre resistivity meter, imaging software, two 32 takeout multicore cables and up to 64 stainless steel electrodes. Saline solution was used at the electrode/ground interface in order to gain a good electrical contact required for the technique to work effectively. The recorded data were processed and viewed immediately after surveying.

5.2.3 Data Processing

The field readings were stored in computer files and inverted using the RES2DINV package (Geotomo Software, 2006) with up to 5 iterations of the measured data carried out for each profile to obtain a 2D-depth model of the resistivities.

The inverted 2D resistivity models and corresponding interpreted geology are displayed on the accompanying drawings alongside the processed seismic sections. Profiles have been contoured using the same contour intervals and colour codes. Distance is indicated along the horizontal axis of the profiles

5.3 Seismic Refraction Profiling

5.3.1 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.

Seismic profiling measures the p-wave velocity (Vp) 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 Vp velocities while soft, loose or fractured materials have lower Vp velocities. Readings are taken using geophones connected via multi-core cable to a seismograph.

5.3.2 Data Collection

A Geode high resolution 24 channel digital seismograph, 24 10HZ vertical geophones and a 10 kg hammer were used to provide first break information, with a 24 take-out cable (2m spacing). Equipment was carried was operated by a two-person crew.

Readings are taken using geophones connected via multi-core cable to a seismograph. The depth of resolution of soil/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, 33m profile ~ 11m depth)

Shots from seven different positions were taken (2 x off-end, 2 x end, 3 x middle) to ensure optimum coverage of all refractors..

5.3.3 Data Processing

The recorded data was processed and interpreted using the ray-tracing and tomographic inversion methods, to acquire depths to boundaries and the P-wave velocities of these layers, using the SeisImager/2D programme from Geometrics.

SeisImager/2D interprets seismic refraction data as a laterally varying layered earth structure. The programme includes three methods for data analysis, time-term inversion, the reciprocal method and tomography.

The tomography method creates an initial velocity model, then traces rays through the model, comparing the calculated and measured traveltimes. The model is then modified and the process repeated to minimise the difference between the calculated and measured times. The data was processed using this method and was then converted to a layer model for display and interpretation.

Approximate errors for Vp velocities are estimated to be +/- 10%. Errors for the calculated layer thicknesses are of the order of +/-20%. Possible errors due to the "hidden layer" and "velocity inversion" effects may also occur (Soske, 1959).

5.4 Multi-channel Analysis of Surface Waves

5.4.1 Principles

The Multi-channel Analysis of Surface Waves (MASW) (Park et al., 1998, 1999) utilizes Surface waves (Rayleigh waves) to determine the elastic properties of the shallow subsurface (<15m). Surface waves carry up to two/thirds of the seismic energy but are usually considered as noise in conventional body wave reflection and refraction seismic surveys. The penetration depth of surface waves changes with wavelength, i.e. longer wavelengths penetrate deeper. When the elastic properties of near surface materials vary with depth, surface waves then become dispersive, i.e. propagation velocity changes with frequency. The propagation (or phase) velocity is determined by the average elastic property of the medium within the penetration depth. Therefore the dispersive nature of surface waves may be used to investigate changes in elastic properties of the shallow subsurface. The MASW method employs 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. a sledgehammer) is used to generate vertical ground motions,

(ii) the ground motions are measured using low frequency geophones, 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 in 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.

5.4.2 Data Collection

The recording equipment consisted of a Geode 24 channel digital seismograph, 24 no. 10HZ vertical geophones, hammer energy source with mounted trigger and a 24 take-out cable.

5.4.3 Data Processing

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

SURFSEIS data processing involves three steps:

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

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

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

The bedrock P-wave velocities were converted to S-wave velocities using the following equation

V_s=(((Vp^2)-2*v*(Vp^2))/((1-v)*2))^0.5

Where V_s = S-wave velocity in m/s, Vp = P-wave velocity in m/s and v = Poisson's ratio.

5.5 Spatial relocation

All the geophysical investigation locations were acquired using Trimble Geo 7X high-accuracy GNSS handheld GPS system using the settings listed below. This system allows collecting GPS data with c.20mm accuracy.

Projection:	Irish Transverse Mercator
Datum:	Ordnance
Coordinate units:	Metres
Altitude units:	Metres
Survey altitude reference:	MSL
Geoid model:	Republic of Ireland

6. APPENDIX B: DRAWINGS

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

AGL17263_01
Fig.1 Geophysical Investigation Locations Scale 1:2000 @A4

AGL17263_02
Fig.1 EM Conductivity Contours Scale 1:2000 @A4

AGL17263_03
Fig.1 Summary Map Scale 1:2000 @A4

AGL17263_04
Fig.1 ERT Profiles R1 & R2 Results Scale 1:1000 @A4

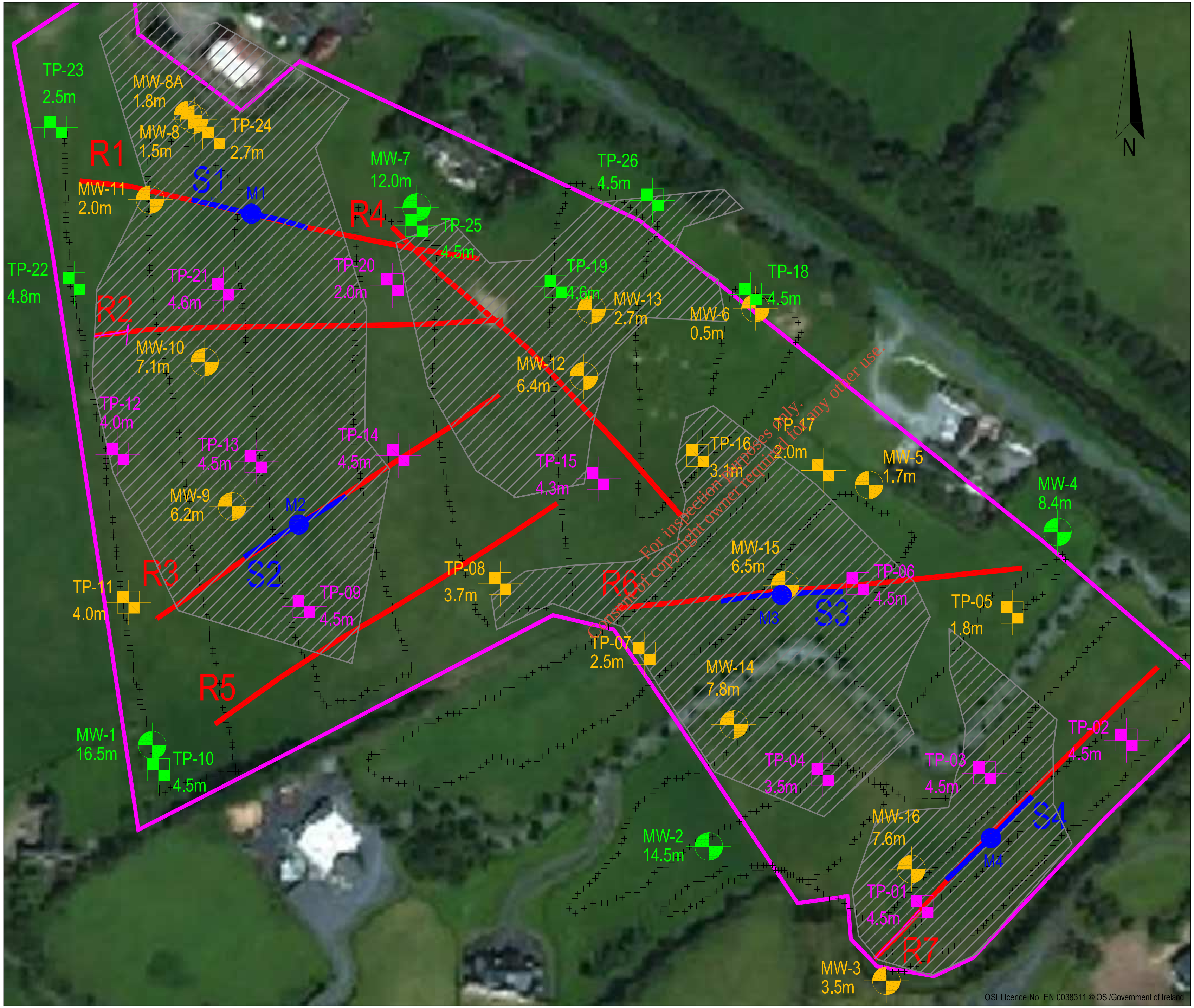
AGL17263_05
Fig.1 ERT Profiles R3 & R5 Results Scale 1:1000 @A4

AGL17263_06
Fig.1 ERT Profiles R4 & R6 Results Scale 1:1000 @A4

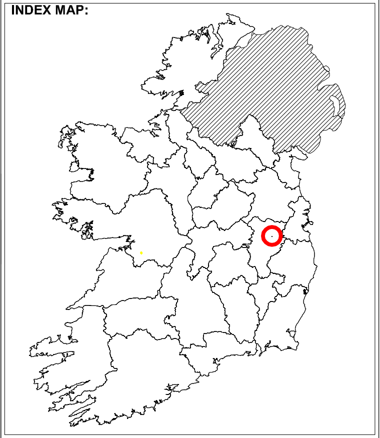
AGL17263_07
Fig.1 ERT Profiles R7 Results Scale 1:1000 @A4

FIGURE 1: GEOPHYSICAL INVESTIGATION LOCATIONS

SCALE 1:2000



INDEX MAP:



LEGEND:

- Site
- EM conductivity/gravity station
- ERT profile
- Seismic refraction profile & 1D MASW
- Approximate outline of client supplied historical gravel pit information
- 2019 Client Supplied Data
- Trial Pit / Monitoring Well - no waste to displayed termination depth
- Trial Pit / Monitoring Well - waste to displayed depth
- Trial Pit / Monitoring Well - waste to displayed termination depth

' The information displayed here is to be used in conjunction with Report AGL17263_01 Report on the Geophysical Investigation at Digby Bridge, Kildare for CDM Smith.
APEX Geoservices Ltd. 03th March 2019'

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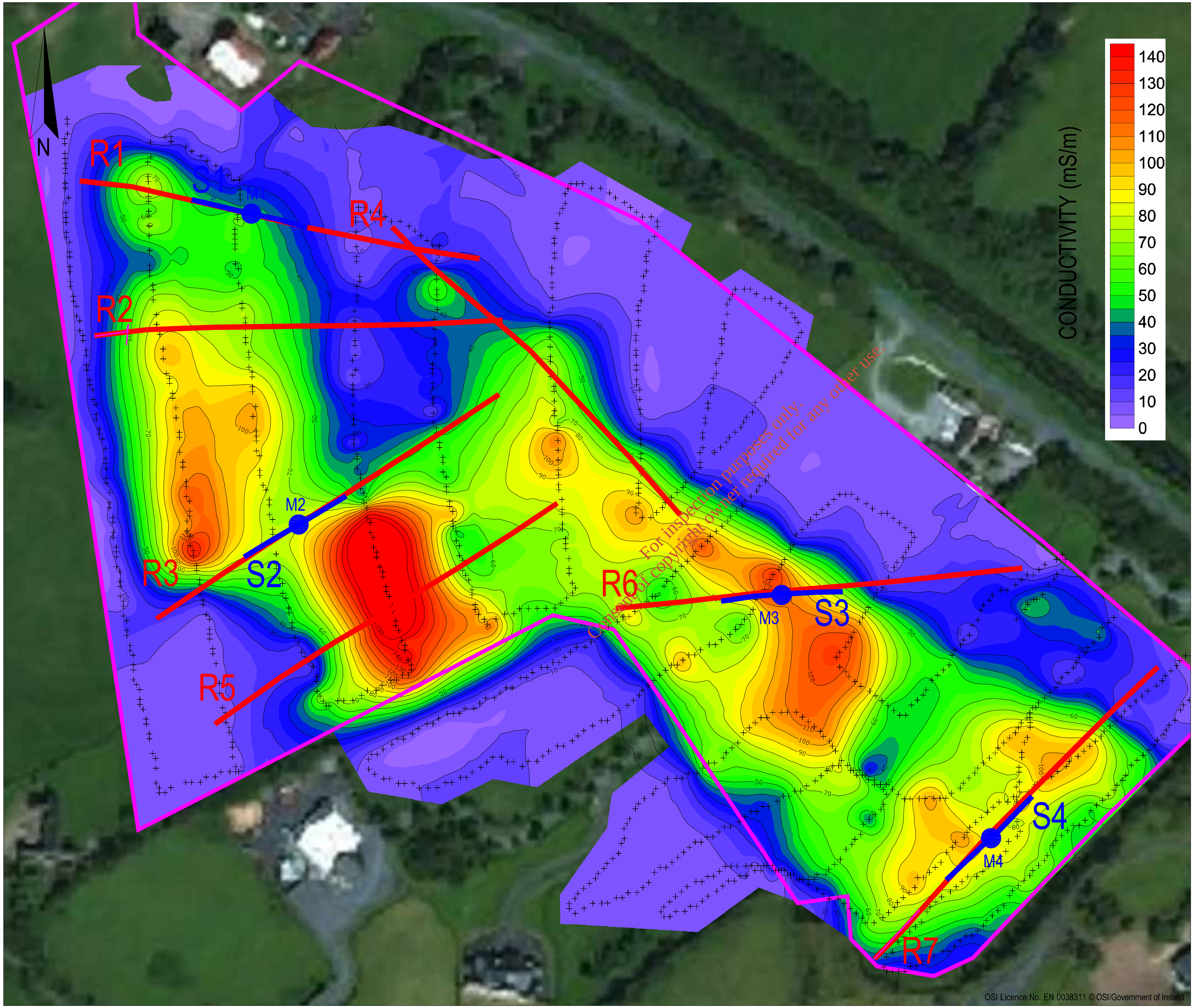
PROJECT:	DIGBY BRIDGE LANDFILL, CO. KILDARE GEOPHYSICAL INVESTIGATION
CLIENT.:	CDM SMITH
DRAWING NO:	AGL17263_01
SCALE:	AS INDICATED @ A4
DATE:	09th NOVEMBER 2017

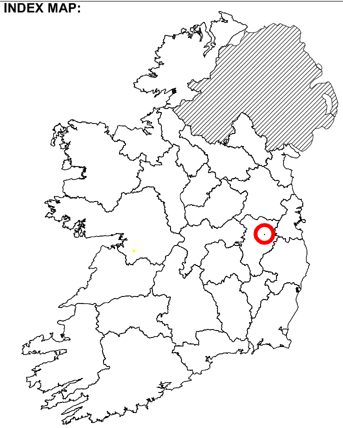
Version:	Date:	Drawn By:	Checked:
01	09/11/2017	TL	POC
02	11/03/2019	TL	KG
03	03/05/2019	TL	MN

FIGURE 1: EM CONDUCTIVITY CONTOURS

SCALE 1:2000



INDEX MAP:



LEGEND:

- Site
- EM conductivity/gravity station
- ERT profile
- Seismic refraction profile & 1D MASW

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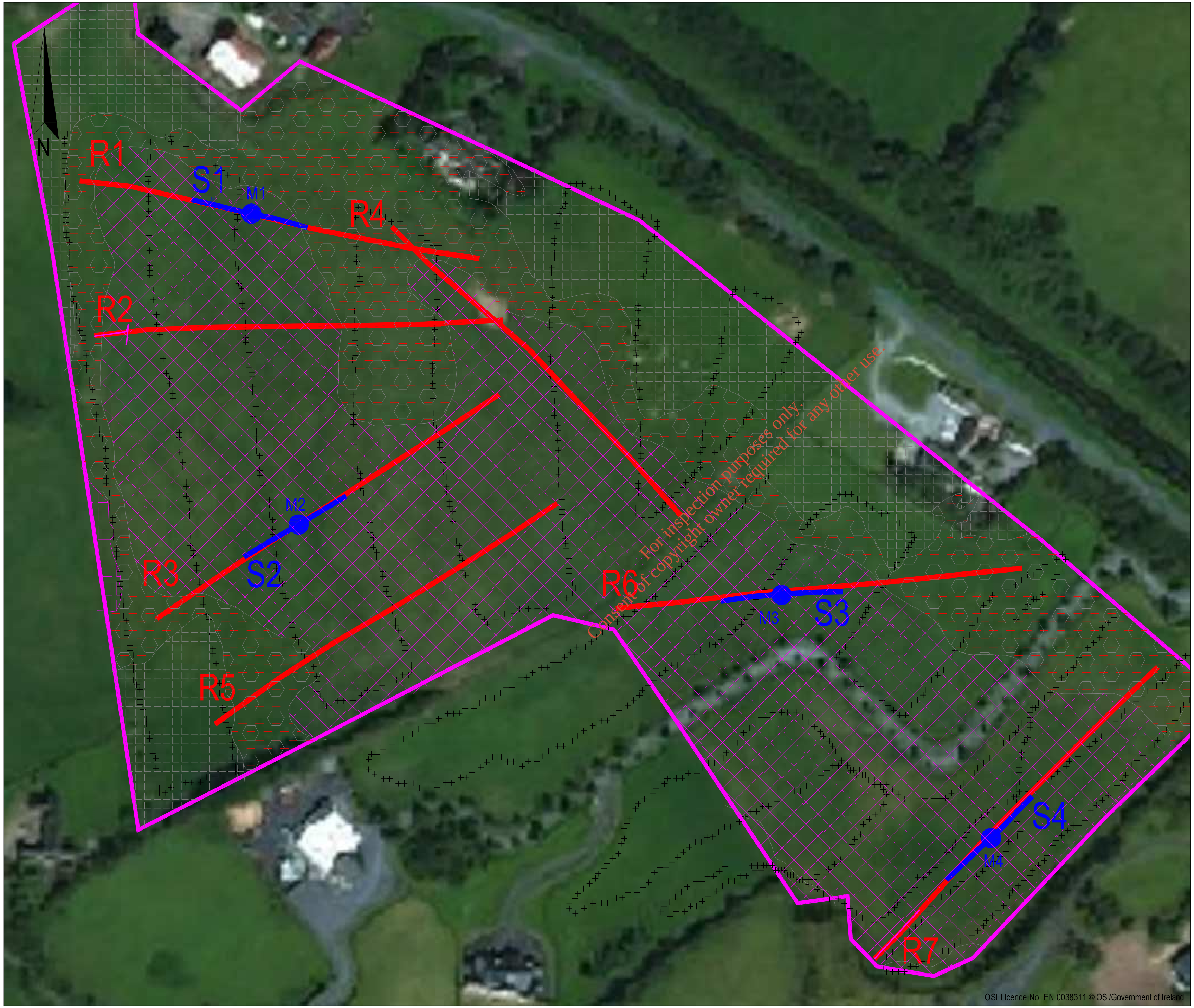
PROJECT:	DIGBY BRIDGE LANDFILL, CO. KILDARE GEOPHYSICAL INVESTIGATION
CLIENT:	CDM SMITH
DRAWING NO:	AGL17263_02
SCALE:	AS INDICATED @ A4
DATE:	09th NOVEMBER 2017

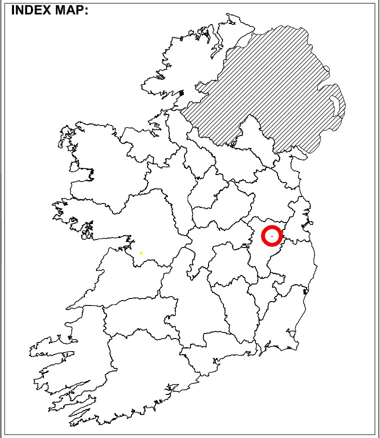
Version:	Date:	Drawn By:	Checked:
01	09/11/2017	TL	POC
02	11/03/2019	TL	KG
03	03/05/2019	TL	MN

FIGURE 1: SUMMARY MAP

SCALE 1:2000



INDEX MAP:



LEGEND:

- Site
- EM conductivity/gravity station
- ERT profile
- Seismic refraction profile & 1D MASW
- Thin MADE GROUND /TOPSOIL(<2m)
- MADE GROUND / TOPSOIL over Sandy Gravelly CLAY / pos. minor waste
- MADE GROUND / WASTE (mixed & organic)

'The information displayed here is to be used in conjunction with Report AGL17263_01 Report on the Geophysical Investigation at Digby Bridge, Kildare for CDM Smith.
APEX Geoservices Ltd. 11th March 2019'

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PROJECT: DIGBY BRIDGE LANDFILL, CO. KILDARE GEOPHYSICAL INVESTIGATION

CLIENT.: CDM SMITH

DRAWING NO: AGL17263_03

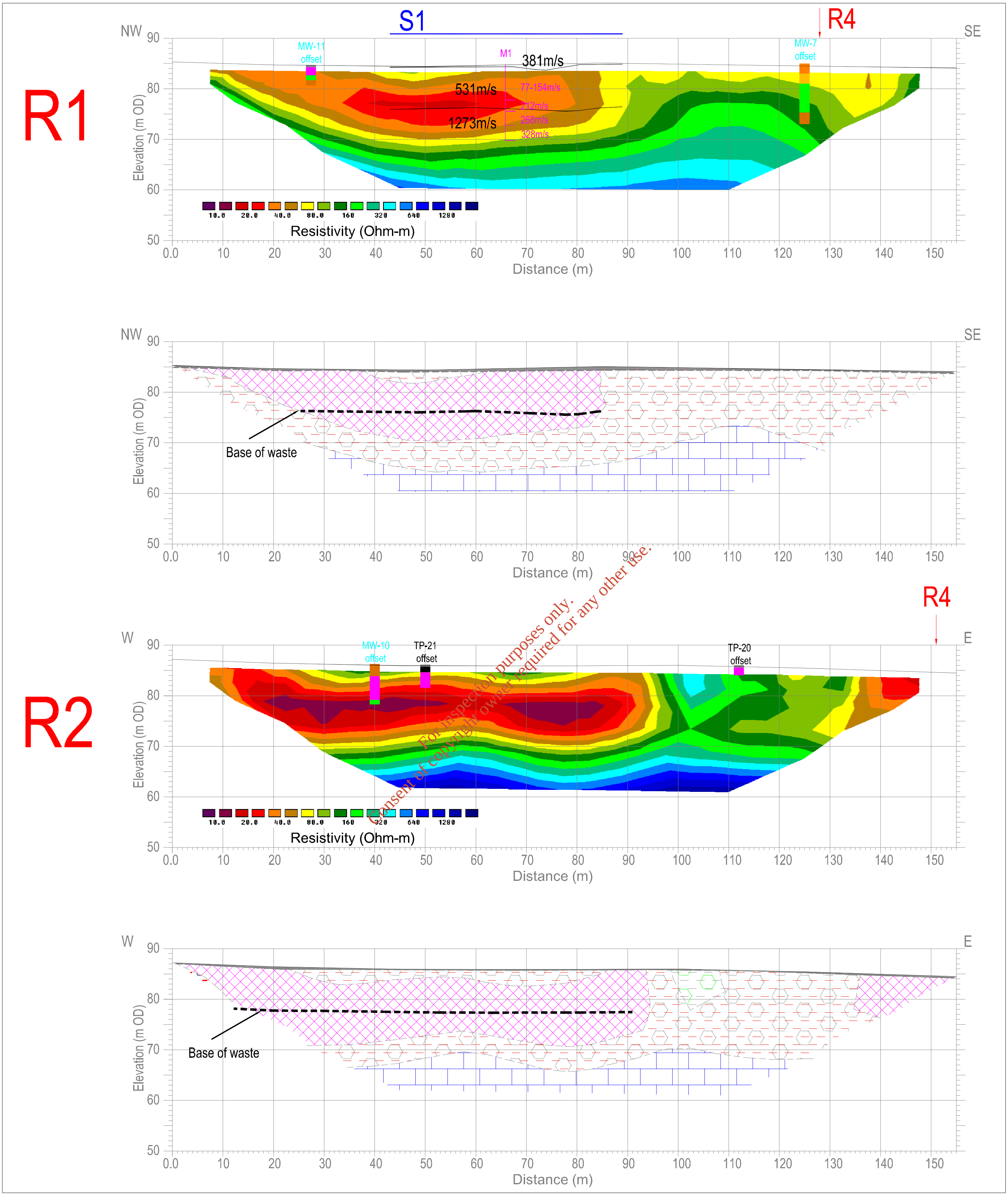
SCALE: AS INDICATED @ A4

DATE: 09th NOVEMBER 2017

Version:	Date:	Drawn By:	Checked:
01	09/11/2017	TL	POC
02	11/03/2019	TL	KG
03	03/05/2019	TL	MN

FIGURE 1: ERT PROFILES R1 & R2 RESULTS

SCALE 1:1000



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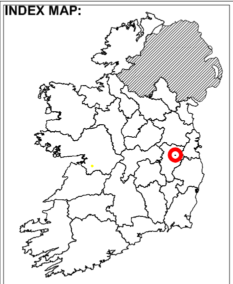
INDEX MAP:



LEGEND:

- MADE GROUND / TOPSOIL
- MADE GROUND / WASTE (mixed & organic) over Sandy Gravelly CLAY with pos. leachate
- Gravelly Sandy CLAY
- Clayey Silty SAND/GRAVEL
- LIMESTONE
- 351m/s Vp Seismic layer & velocity
- 160m/s Vs Seismic layer & velocity
- Base of waste (from S.R., MASW, trial pits and borehole)

Summary of 2019 Client Data

- MADE GROUND / TOPSOIL
- MADE GROUND / WASTE
- MADE GROUND / WASTE (inlud. organic)
- Silty GRAVEL
- Sandy GRAVEL
- Clayey GRAVEL / Gravelly CLAY
- GRAVEL
- LIMESTONE

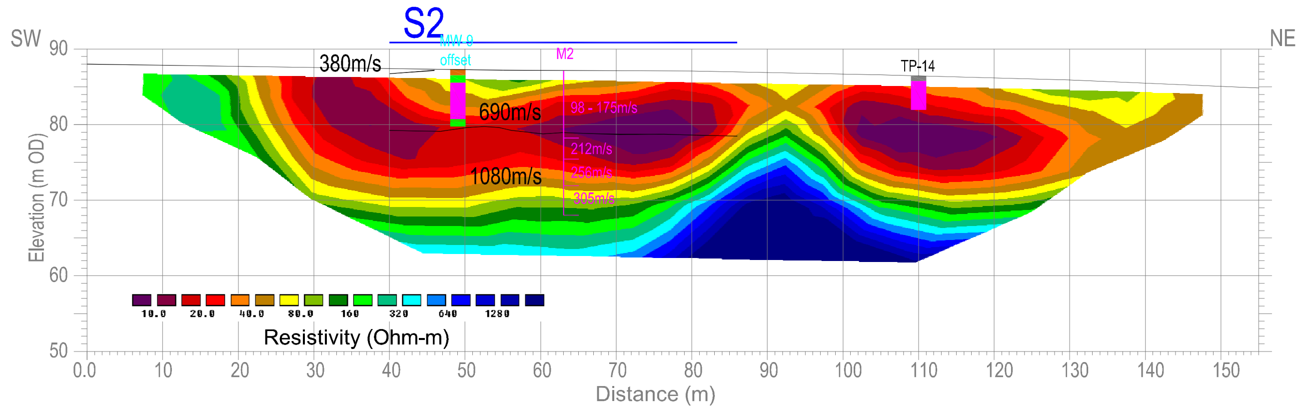
PROJECT:	DIGBY BRIDGE LANDFILL, CO. KILDARE GEOPHYSICAL INVESTIGATION
CLIENT.:	CDM SMITH
DRAWING NO:	AGL17263_04
SCALE:	AS INDICATED @ A4
DATE:	09th NOVEMBER 2017

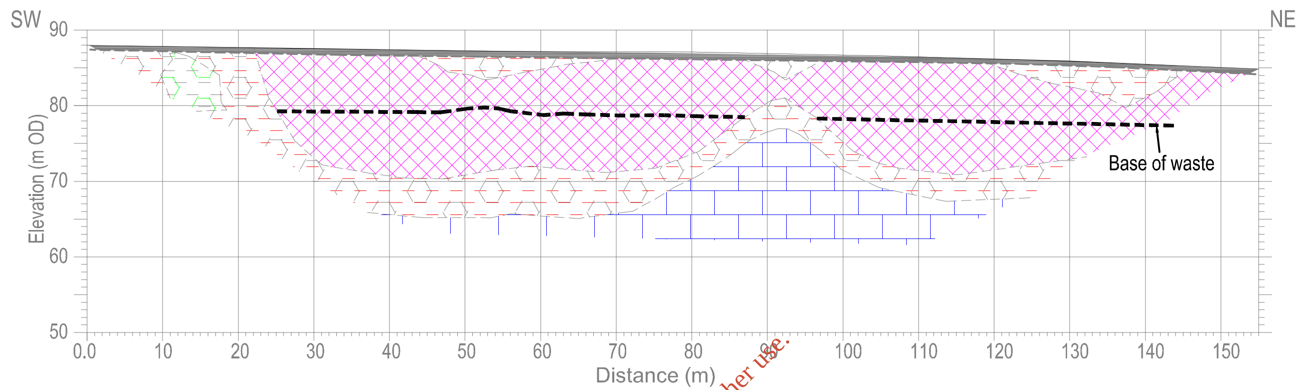
Version:	Date:	Drawn By:	Checked:
01	09/11/2017	TL	POC
02	11/03/2019	TL	KG
03	03/05/2019	TL	MN

FIGURE 1: ERT PROFILES R3 & R5 RESULTS

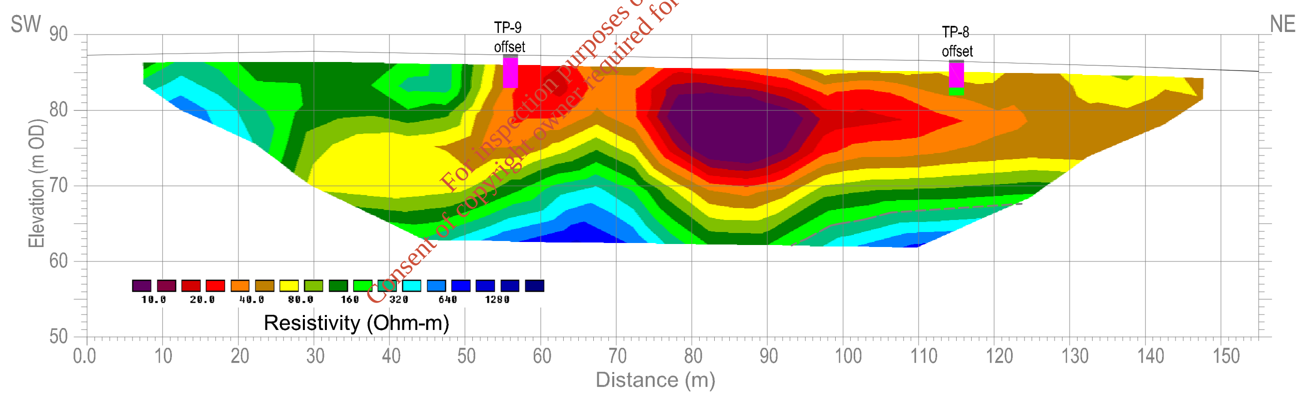
SCALE 1:1000

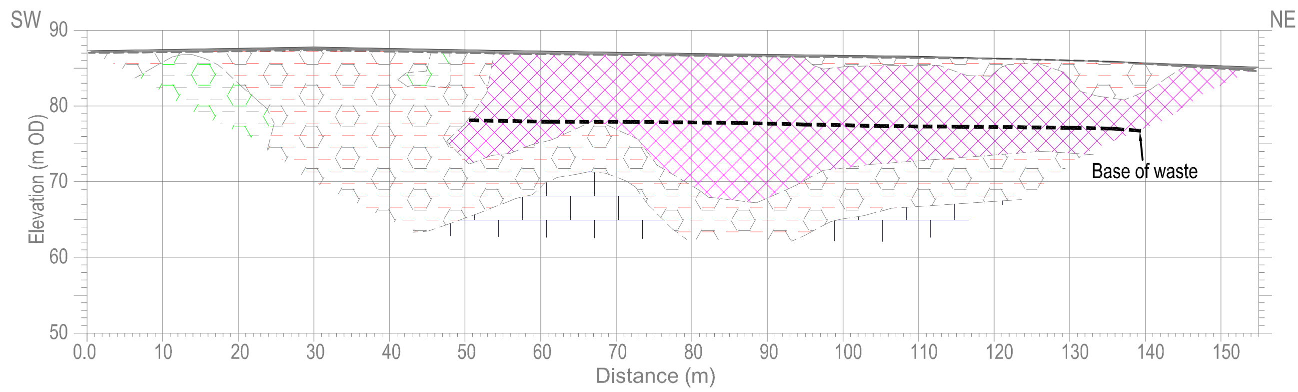
R3





R5





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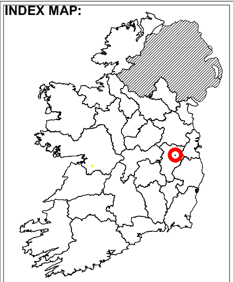
INDEX MAP:



LEGEND:

- MADE GROUND / TOPSOIL
- MADE GROUND / WASTE (mixed & organic) over Sandy Gravelly CLAY with pos. leachate
- Gravelly Sandy CLAY
- Clayey Silty SAND/GRAVEL
- LIMESTONE
- 351m/s Vp Seismic layer & velocity
- 160m/s Vs Seismic layer & velocity
- Base of waste (from S.R., MASW, trial pits and borehole)

Summary of 2019 Client Data

- MADE GROUND / TOPSOIL
- MADE GROUND / WASTE
- MADE GROUND / WASTE (inlud. organic)
- Silty GRAVEL
- Sandy GRAVEL
- Clayey GRAVEL / Gravelly CLAY
- GRAVEL
- LIMESTONE

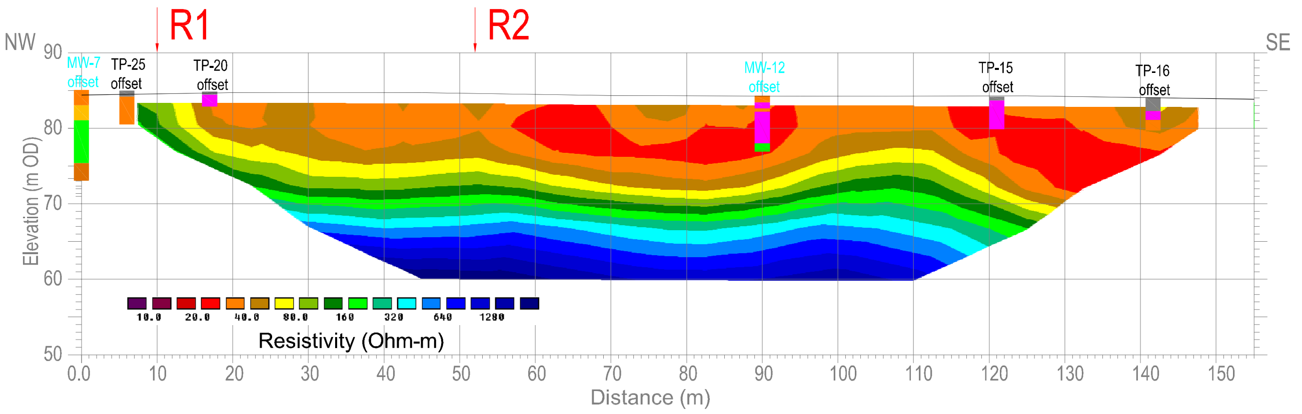
PROJECT:	DIGBY BRIDGE LANDFILL, CO. KILDARE GEOPHYSICAL INVESTIGATION
CLIENT.:	CDM SMITH
DRAWING NO:	AGL17263_05
SCALE:	AS INDICATED @ A4
DATE:	09th NOVEMBER 2017

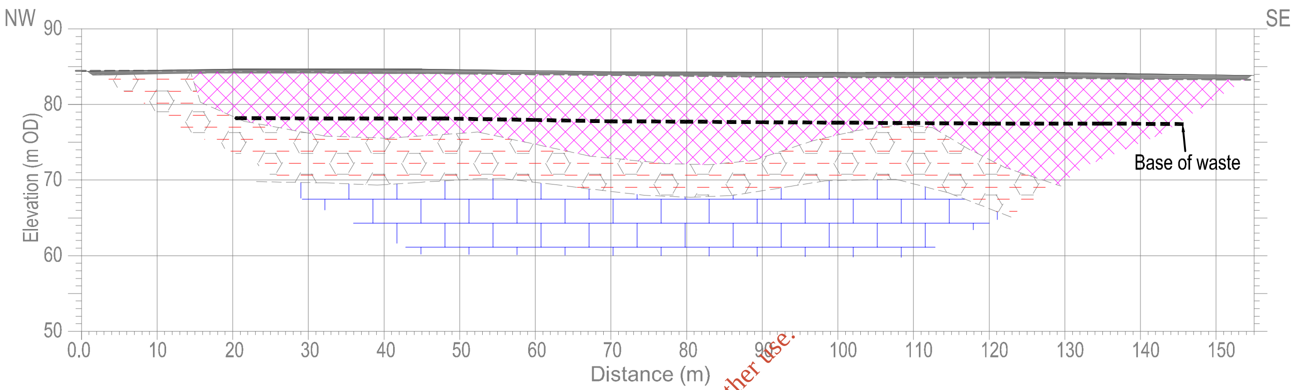
Version:	Date:	Drawn By:	Checked:
01	09/11/2017	TL	POC
02	11/03/2019	TL	KG
03	03/05/2019	TL	MN

FIGURE 1: ERT PROFILES R4 & R6 RESULTS

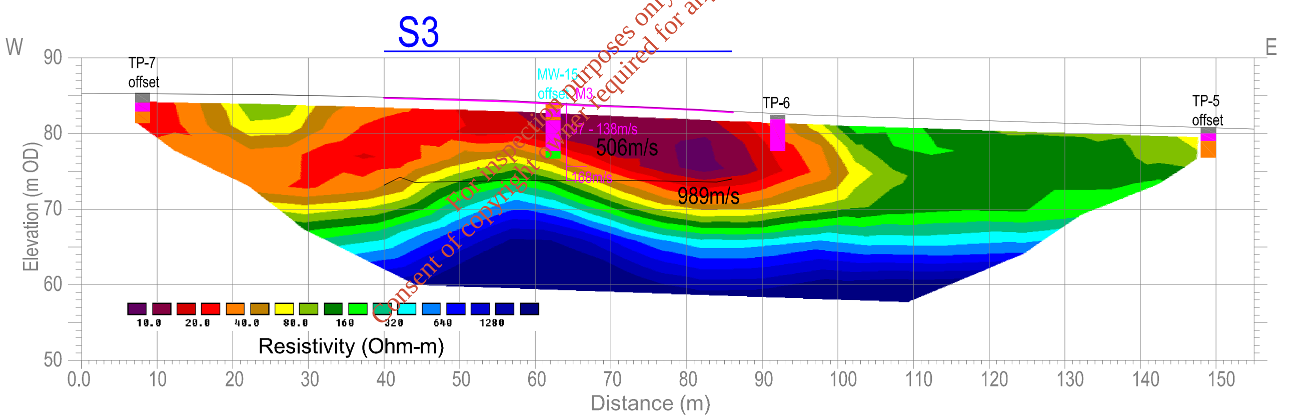
SCALE 1:1000

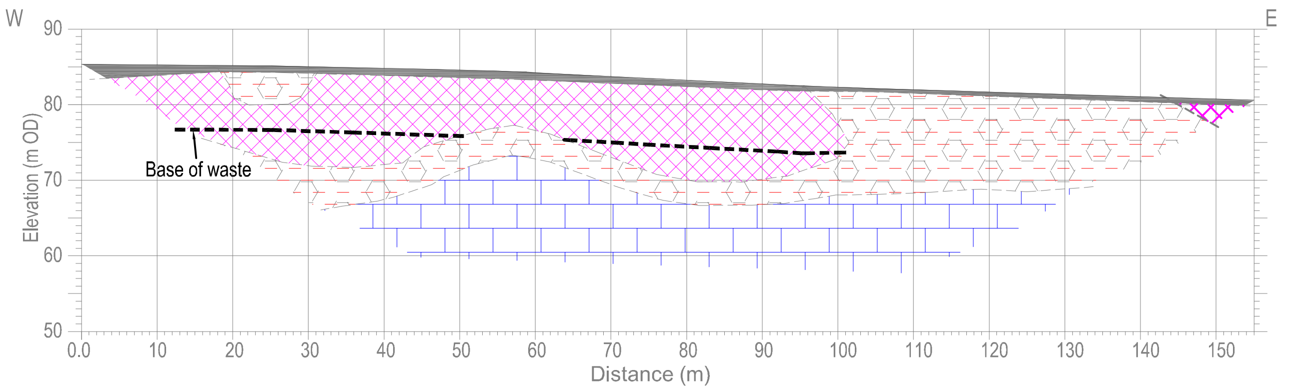
R4





R6





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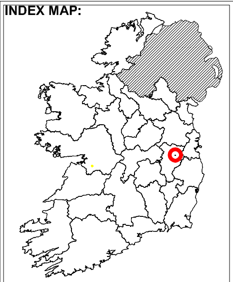
INDEX MAP:



LEGEND:

- MADE GROUND / TOPSOIL
- MADE GROUND / WASTE (mixed & organic) over Sandy Gravelly CLAY with pos. leachate
- Gravelly Sandy CLAY
- Clayey Silty SAND/GRAVEL
- LIMESTONE
- 351m/s Vp Seismic layer & velocity
- 160m/s Vs Seismic layer & velocity
- Base of waste (from S.R., MASW, trial pits and borehole)

Summary of 2019 Client Data

- MADE GROUND / TOPSOIL
- MADE GROUND / WASTE
- MADE GROUND / WASTE (inlud. organic)
- Silty GRAVEL
- Sandy GRAVEL
- Clayey GRAVEL / Gravelly CLAY
- GRAVEL
- LIMESTONE

PROJECT: DIGBY BRIDGE LANDFILL, CO. KILDARE GEOPHYSICAL INVESTIGATION

CLIENT.: CDM SMITH

DRAWING NO: AGL17263_06

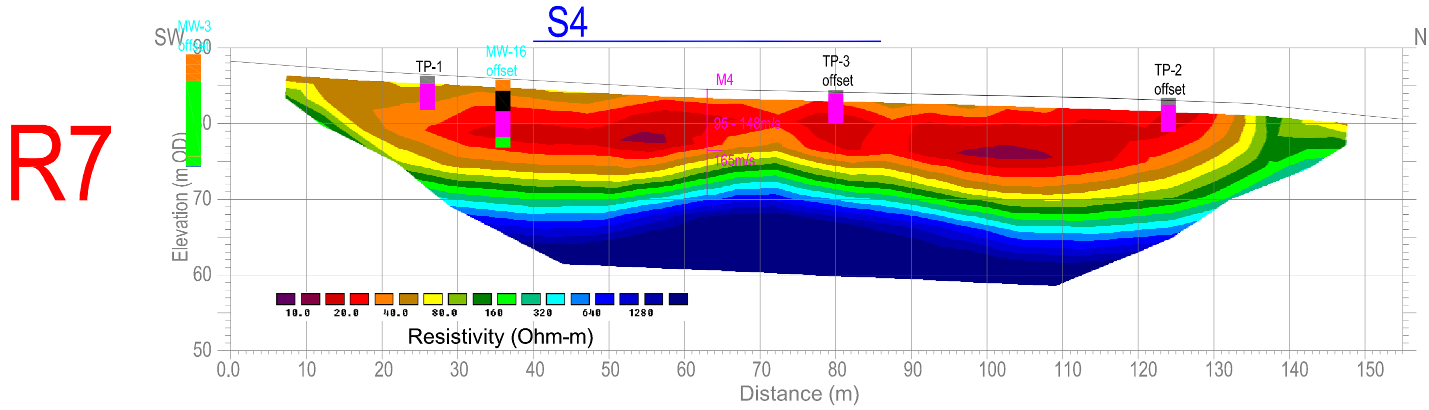
SCALE: AS INDICATED @ A4

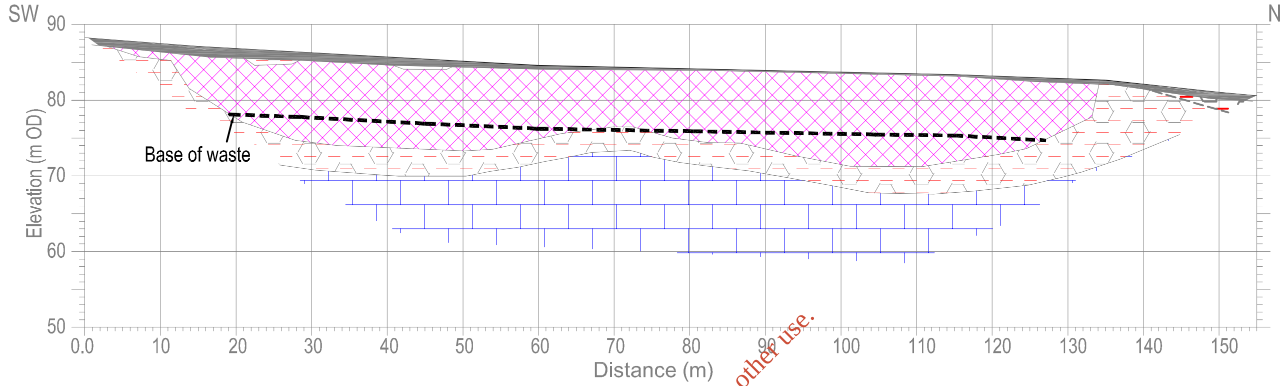
DATE: 09th NOVEMBER 2017

Version:	Date:	Drawn By:	Checked:
01	09/11/2017	TL	POC
02	11/03/2019	TL	KG
03	03/05/2019	TL	MN

FIGURE 1: ERT PROFILE R7 RESULTS

SCALE 1:1000





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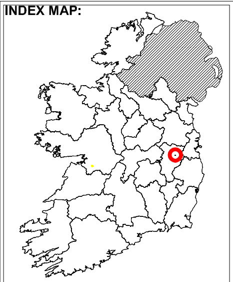
INDEX MAP:



LEGEND:

- MADE GROUND / TOPSOIL
- MADE GROUND / WASTE (mixed & organic) over Sandy Gravelly CLAY with pos. leachate
- Gravelly Sandy CLAY
- Clayey Silty SAND/GRAVEL
- LIMESTONE
- 351m/s Vp Seismic layer & velocity
- 160m/s Vs Seismic layer & velocity
- Base of waste (from S.R., MASW, trial pits and borehole)

Summary of 2019 Client Data

- MADE GROUND / TOPSOIL
- MADE GROUND / WASTE
- MADE GROUND / WASTE (inlud. organic)
- Silty GRAVEL
- Sandy GRAVEL
- Clayey GRAVEL / Gravelly CLAY
- GRAVEL
- LIMESTONE

PROJECT:	DIGBY BRIDGE LANDFILL, CO. KILDARE GEOPHYSICAL INVESTIGATION
CLIENT.:	CDM SMITH
DRAWING NO:	AGL17263_07
SCALE:	AS INDICATED @ A4
DATE:	09th NOVEMBER 2017

Version:	Date:	Drawn By:	Checked:
01	09/11/2017	TL	POC
02	11/03/2019	TL	KG
03	03/05/2019	TL	MN

7. APPENDIX C: SEISMIC PLATES

The seismic refraction plates are shown below.

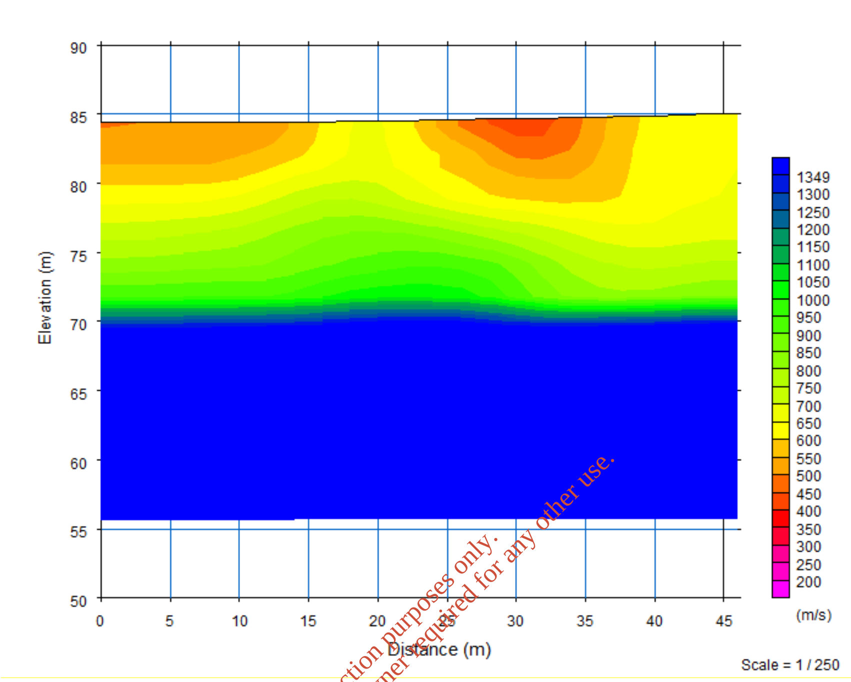


Figure 7.1 seismic refraction profiles S1 tomographic inversion.

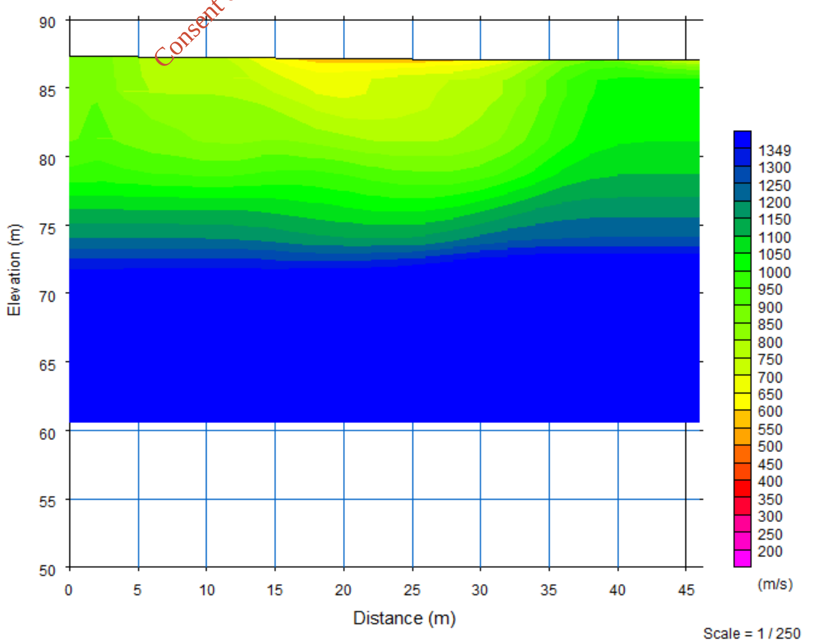


Figure 7.2 seismic refraction profiles S2 tomographic inversion.

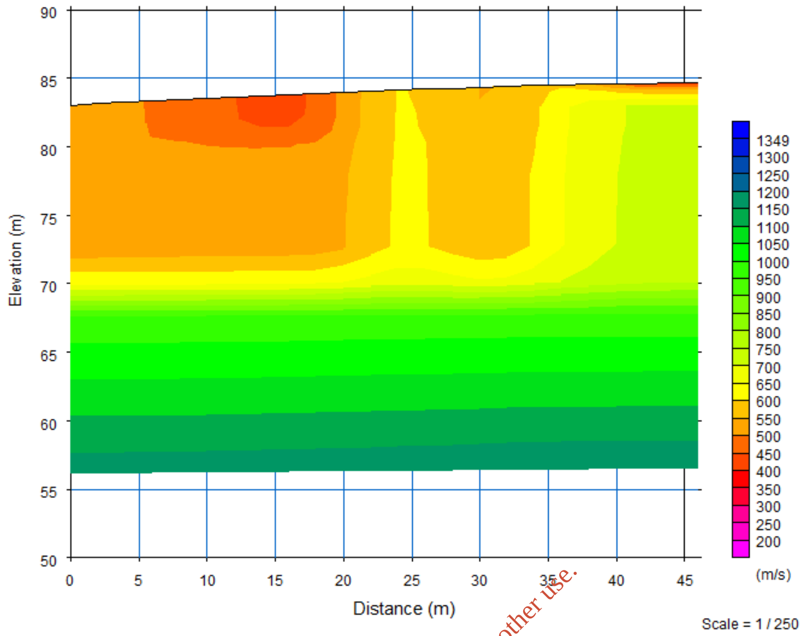
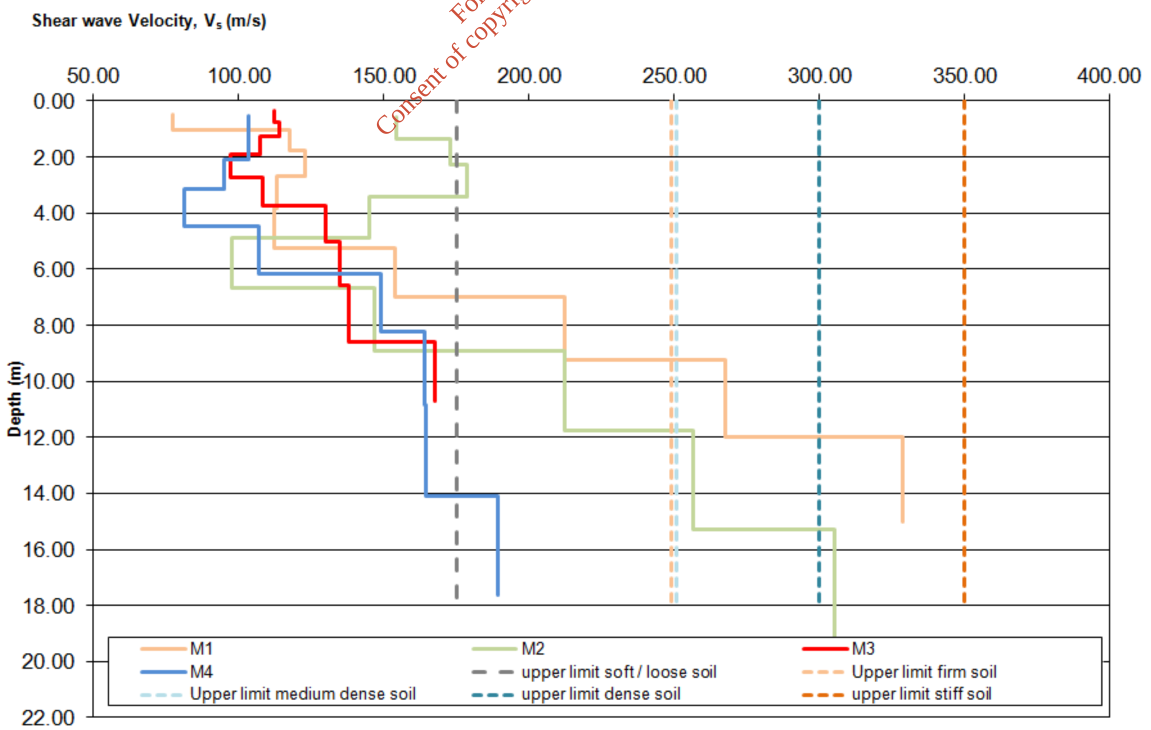


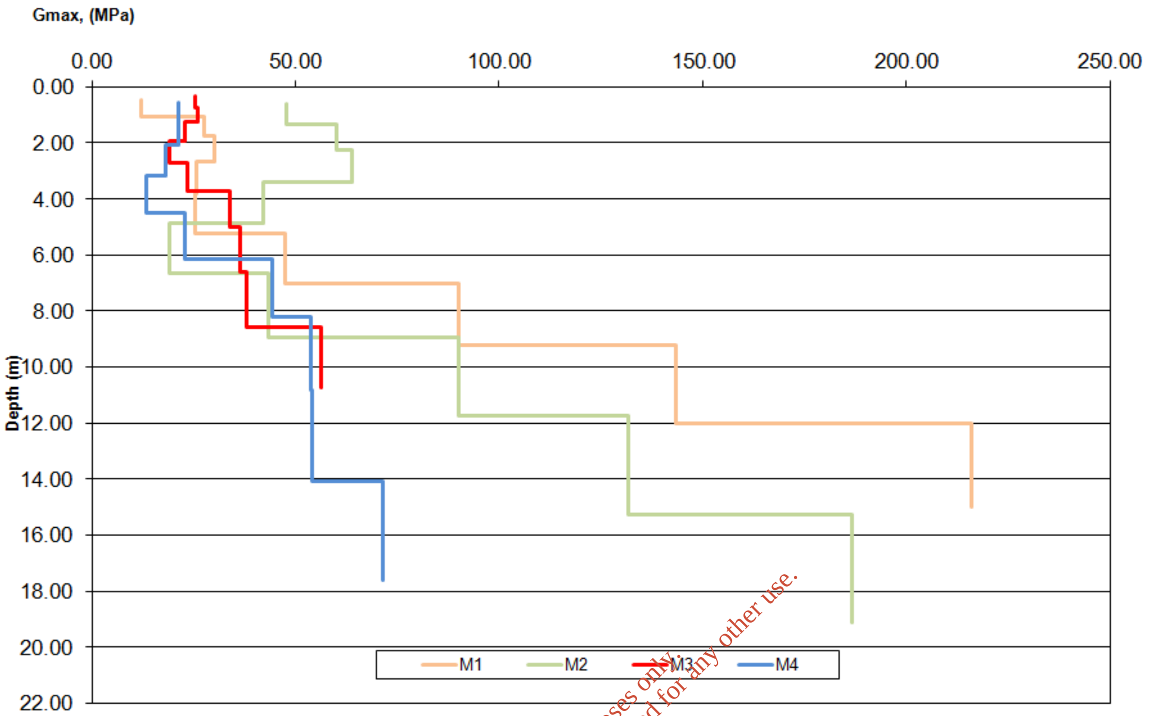
Figure 7.3 seismic refraction profiles S3 tomographic inversion.

8. APPENDIX D: MASW DATA

The Vs and Gmax values recorded at M1 – M4 (centred on S1 – S4) are shown below.

M1		1049	M2		1036	M3		1023	M4		1236
Depth	Vs	Gmax	Depth	Vs	Gmax	Depth	Vs	Gmax	Depth	Vs	Gmax
m	m/s	MPa	m	m/s	MPa	m	m/s	MPa	m	m/s	MPa
0.47	77.46	12.00	0.59	154.35	47.65	0.33	112.48	25.30	0.55	103.40	21.38
1.05	77.46	12.00	1.33	154.35	47.65	0.75	112.48	25.30	1.23	103.40	21.38
1.05	117.51	27.62	1.33	173.18	59.98	0.75	114.05	26.01	1.23	103.42	21.39
1.77	117.51	27.62	2.26	173.18	59.98	1.27	114.05	26.01	2.08	103.42	21.39
1.77	122.77	30.14	2.26	178.67	63.85	1.27	107.30	23.03	2.08	95.11	18.09
2.68	122.77	30.14	3.42	178.67	63.85	1.92	107.30	23.03	3.15	95.11	18.09
2.68	113.24	25.65	3.42	145.02	42.06	1.92	97.47	19.00	3.15	81.52	13.29
3.82	113.24	25.65	4.86	145.02	42.06	2.73	97.47	19.00	4.48	81.52	13.29
3.82	112.50	25.31	4.86	97.58	19.04	2.73	108.32	23.46	4.48	107.17	22.97
5.23	112.50	25.31	6.67	97.58	19.04	3.74	108.32	23.46	6.15	107.17	22.97
5.23	154.06	47.47	6.67	147.03	43.23	3.74	130.17	33.89	6.15	148.98	44.39
7.01	154.06	47.47	8.93	147.03	43.23	5.01	130.17	33.89	8.23	148.98	44.39
7.01	212.21	90.07	8.93	212.29	90.13	5.01	134.99	36.44	8.23	164.25	53.95
9.22	212.21	90.07	11.76	212.29	90.13	6.59	134.99	36.44	10.84	164.25	53.95
9.22	267.76	143.39	11.76	256.71	131.80	6.59	137.79	37.97	10.84	164.55	54.15
12.00	267.76	143.39	15.29	256.71	131.80	8.57	137.79	37.97	14.10	164.55	54.15
12.00	328.59	215.94	15.29	305.55	186.72	8.57	167.88	56.37	14.10	189.24	71.63
14.99	328.59	215.94	19.11	305.55	186.72	10.72	167.88	56.37	17.62	189.24	71.63




Gmax, (MPa)
0.00
50.00
100.00
150.00
200.00
250.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
Depth (m)
M1
M2
M3
M4