APPENDIX 4-3

APEX GEOPHYSICS PHASE 2 REPORT

AGP22044_01_PH2_V2

Report

On The

Geophysical Investigation

At

Laurclavagh Wind Farm Phase 2

County Galway

For

Ghrian Energy Limited

17th July 2023

APEX Geophysics Limited
Unit 6, Knockmullen Business Park
Gorey
Co. Wexford

T: 0402 21842
E: info@apexgeophysics.ie
W: www.apexgeophysics.com

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TONY LOMBARD M.SC (GEOPHYSICS)	IAN SHARKEY (DIP MIN ENG)	V.01	12TH DECEMBER 2022
TONY LOMBARD M.SC (GEOPHYSICS)		V.02	17TH JULY 2023

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1. EXECUTIVE SUMMARY

APEX Geophysics Limited was requested by Ghrian Energy Limited to carry out a geophysical investigation for the Laurclavagh Wind Farm, Co. Galway. The purpose of this Phase 2 survey was to assess the sub-soil conditions at six proposed turbine bases (T1a, T2a and T4a-T7a).

A previous survey, Phase 1, was conducted to assess the sub-soil conditions at eight proposed turbine bases (T1-T8) and at a proposed substation (Report AGP22050_01 Report on the Geophysical Investigation at Laurclavagh Wind Farm, County Galway).

The objectives of the geophysical investigation were to provide information on soil type, thickness and stiffness, depth to and type of bedrock, weathering and excavatability of the bedrock and to identify potential karst features and fault/fissure zones within the bedrock.

The site, situated southwest of Tuam, Co. Galway is within open agricultural land with elevation ranging from 23.8 m OD in the west at T1a to 54.9 m OD in the north at T4a.

The Geological Survey of Ireland (GSI) Quaternary sediments map for the area indicates till derived from limestones and areas of karstified bedrock outcrop or subcrop at the turbine sites. The GSI bedrock map indicates the turbine sites are underlain by pale grey clean skeletal limestone of the Burren Formation. The GSI karst database shows a spring c. 1km m northeast of turbine T7a.

Direct investigation information consisting of trial pit, infiltration trial pits and rotary core holes was provided in June 2023 for incorporation into the report.

The geophysical data, in conjunction with the direct investigation data, generally indicated thin soils of sandy gravelly clay, sandy gravelly clay with cobbles and boulders and clayey sandy gravel/cobbles/boulders across the turbine bases over limestone bedrock. Thicker soils are indicated at base T6a.

While one zone of highly weathered/fractured/possible karstified limestone is interpreted north of base T2a the bedrock is generally interpreted as a thin layer of highly-moderately weathered/fractured limestone (returned as gravel/cobbles/boulders in some rotary coreholes) over slightly weathered to fresh limestone.

Within the slightly weathered to fresh limestone at bases T1a and T7a areas of reduced resistivity values may indicate increased weathering of the bedrock.

As karstification of limestone typically involves dissolution of the bedrock and subsequent infill with glacial material, any groundwork or an altered surface drainage pattern in the vicinity of karstified limestone may lead to a reactivation of karst features. The normal mitigation measures applying to construction over karstic limestones, such as sealed drainage, and foundations capable of spanning voids that may come to the surface, should therefore be incorporated into any works.

The results of the geophysical investigation should be reviewed based on the findings of any further direct investigation.

2. INTRODUCTION

APEX Geophysics Limited was requested by Ghrian Energy Limited to carry out a geophysical investigation for the Laurclavagh Wind Farm, Co. Galway. The purpose of this Phase 2 survey was to assess the sub-soil conditions at six proposed turbine bases (T1a, T2a and T4a-T7a).

A previous survey, Phase 1, was conducted to assess the sub-soil conditions at eight proposed turbine bases (T1-T8) and at a proposed substation (Report AGP22050_01 Report on the Geophysical Investigation at Laurclavagh Wind Farm, County Galway).

2.1 Survey Objectives

The objectives of the survey were to provide information on:

- Soil type, thickness and stiffness,
- Depth to and type of bedrock,
- Weathering and excavatability of the bedrock,
- To identify potential karst features and fault/fissure zones within the bedrock.

2.2 Site Background

The proposed Laurclavagh Wind Farm is located 8.5 km southwest of Tuam, County Galway. The site investigation locations are all within areas of open agricultural land (Fig.2.1) with elevation ranging from 23.8 m OD in the west at T1a to 54.9 m OD in the north at T4a.

Fig 2.1: Location map with turbine bases in magenta.

2.2.1 Soils

The Geological Survey of Ireland (GSI) Quaternary sediments map for the area (GSIc, 2019) indicates that the soils across the site comprise of till derived from limestones (T1a-T6a) and areas of karstified bedrock outcrop or subcrop (T7a), (Fig. 2.2).

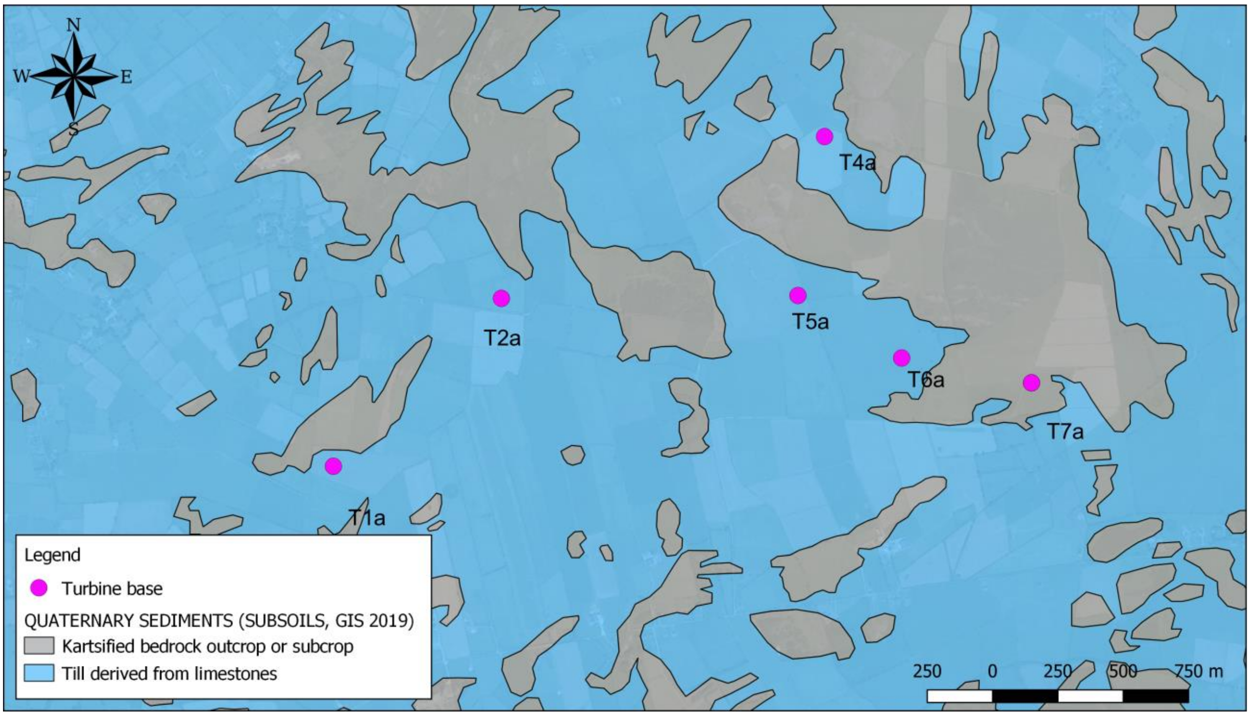

Fig 2.2: The GSI Quaternary sediments map.

2.2.2 Geology

The GSI 1:100k Bedrock Geology map for the area (GSI, 2018) indicates that the survey area is underlain by pale grey clean skeletal limestone of the Burren Formation (Fig. 2.3). Several bedrock outcrops are mapped across the survey area. The GSI karst database shows a spring c. 1km m northeast of turbine T7a.

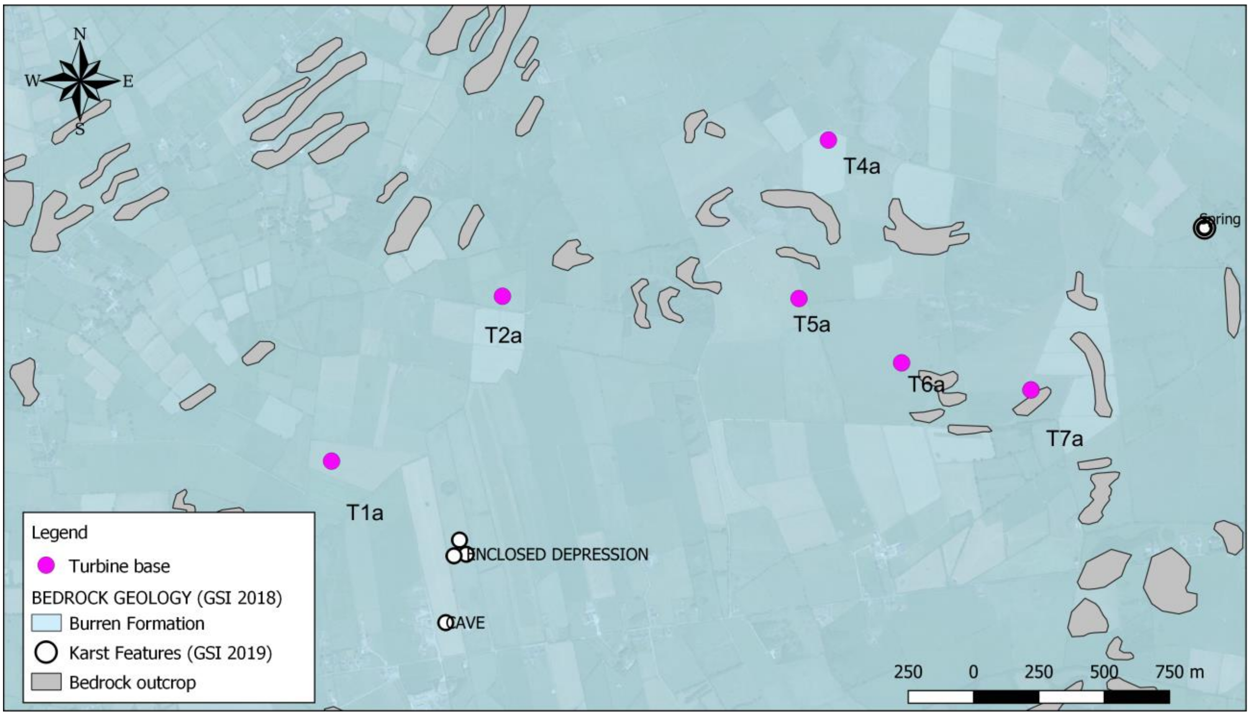

Fig 2.3: The GSI bedrock geology map with karst features from GSI karst database.

2.2.3 Groundwater

The groundwater vulnerability rating for the site (GSIb, 2019) is classified as 'high' at T2a, 'extreme' at T1a, T4a, T5a and T6a to 'rock at or near surface' at T7a (Fig. 2.4). The limestone bedrock is classified as a 'Regionally Important Aquifer - Karstified (conduit).

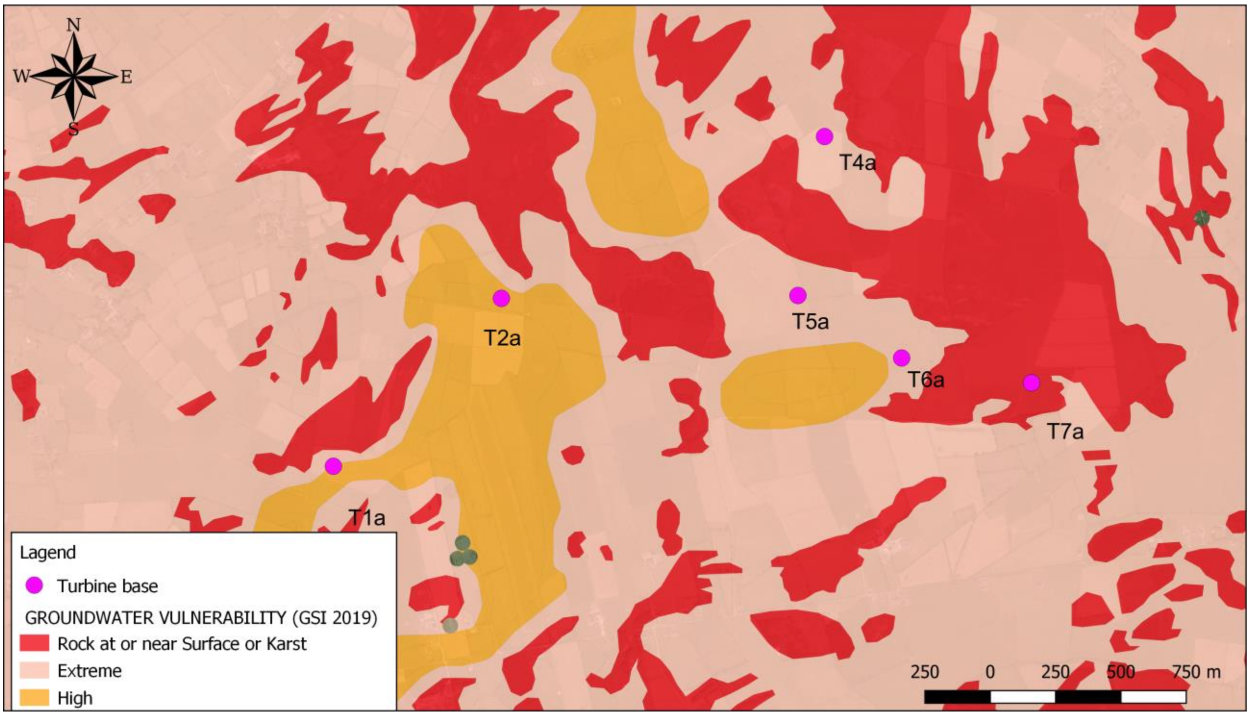

Fig 2.4: The GSI vulnerability classification map.

2.2.4 Historical Data

The historical 6 inch sheet for the area indicates outcropping limestone crags in localised areas across the site (blue areas on Fig. 2.5) as well as large angular blocks of limestone and slightly undulating drift across much of the site.

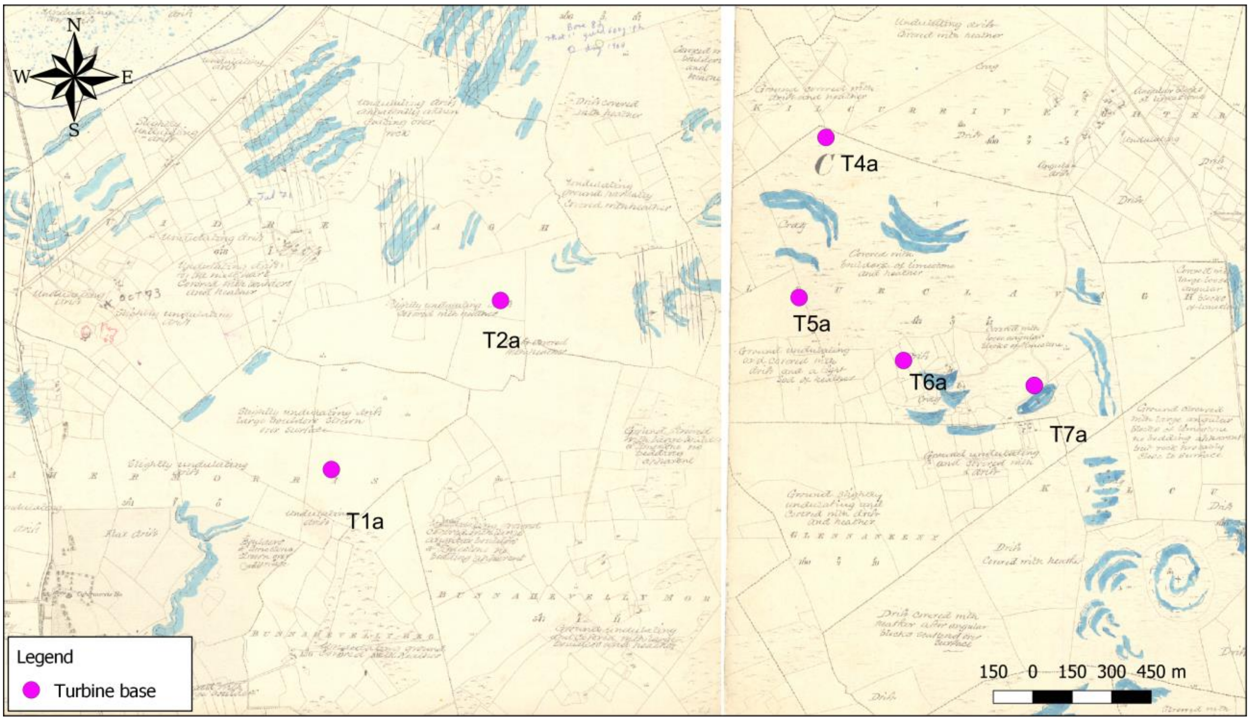

Fig 2.5: The historical 6inch map – limestone outcrops marked with blue.

2.2.5 Direct Investigation Data

Direct investigation information consisting of trial pit, infiltration trial pits and rotary core holes was provided in June 2023 for incorporation into the report. The locations of the pits and core holes acquired close to the proposed turbine bases are shown on Drawing AGP22050_01.

The infiltration trial pits encountered thin topsoil 0.1 to 0.35 m thick over firm to stiff sandy gravelly clay, gravelly clayey sand, boulders of limestone and stiff gravelly sandy silt to termination depths of 1.0 m to 2.7 m below ground level (bgl). No groundwater was encountered in the pits and all terminated on possible bedrock.

Ten rotary cores encountered 1.2 to 3.0 m of soft to firm clay and slightly sandy clay over stiff to very stiff sandy gravelly clay, loose cobbles and boulders and medium dense to dense sandy clayey gravel, gravel (possible bedrock – Driller's description) and slightly clayey gravelly sand over rock. Medium strong to strong moderately to slightly weathered light to dark grey limestone with discolouration on fracture surfaces at depths of 2.5 to 5.85 m below ground level (bgl).

2.3 Survey Rationale

The geophysical investigation consisted of 2D Electrical Resistivity Tomography (ERT), Seismic Refraction profiling and Multi-channel Analysis of Surface Waves (MASW) to examine the sub-soil conditions at six turbine bases (T1a-T6a).

ERT images the resistivity of the materials in the subsurface along a profile to produce a cross-section showing the variation in resistivity with depth, depending on the length of the profile. Each cross-section will be interpreted to determine the material type along the profile at increasing depth, based on the typical resistivities returned for Irish ground materials.

Seismic Refraction profiling 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. Readings are taken using geophones connected via multi-core cable to a seismograph. This method should allow profiling of depth to the top of the bedrock across the site.

The **MASW** method is used to estimate shear-wave (S-wave) velocities in the ground material to indicate possible soft zones. Soil material with an S-wave velocity of <175 m/s is generally classified as soft/loose. The depth of investigation for this method will depend on the source type and geophone spacing. This method may also be used to indicate weathered bedrock depth.

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 GEOPHYSICAL METHODOLOGY**.

3. RESULTS

The survey was carried out between the 29th of September and 21st November 2022 and involved the collection of 11 ERT profiles (T1aR1-T7aR2), 11 No. seismic refraction profiles (T1aS1-T7aS2) and 11 No. 1D MASW profiles (T2aR1, T2aS1 and T2aM1 were previously acquired in Phase 1). The geophysical survey locations are indicated on Drawings AGP22050_T1a to AGP22050_T7a in Appendix D.

3.1 ERT

Two orthogonal ERT Profiles were recorded at each turbine base. The resistivity values have been interpreted, in conjunction with the direct investigation data, on the following basis;

Resistivity (Ohm-m)	Interpretation
150 - 250	Sandy Gravelly CLAY
250-500	Sandy Gravelly CLAY with cobbles (near surface)
500-1,000	Clayey sandy GRAVEL/cobbles/boulders
150-250	Highly Weathered/fracture/possible karstified LIMESTONE
250-1,500	Weathered/Fractured LIMESTONE
>1,500	LIMESTONE

3.2 Seismic Refraction Profiling

Two orthogonal seismic refraction spreads were recorded at each turbine base. Each seismic refraction dataset was processed using a tomographic inversion and resultant subsurface velocities have been interpreted, in conjunction with the ERT data, as follows:

Seismic Velocity (m/s)	Interpretation	Stiffness/ Rock Quality	Excavatability
240-500	Soil	Soft/Loose	Diggable
500-1,000	Soil	Firm/Medium Dense	Diggable
1,000-1,800	Soil	Stiff/Dense	Diggable
1,800-2,200	Soil	Very Stiff/Very Dense	Diggable
1,000-2,400	Highly to Moderately Weathered Rock	Poor-Good	Rippable-Breaking/Blasting
1,800-2,400	Moderately to Slightly Weathered Rock	Good	Breaking/Blasting
2,400-5,254	Slightly Weathered to Fresh Rock	Good	Breaking/Blasting

* *It should be noted that the cut-off velocity for excavatability will be lower if excavating in trenches and when excavating parallel to the regional geological strike, due to seismic anisotropy of the bedrock.*

3.3 MASW

Two orthogonal MASW profiles were acquired at each turbine base with the aim of resolving a 1D Shear-wave velocity (Vs) profile and calculating a 1D Gmax profile of the soil layers underlying each proposed turbine location. Due to the presence of thin soils and shallow rock at the turbine bases, the Vs and Gmax profiles could not be determined. While thicker soils are present at T6a the data did not yield good definition of soil Vs values indicating the soil may have similar Vs values to rock.

3.4 Integrated Interpretation

3.4.1 Turbine Base T1a

The results at turbine base T1a are shown on Drawing AGP22050_T1a.

The soil layers at Turbine Base T1a have been interpreted as comprising of 0.3 to 0.8 m of loose soil and 0.2 to 3.2 m of soft-firm soil over an intermittent layer of medium dense soil up to 2.2 m thick. Soil type is interpreted as sandy gravelly clay with cobbles and clayey sandy gravel.

The geophysical data indicates a layer of dense to very dense gravel/cobbles/boulders and/or highly to moderately weathered/fractured limestone at depths of 0.4 to 3.8 m bgl (0.4m at turbine centre). This material, which is returned in rotary corehole RC03 as dense gravel, ranges in thickness from 0.9 to 5.5 m and overlies slightly weathered to fresh limestone at a depth of 1.8 to 7.9 m bgl.

3.4.2 Turbine Base T2a

The results at turbine base T2a are shown on Drawing AGP22050_T2a.

The soil layers at Turbine Base T2a have been interpreted as comprising of 0.2 to 3.0 m of soft/loose soil over an intermittent layer of firm/medium dense soil up to 3.2 m thick becoming stiff-very stiff/dense-very dense with depth. Soil type is interpreted as primarily sandy gravelly clay and a small area of clayey sandy gravel west of the base.

The geophysical data indicates a layer of dense to very dense gravel/cobbles/boulders and/or highly to moderately weathered/fractured limestone at depths of 0.9 m to 7.7 m bgl (2.2 m at the turbine centre) which ranges from 0.8 to 7.7 m thick and overlies moderately to slightly weathered/fractured limestone at a depth of 1.9 to 15.7 m bgl. A zone of highly weathered/fractured/possible karstified limestone has been interpreted offset 50 m to the north of the turbine centre. Increased weathering/fracturing of the limestone at T2a is also indicated by low RQD values of 10% to 35% in the upper 6.5 and 4.0 m of encountered rock in rotary coreholes RC01 and RC04.

3.4.3 Turbine Base T4a

The results at turbine base T4a are shown on Drawing AGP22050_T4a.

The soil layers at Turbine Base T4a have been interpreted as comprising of an intermittent layer of soft to firm soil 0.4 to 2.2 m thick over 0.2 to 2.1 m of medium dense soil. Soil type is interpreted as sandy gravelly clay with cobbles and clayey sandy gravel.

The geophysical data indicates a layer of dense to very dense gravel/cobbles/boulders and/or highly to moderately weathered/fractured limestone, returned in rotary corehole RC02 as cobbles, boulders and gravel (possible bedrock-driller's description), at depths of 0.6 to 2.6 m bgl (0.7 m bgl at turbine centre). This layer ranges in thickness from 1.0 to 2.8 m and overlies slightly weathered to fresh Limestone at a depth of 1.5 to 4.2 m bgl.

3.4.4 Turbine Base T5a

The results at turbine base T5a are shown on Drawing AGP22050_T5a.

The soil layers at Turbine Base T5a have been interpreted as comprising of 0.2 to 0.8 m of soft/loose soil over an intermittent layer of medium dense soil up to 0.4 m thick. Soil type is interpreted as sandy gravelly clay with cobbles and clayey sandy gravel.

The geophysical data indicates a layer of dense to very dense gravel/cobbles/boulders and/or highly to moderately weathered/fractured limestone at depths of 0.3 m to 1.0 m bgl (0.8 m at the turbine centre). This layer ranges in thickness from 1.0 to 3.2 m and overlies slightly weathered to fresh Limestone at a depth of 1.5 to 3.7 m bgl. There is a good correlation between interpreted depth to slightly weathered to fresh limestone and encountered rock depth in rotary coreholes RC05, RC08 and RC11. A zone of slightly reduced model resistivity values (2,000-7,000 Ohm-m) present on ERT profiles T5aR1 and T5aR2 indicate a possible slight increase in bedrock weathering/fracturing in a c. 10 m wide zone c. 10 to 15 m west of the turbine centre.

3.4.5 Turbine Base T6a

The results at turbine base T6a are shown on Drawing AGP22050_T6a.

The soil layers at Turbine Base T6a have been interpreted as comprising of an intermittent layer 0.3 to 1.0 m of loose and 0.4 to 1.8 m of soft to firm soil over firm/medium dense soil becoming stiff-very stiff/dense-very dense with depth. Soil type is interpreted as sandy gravelly clay and sandy gravelly clay with cobbles close to the turbine centre and clayey sandy gravel.

Undulating limestone bedrock has been interpreted at depths of 0.87 to 7.8 m bgl (6.8 m bgl at the turbine centre). The geophysical data indicates a small area of highly to moderately weathered limestone c. 55 m southeast of the turbine centre. Across the surveyed area an upper layer of moderately to slightly weathered/fractured limestone from 0.4 to 3.8 m thick overlies slightly weathered to fresh Limestone at a depth of 2.6 to 10.1 m bgl.

While rotary corehole RC09 encountered shallower slightly weathered rock at 3.0 m bgl close to the turbine centre the geophysical data indicates that if present at this depth rock would be low resistivity moderately weathered/ fractured rock.

3.4.6 Turbine Base T7a

The results at turbine base T7a are shown on Drawing AGP22050_T7a.

The soil layers at Turbine Base T7a have been interpreted as comprising an intermittent layer of loose soil up to 1.55m thick and soft to firm soil up to 3.2 m thick over 0.7 to 2.9 m of firm/medium dense soil becoming dense with depth. Soil type is interpreted as clayey sandy gravel, sandy gravelly clay east of the turbine centre and sandy gravelly clay with cobbles.

The geophysical data indicates a layer of gravel/cobbles/boulders and/or highly to moderately weathered/fractured limestone at depths of 0.8 to .9 m bgl, (0.8 m at turbine centre) ranging from 0.6 to 3.2 m thick over slightly weathered to fresh Limestone at a depth of 1.4 to 15.4 m bgl. Within the bedrock, areas of reduced model resistivity (650-1,5000 Ohm-m) may indicate increased weathering of the bedrock. These areas are highlighted on ERT profiles T7aR1 and T7aR2 on Drawing AGP22050_T7a and are interpreted as zones of moderately to slightly weathered/fractured limestone east of the turbine centre.

Where bedrock excavation is proposed the highly to moderately weathered/fractured rock will be rippable to requiring breaking/blasting and the moderately to slightly weathered/fractured rock and slightly weathered to fresh rock will require breaking/blasting. More detailed discussion of velocity and excavatability is contained in Appendix C.

4. RECOMMENDATIONS

Where bedrock excavation is proposed, a detailed assessment of excavatability should be carried out combining the results of the geophysical survey, rotary core drilling, strength testing, and trial excavation pits down to formation level using a high powered excavator of similar rating to that to be used during construction.

As karstification of limestone typically involves dissolution of the bedrock and subsequent infill with glacial material, any groundwork or an altered surface drainage pattern in the vicinity of karstified limestone may lead to a reactivation of karst features. The normal mitigation measures applying to construction over karstic limestones, such as sealed drainage, and foundations capable of spanning voids that may come to the surface, should therefore be incorporated into any works.

The geophysical report should be reviewed after the completion of any further direct investigation.

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APPENDIX A: DETAILED GEOPHYSICAL METHODOLOGY

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

Electrical Resistivity Tomography (ERT)

Electrical Resistivity Tomography was carried out to provide information on lateral variations in the overburden material as well as on the underlying overburden and bedrock.

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.

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.

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.

Seismic Refraction Profiling

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.

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. Equipment was carried and 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).

Data Processing
First break picking in digital format was carried out using the SeisImager/2D PICKWIN software program from Geometrics to construct p-wave (Vp) traveltime plots for each spread. The processing and interpretation uses the ray-tracing and tomographic inversion methods, to acquire depths to boundaries and the P-wave velocities of these layers, using the SeisImager/2D PLOTREFA program.

SeisImager/2D interprets seismic refraction data as a laterally varying layered earth structure. The program 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).

Multichannel Analysis of Surface Waves (MASW)

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,

(iv) 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.

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.

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) veolocity profile.

SURFSEIS data processing involves three steps:

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

(ii) Production of a dispersion curve from a spectral analysis of the data showing the variation of Raleigh wave phase velocity with wavelength. Confidence in the dispersion curve can be estaimated 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.

Spatial Relocation

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

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

APPENDIX B: SEISMIC REFRACTION DATA

The tomographic inversions of the seismic refraction datasets are shown below.

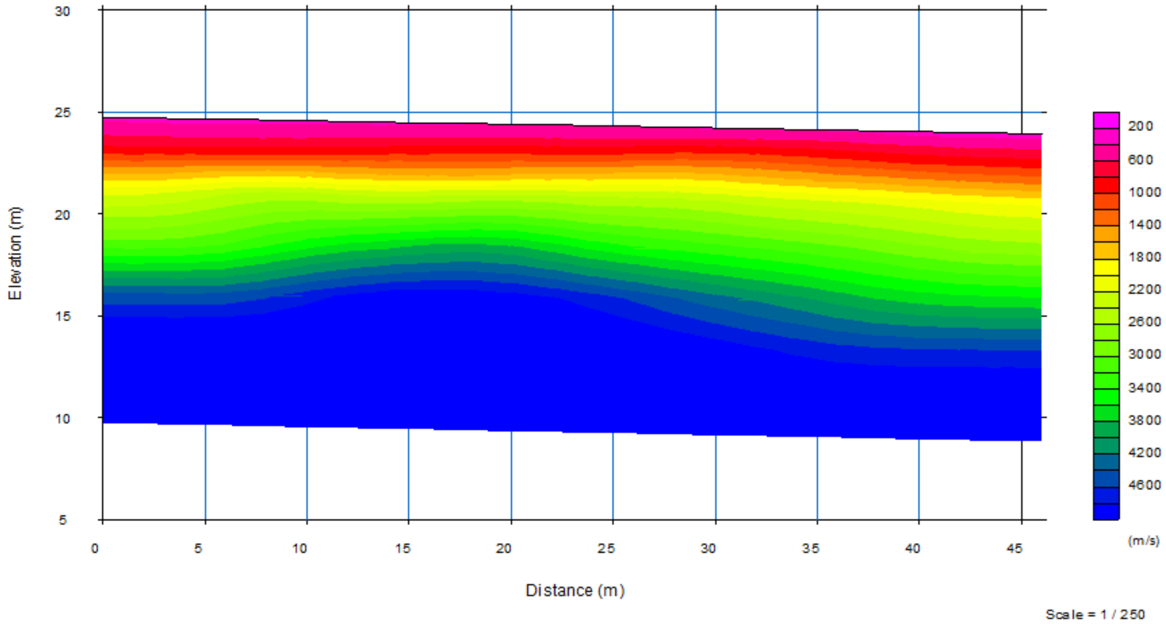

Fig B.1: Seismic Refraction T1aS1 Tomographic Inversion.

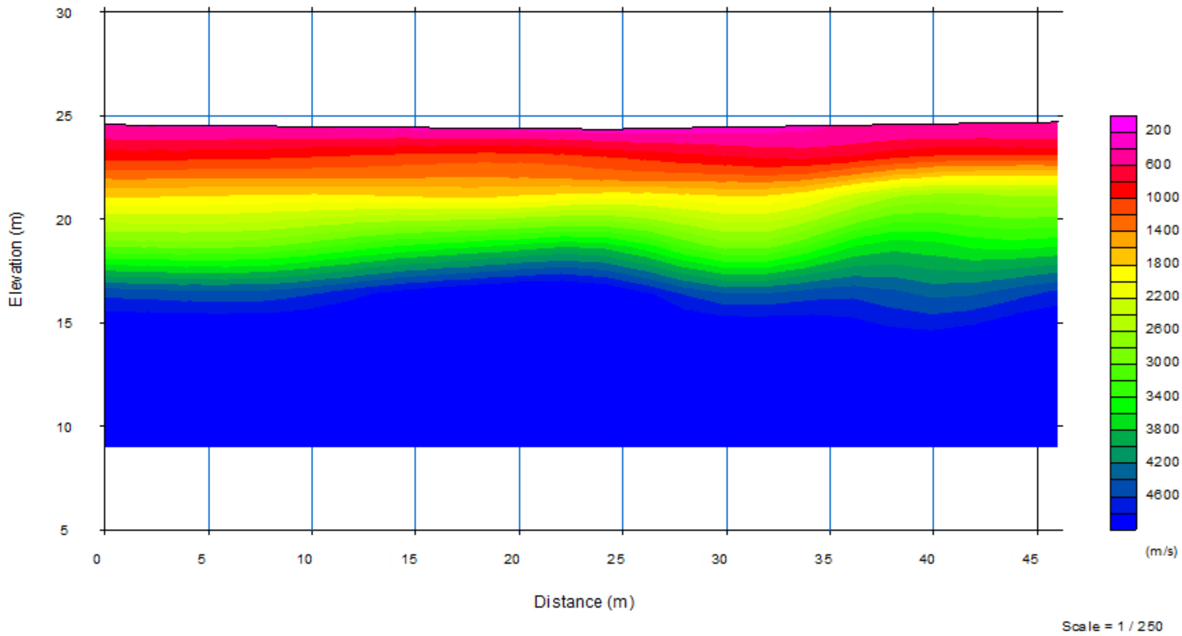

Fig B.2: Seismic Refraction T1aS2 Tomographic Inversion.

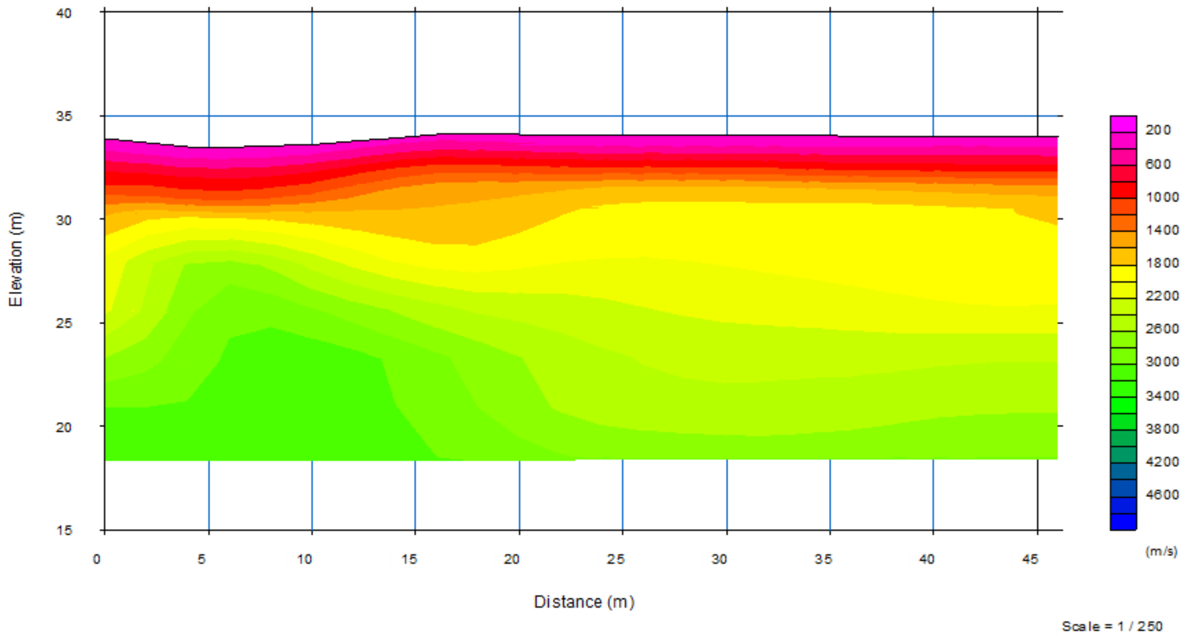

Fig B.3: Seismic Refraction T2aS1 Tomographic Inversion.

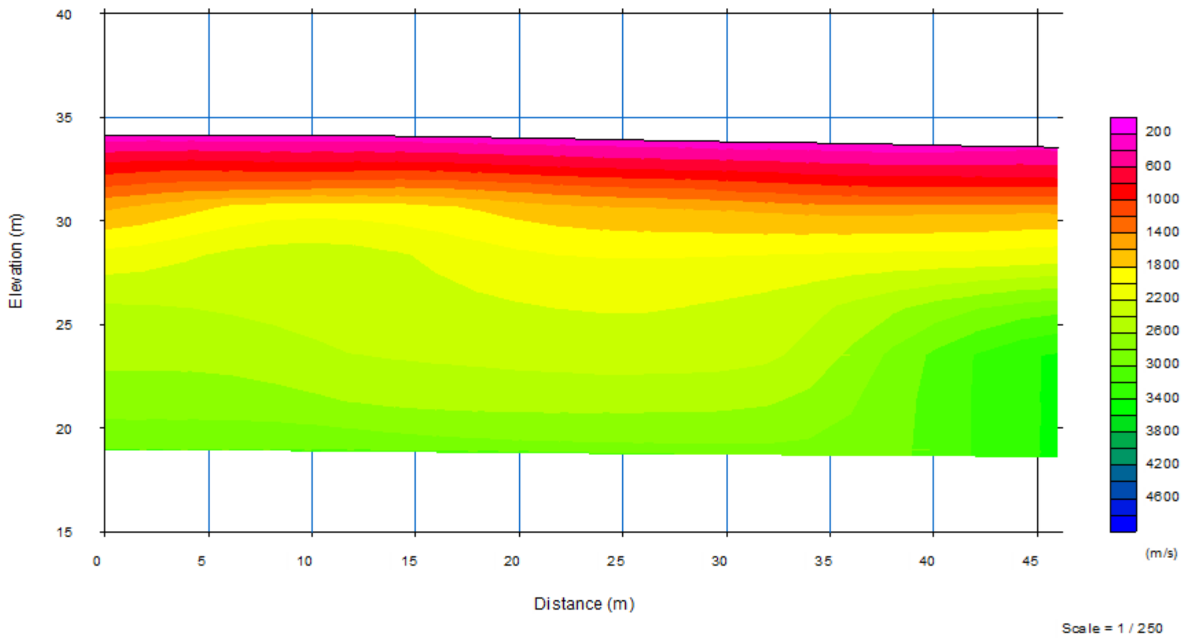

Fig B.4: Seismic Refraction T2aS2 Tomographic Inversion.

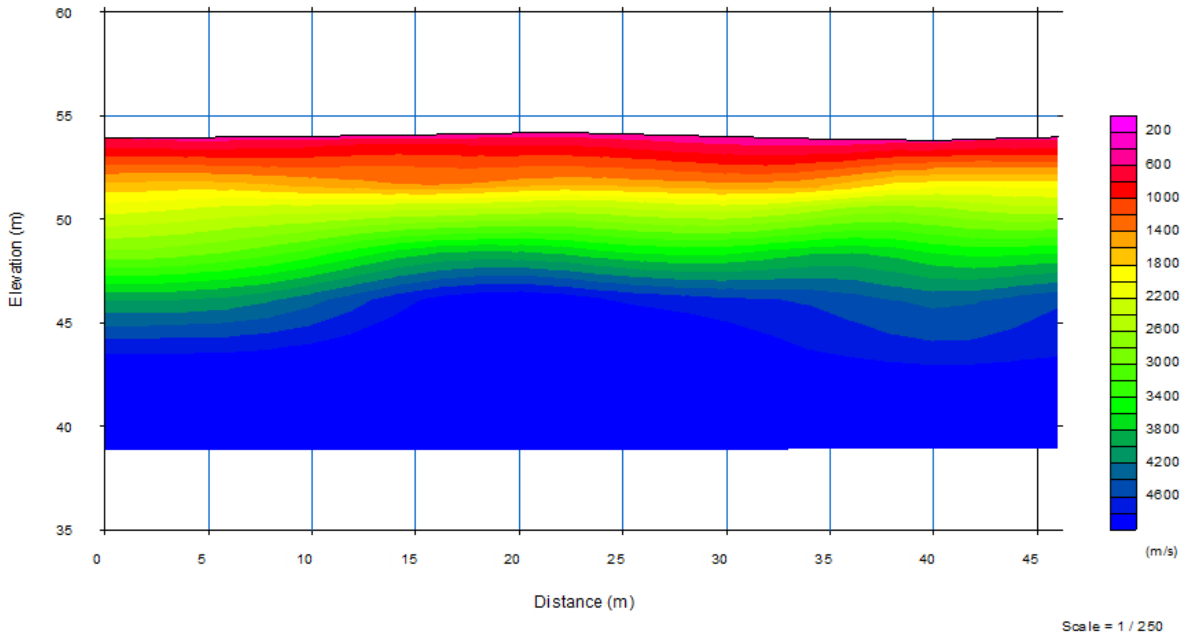

Fig B.5: Seismic Refraction T4aS1 Tomographic Inversion.

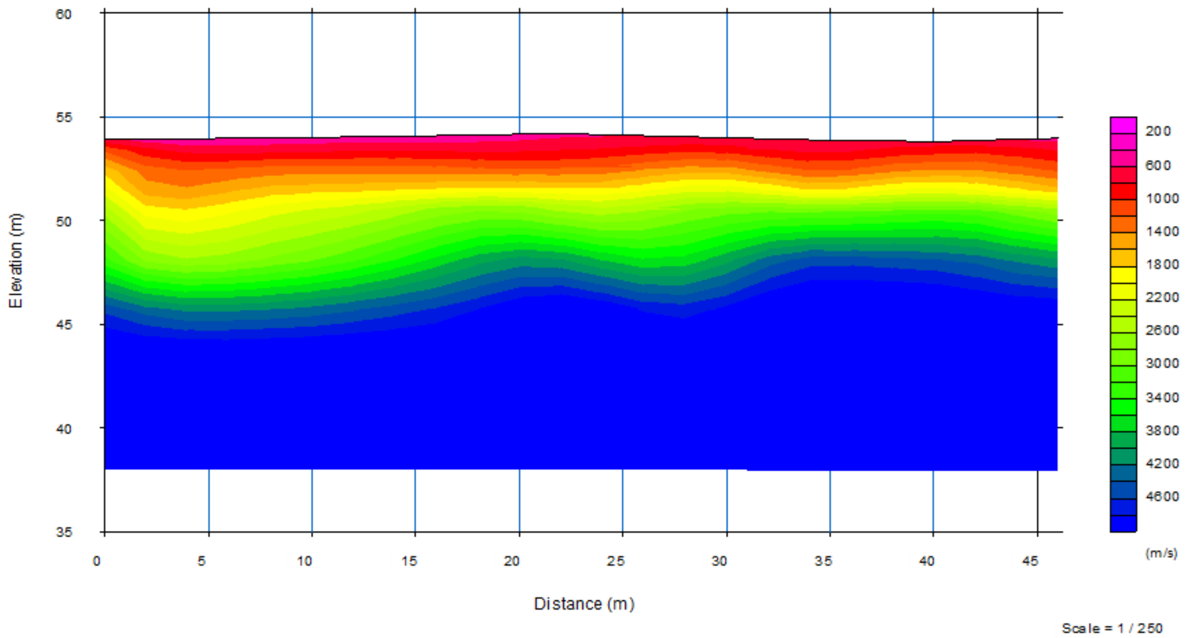

Fig B.6: Seismic Refraction T4bS2 Tomographic Inversion.

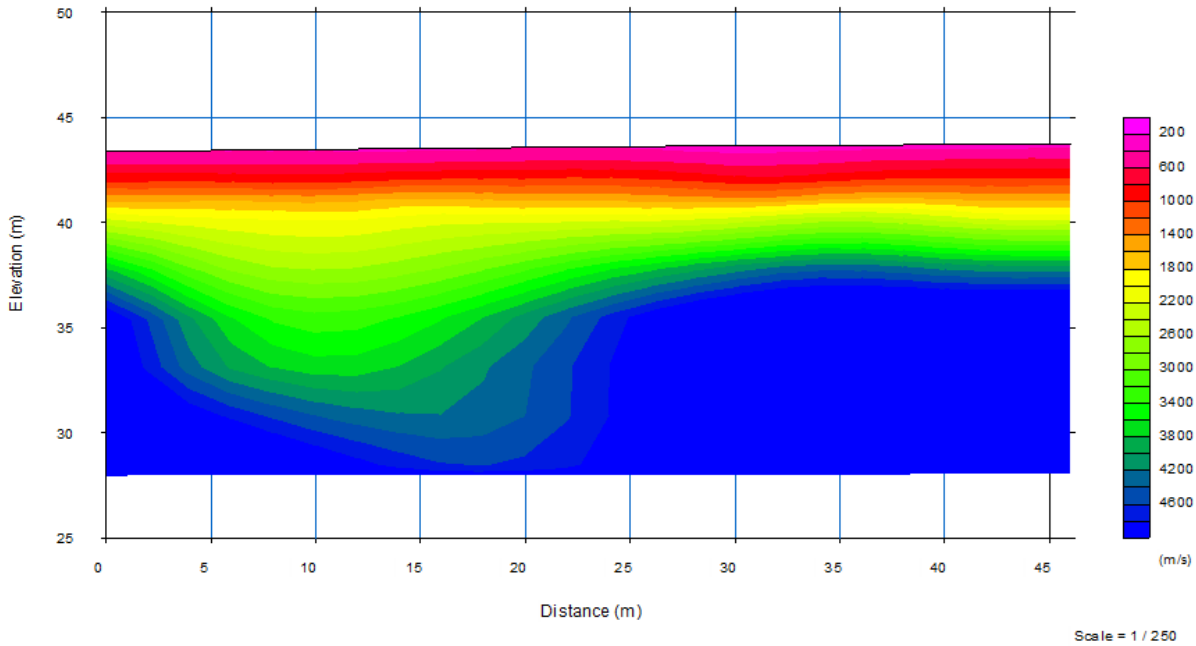

Fig B.7: Seismic Refraction T5aS1 Tomographic Inversion.

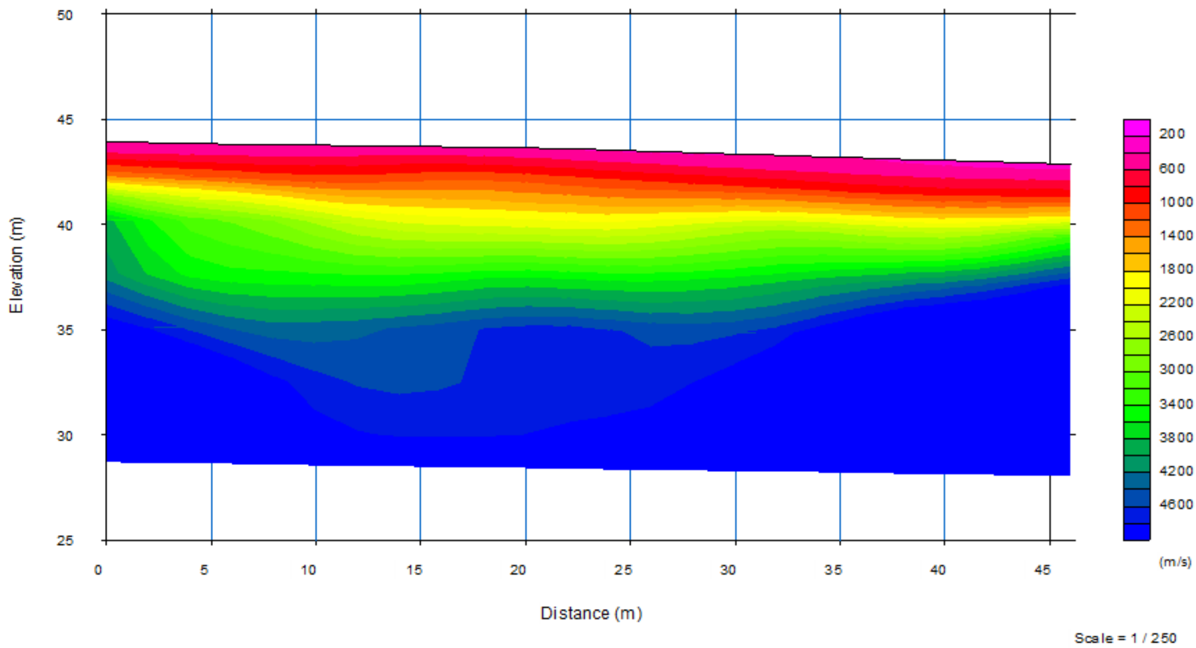

Fig B.8: Seismic Refraction T5aS2 Tomographic Inversion.

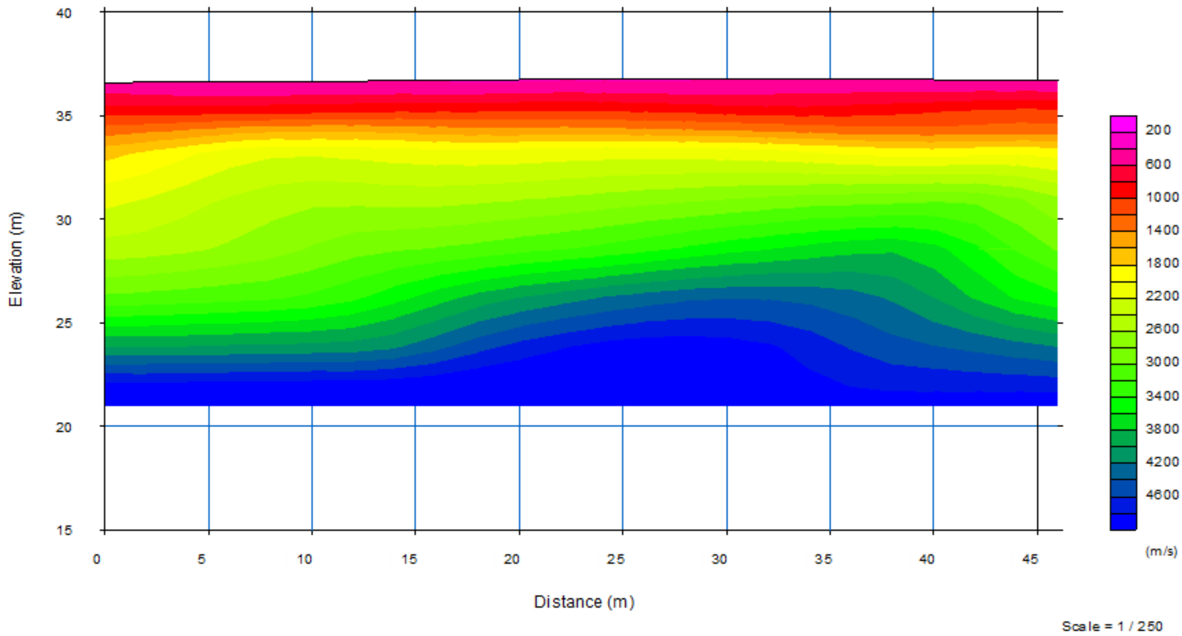

Fig B.9: Seismic Refraction T6aS1 Tomographic Inversion.

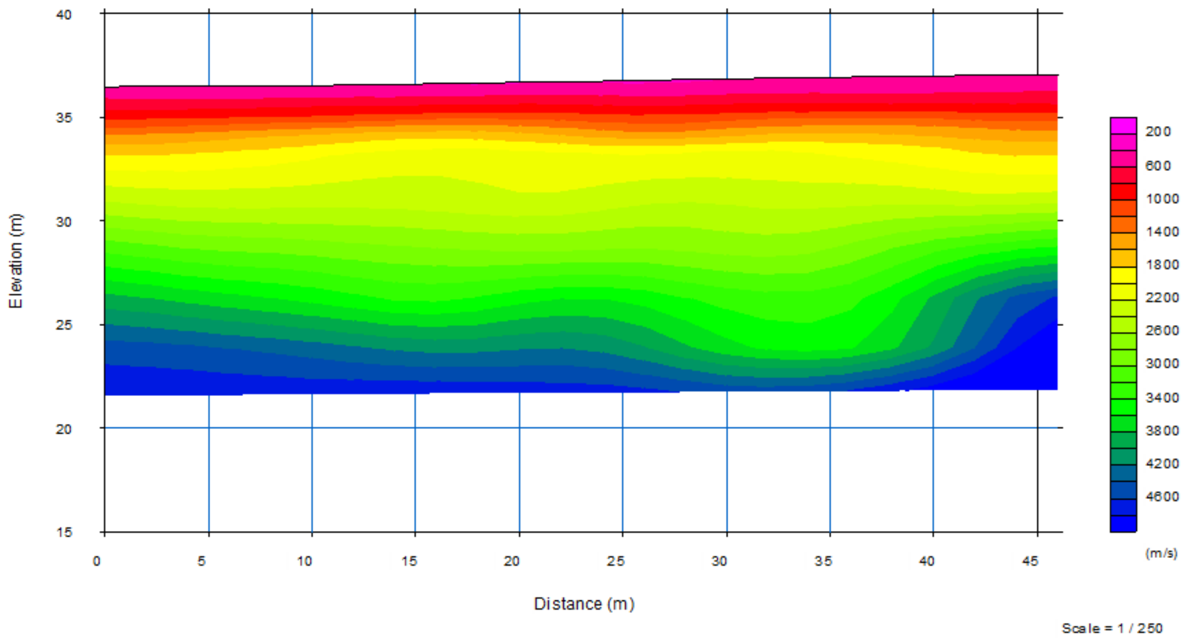

Fig B.10: Seismic Refraction T6aS2 Tomographic Inversion.

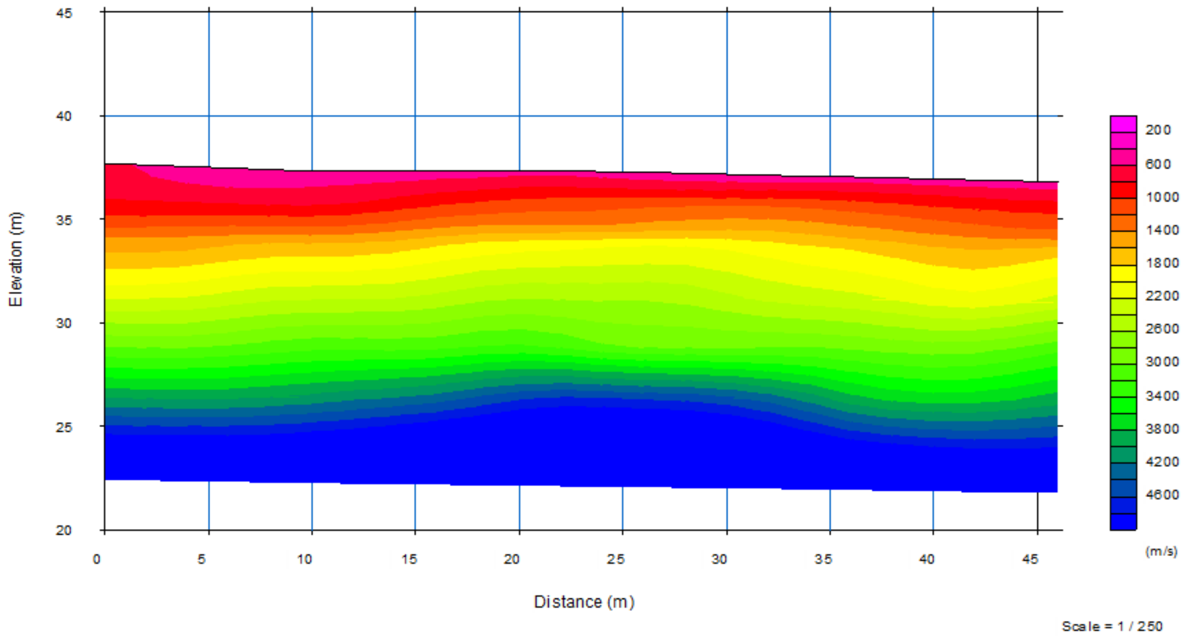

Fig B.11: Seismic Refraction T7aS1 Tomographic Inversion.

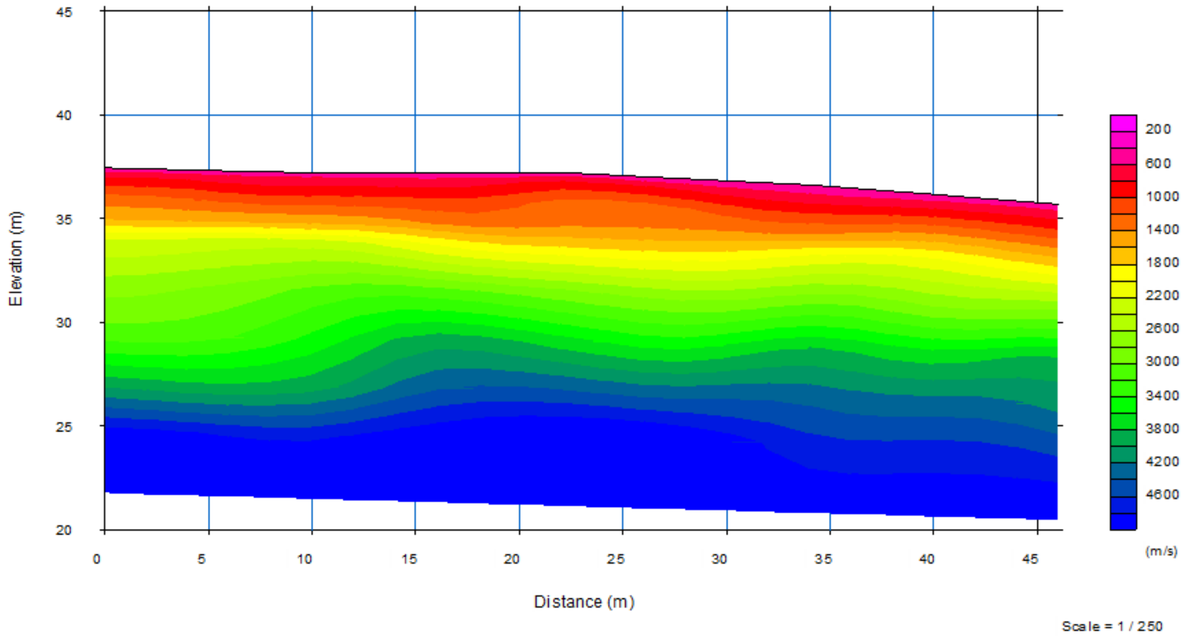

Fig B.12: Seismic Refraction T7aS2 Tomographic Inversion.

APPENDIX C: EXCAVATABILITY

The seismic velocity of a rock formation is related to characteristics of the rock mass which include rock hardness and strength, degree of weathering and discontinuities. Usually the velocity is just one of several parameters used in the assessment of excavatability. The excavatability of a rock formation is favoured by the following factors:

- Open fractures, faults and other planes of weakness of any kind
- Weathering
- Brittleness and crystalline nature
- High degree of stratification or lamination
- Large grain size
- Low compressive strength

Weaver (1975) presented a comprehensive rippability rating chart (Fig.1) in which the p-wave velocity value and the relevant geological factors could be entered and assigned appropriate weightings. The total weighted index was found to correlate very well with actual rippability.

Fig.1 Rippability Rating Chart

Rock class	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock
Seismic velocity (m/s)	>2150	2150-1850	1850-1500	1500-1200	1200-450
Rating	26	24	20	12	5
Rock hardness	Extremely hard rock	Very hard rock	Hard rock	Soft rock	Very soft rock
Rating	10	5	2	1	0
Rock weathering	Unweathered	Slightly weathered	Weathered	Highly weathered	Completely weathered
Rating	9	7	5	3	1
Joint spacing (mm)	>3000	3000-1000	1000-300	300-50	<50
Rating	30	25	20	10	5
Joint continuity	Non continuous	Slightly continuous	Continuous-no gouge	Continuous-some gouge	Continuous-with gouge
Rating	5	5	3	0	0
Joint gouge	No separation	Slight separation	Separation <1mm	Gouge <5mm	Gouge >5mm
Rating	5	5	4	3	1
Strike and dip orientation	Very unfavourable	Unfavourable	Slightly unfavourable	Favourable	Very favourable
Rating	15	13	10	5	3
Total rating	100-90	90-70*	70-50	50-25	<25
Rippability assessment	Blasting	Extremely hard ripping and blasting	Very hard ripping	Hard ripping	Easy ripping
Tractor horsepower		770/385	385/270	270/180	180
Tractor kilowatts		575/290	290/200	200/135	135

APPENDIX D: DRAWINGS

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

AGP22050_01a	Geophysical Investigation Locations	1:15000@ A4
AGP22050_T1a	Fig. 1 Turbine Base T1a Results and Interpretation T1aR1 & T1aS1	1:1250 @ A4
	Fig. 2 Turbine Base T1a Results and Interpretation T1aR2 & T1aS2	1:1250 @ A4
AGP22050_T2a	Fig. 1 Turbine Base T2a Results and Interpretation T2aR1 & T2aS1	1:1250 @ A4
	Fig. 2 Turbine Base T2a Results and Interpretation T2aR2 & T2aS2	1:1250 @ A4
AGP22050_T4a	Fig. 1 Turbine Base T4a Results and Interpretation T4aR1 & T4aS1	1:1250 @ A4
	Fig. 2 Turbine Base T4a Results and Interpretation T4aR2 & T4aS2	1:1250 @ A4
AGP22050_T5a	Fig. 1 Turbine Base T5a Results and Interpretation T5aR1 & T5aS1	1:1250 @ A4
	Fig. 2 Turbine Base T5a Results and Interpretation T5aR2 & T5aS2	1:1250 @ A4
AGP22050_T6a	Fig. 1 Turbine Base T6a Results and Interpretation T6aR1 & T6aS1	1:1250 @ A4
	Fig. 2 Turbine Base T6a Results and Interpretation T6aR2 & T6aS2	1:1250 @ A4
AGP22050_T7a	Fig. 1 Turbine Base T7a Results and Interpretation T7aR1 & T7aS1	1:1250 @ A4
	Fig. 2 Turbine Base T7a Results and Interpretation T7aR2 & T7aS2	1:1250 @ A4

GEOPHYSICAL INVESTIAGTION LOCATIONS

SCALE 1:15000

INDEX MAP:

LEGEND:

- Proposed Turbine Centre
- T1R1 2D resistivity profile
- T1S1 Seismic refraction profile
- MT1M1/M2 MASW Locations
- BH1 Borehole
- TP1 Trial pit

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apex geophysics

6 Knockmullen Business Park
Gorey
Co. Wexford
Ireland

T +353 (0)402-21842
E info@apexgeophysics.ie
www.apexgeophysics.ie

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FIG. 1: TURBINE BASE T1a RESULTS AND INTERPRETATION T1aR1 & T1aS1

SCALE 1:1250

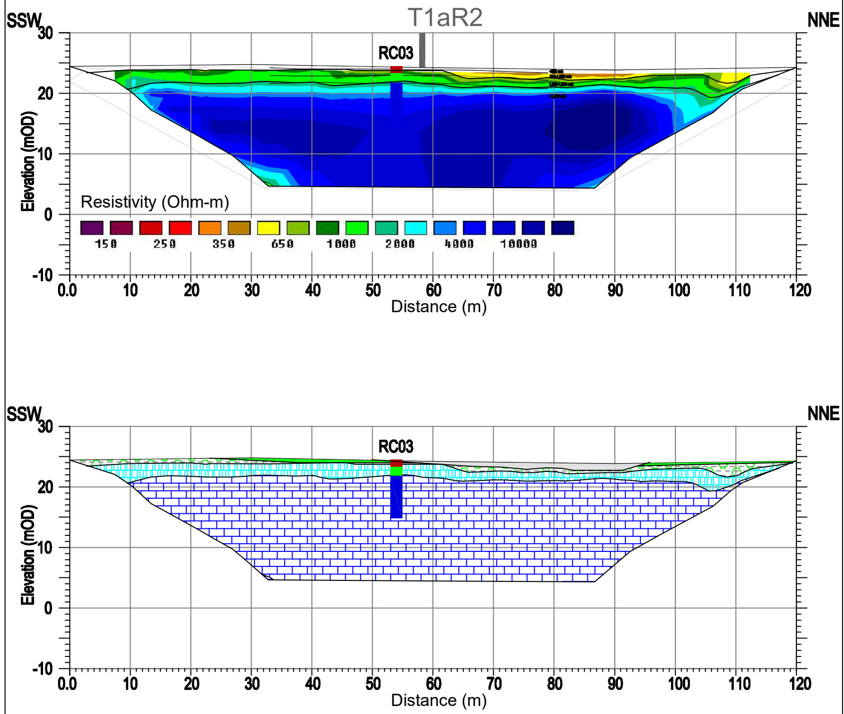
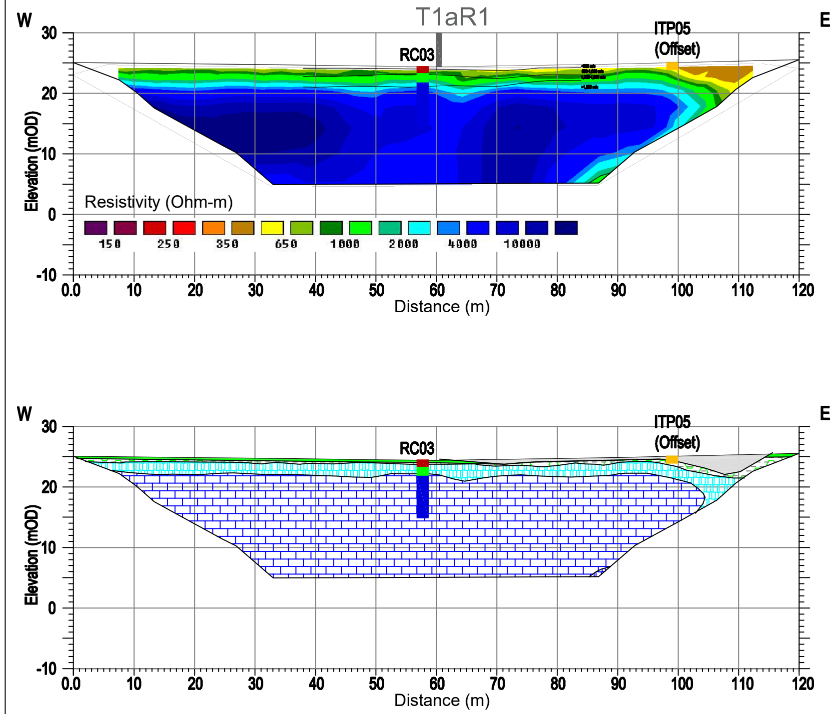


FIG. 2: TURBINE BASE T1a RESULTS AND INTERPRETATION T1aR2 & T1aS2

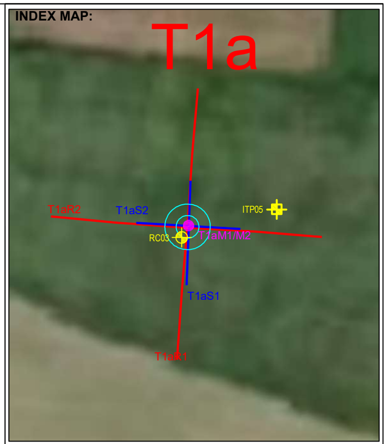
SCALE 1:1250



SUMMARY LOG LEGEND

- Sandy CLAY
- Firm to stiff sandy gravelly CLAY
- Stiff to very stiff Sandy gravelly CLAY
- CLAY
- Firm to stiff sandy gravelly SILT
- Sandy clayey GRAVEL
- GRAVEL
- COBBLES AND BOULDERS
- Gravelly clayey SAND
- STRONG DOLOMOTISED LIMESTONE
- MEDIUM STRONG TO STRONG LIMESTONE
- STRONG LIMESTONE

INDEX MAP:



LEGEND:

- Seismic Refraction layer with Vp velocity
- Soft sandy gravelly CLAY
- Soft-Firm sandy gravelly CLAY with cobbles & boulders
- Stiff sandy gravelly CLAY with cobbles
- Very stiff sandy gravelly CLAY with cobbles
- Firm sandy gravelly CLAY
- Stiff sandy gravelly CLAY
- Very stiff sandy gravelly CLAY
- Loose clayey sandy GRAVEL
- Medium dense clayey sandy GRAVEL
- Dense clayey sandy GRAVEL
- Very dense clayey sandy GRAVEL
- Dense-Very Dense GRAVEL/COBBLES/BOULDERS/ Highly-moderately weathered/fractured LIMESTONE
- Moderately-slightly weathered/fractured LIMESTONE
- Slightly weathered-fresh LIMESTONE

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apex geophysics

6 Knockmullen Business Park
Gorey
Co. Wexford
Ireland

T +353 (0)402-21842
E info@apexgeophysics.ie
www.apexgeophysics.ie

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DRAWING 01: AGP22050_T1a

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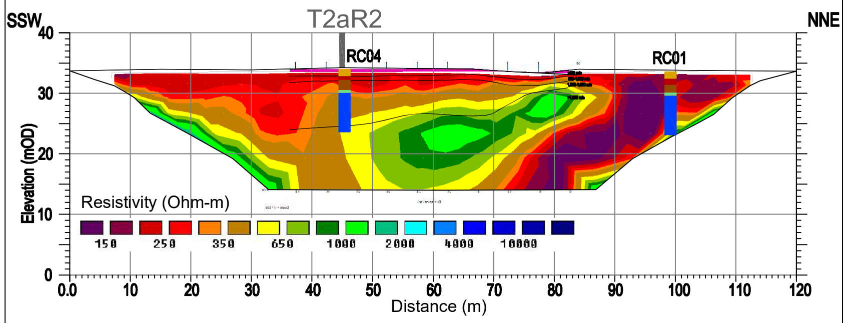
FIG. 1: TURBINE BASE T2a RESULTS AND INTERPRETATION T2aR1 & T2aS1

SCALE 1:1250



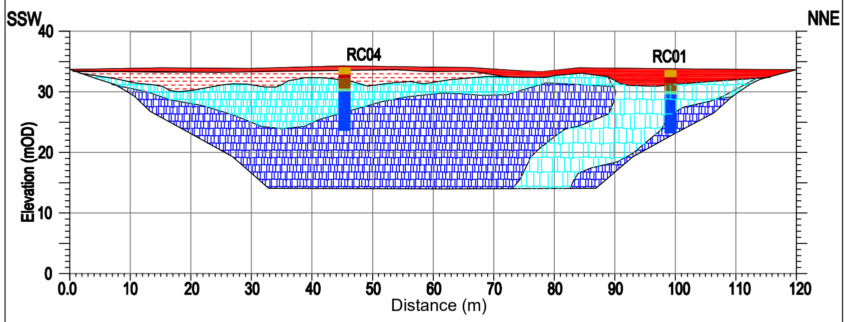


FIG. 2: TURBINE BASE T2a RESULTS AND INTERPRETATION T2aR2 & T2aS2

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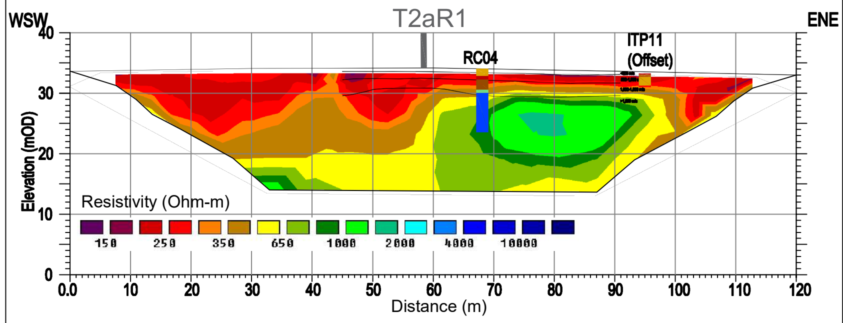
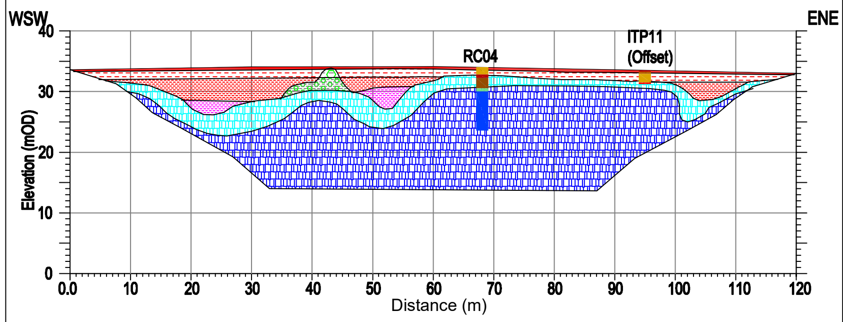
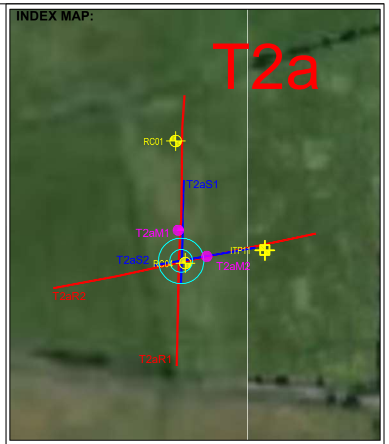




SUMMARY LOG LEGEND

- Sandy CLAY
- Firm to stiff sandy gravelly CLAY
- Stiff to very stiff Sandy gravelly CLAY
- CLAY
- Firm to stiff sandy gravelly SILT
- Sandy clayey GRAVEL
- GRAVEL
- COBBLES AND BOULDERS
- Gravelly clayey SAND
- STRONG DOLOMOTISED LIMESTONE
- MEDIUM STRONG TO STRONG LIMESTONE
- STRONG LIMESTONE

INDEX MAP:



LEGEND:

- Seismic Refraction layer with Vp velocity
- Soft sandy gravelly CLAY
- Soft-Firm sandy gravelly CLAY with cobbles
- Stiff sandy gravelly CLAY with cobbles
- Very stiff sandy gravelly CLAY with cobbles
- Firm sandy gravelly CLAY
- Stiff sandy gravelly CLAY
- Very stiff sandy gravelly CLAY
- Loose clayey sandy GRAVEL
- Medium dense clayey sandy GRAVEL
- Dense clayey sandy GRAVEL
- Very dense clayey sandy GRAVEL
- Highly weathered/fractured/possible karstified LIMESTONE
- Dense-Very Dense GRAVEL/COBBLES/BOULDERS/ Highly-moderately weathered/fractured LIMESTONE
- Moderately-slightly weathered/fractured LIMESTONE
- Slightly weathered-fresh LIMESTONE

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apex geophysics

6 Knockmullen Business Park
Gorey
Co. Wexford
Ireland

T +353 (0)402-21842
E info@apexgeophysics.ie
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FIG. 1: TURBINE BASE T4a RESULTS AND INTERPRETATION T4aR1 & T4aS1

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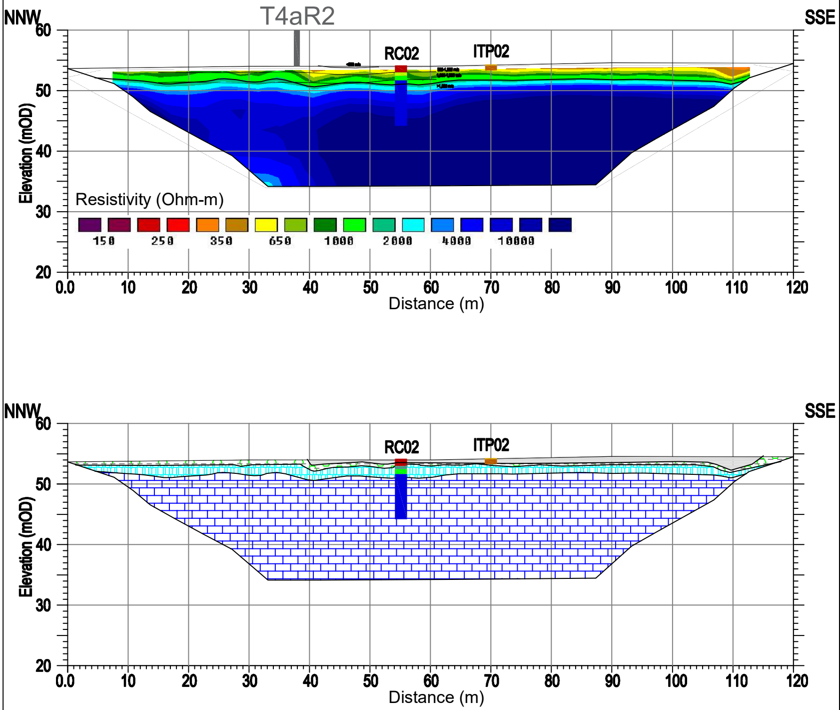

FIG. 2: TURBINE BASE T4a RESULTS AND INTERPRETATION T4aR2 & T4aS2

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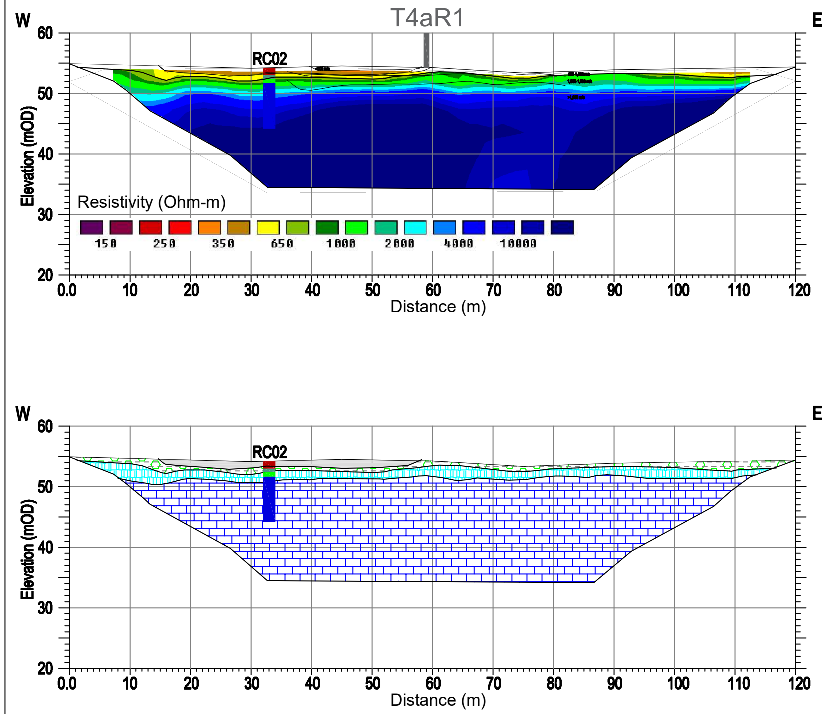
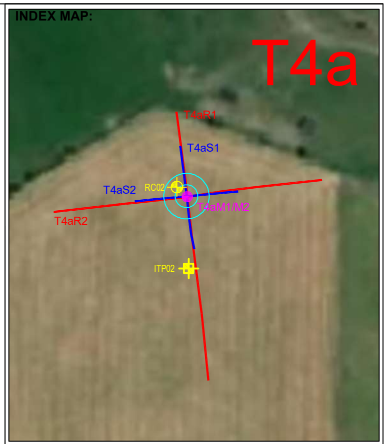


INDEX MAP:



LEGEND:

- Seismic Refraction layer with Vp velocity
- Soft sandy gravelly CLAY
- Soft-Firm sandy gravelly CLAY with cobbles & boulders
- Stiff sandy gravelly CLAY with cobbles
- Very stiff sandy gravelly CLAY with cobbles
- Firm sandy gravelly CLAY
- Stiff sandy gravelly CLAY
- Very stiff sandy gravelly CLAY
- Loose clayey sandy GRAVEL
- Medium dense clayey sandy GRAVEL
- Dense clayey sandy GRAVEL
- Very dense clayey sandy GRAVEL
- Dense-Very Dense GRAVEL/COBBLES/BOULDERS/ Highly-moderately weathered/fractured LIMESTONE
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SUMMARY LOG LEGEND

- Sandy CLAY
- Firm to stiff sandy gravelly CLAY
- Stiff to very stiff Sandy gravelly CLAY
- CLAY
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- GRAVEL
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FIG. 2: TURBINE BASE T5a RESULTS AND INTERPRETATION T5aR1 & T5aS1

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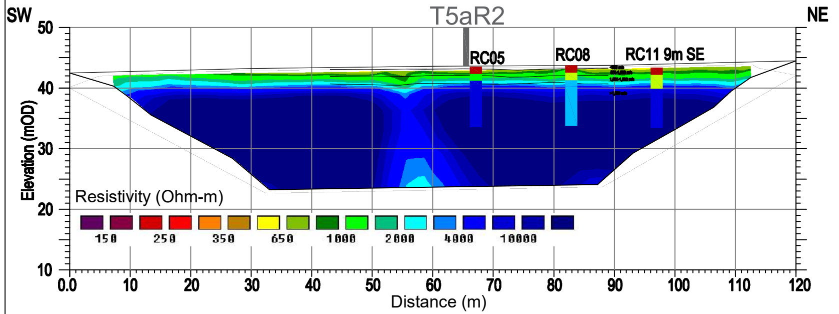

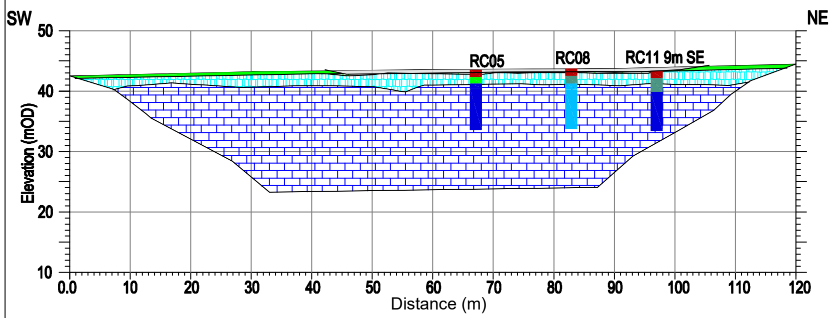

FIG. 2: TURBINE BASE T5a RESULTS AND INTERPRETATION T5aR2 & T5aS2

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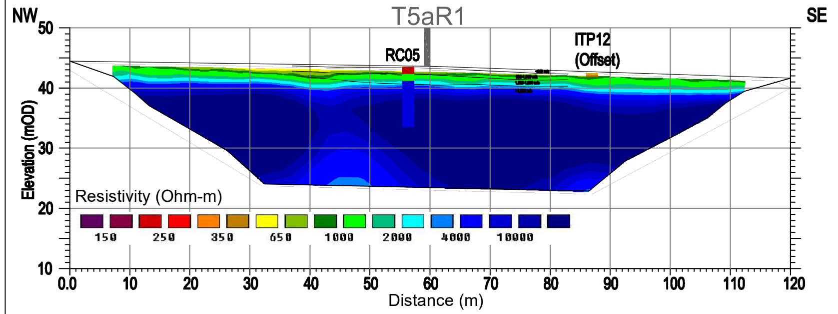

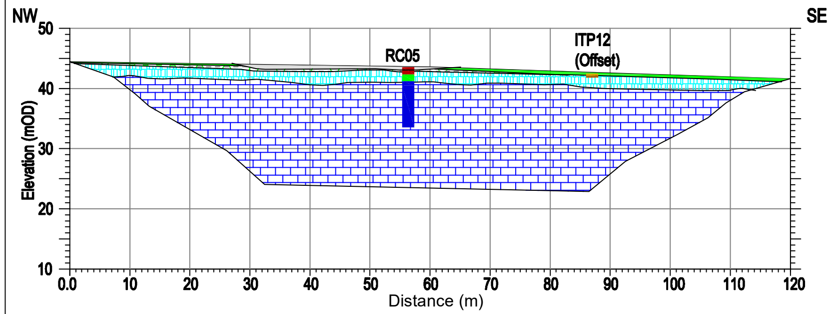

SUMMARY LOG LEGEND

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- Firm to stiff sandy gravelly CLAY
- Stiff to very stiff Sandy gravelly CLAY
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- GRAVEL
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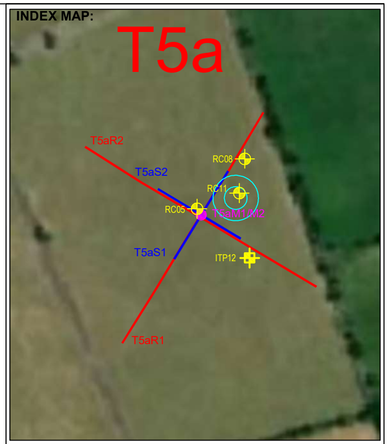
- Gravelly clayey SAND
- STRONG DOLOMOTISED LIMESTONE
- MEDIUM STRONG TO STRONG LIMESTONE
- STRONG LIMESTONE

INDEX MAP:



LEGEND:

- Seismic Refraction layer with Vp velocity
- Soft sandy gravelly CLAY
- Soft-Firm sandy gravelly CLAY with cobbles & boulders
- Stiff sandy gravelly CLAY with cobbles
- Very stiff sandy gravelly CLAY with cobbles
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FIG.1: TURBINE BASE T6a RESULTS AND INTERPRETATION T6aR1 & T6aS1

SCALE 1:1250

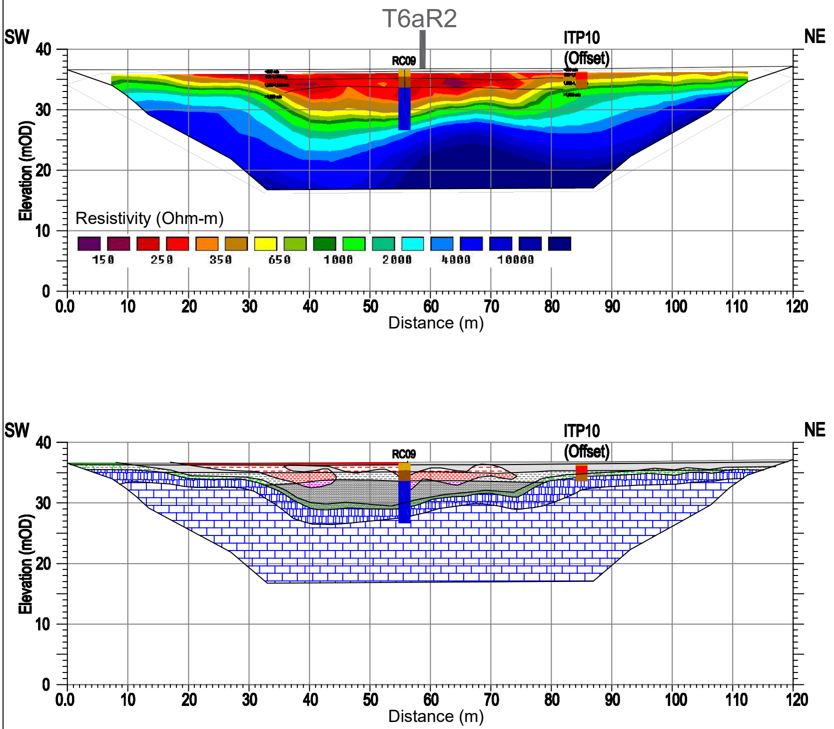

FIG. 2: TURBINE BASE T6a RESULTS AND INTERPRETATION T6aR2 & T6aS2

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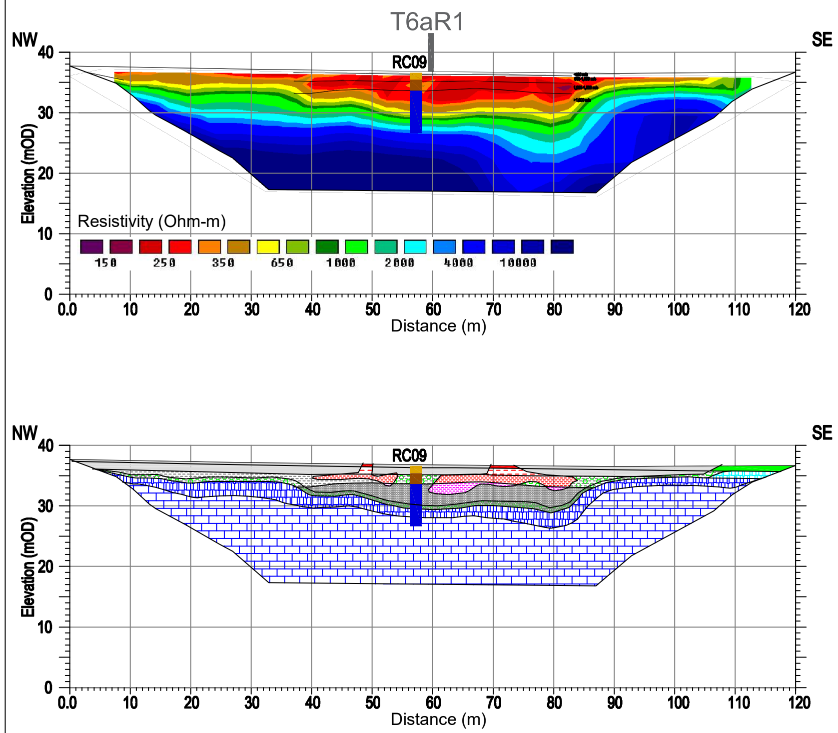

SUMMARY LOG LEGEND

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- Firm to stiff sandy gravelly CLAY
- Stiff to very stiff Sandy gravelly CLAY
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- Firm to stiff sandy gravelly SILT
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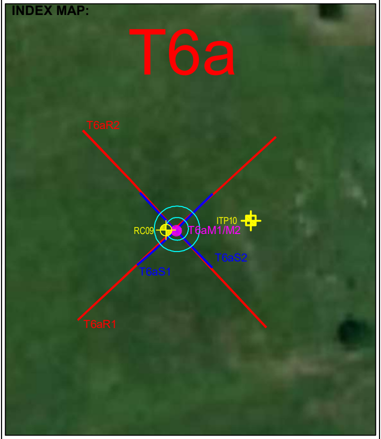
- GRAVEL
- COBBLES AND BOULDERS
- Gravelly clayey SAND
- STRONG DOLOMOTISED LIMESTONE
- MEDIUM STRONG TO STRONG LIMESTONE
- STRONG LIMESTONE

INDEX MAP:



LEGEND:

- Seismic Refraction layer with Vp velocity
- Soft sandy gravelly CLAY
- Soft-Firm sandy gravelly CLAY with cobbles & boulders
- Stiff sandy gravelly CLAY with cobbles
- Very stiff sandy gravelly CLAY with cobbles
- Firm sandy gravelly CLAY
- Stiff sandy gravelly CLAY
- Very stiff sandy gravelly CLAY
- Loose clayey sandy GRAVEL
- Medium dense clayey sandy GRAVEL
- Dense clayey sandy GRAVEL
- Very dense clayey sandy GRAVEL
- Dense-Very Dense GRAVEL/COBBLES/BOULDERS/ Highly-moderately weathered/fractured LIMESTONE
- Moderately-slightly weathered/fractured LIMESTONE
- Slightly weathered-fresh LIMESTONE

The information displayed here is to be used in conjunction with AGP22050_01 Report on the Geophysical Investigation at Laurclavagh Wind Farm Phase 2, Co. Galway for Ghrian Energy Ltd., APEX Geophysics Ltd. 17th July 2023.

apex geophysics

6 Knockmullen Business Park
Gorey
Co. Wexford
Ireland

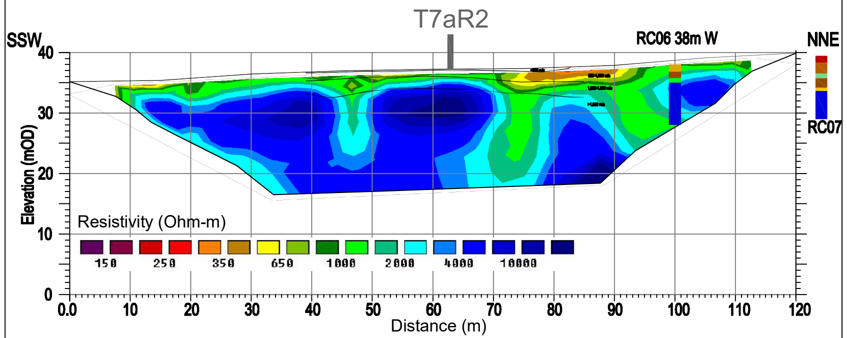
T +353 (0)402-21842
E info@apexgeophysics.ie
www.apexgeophysics.ie

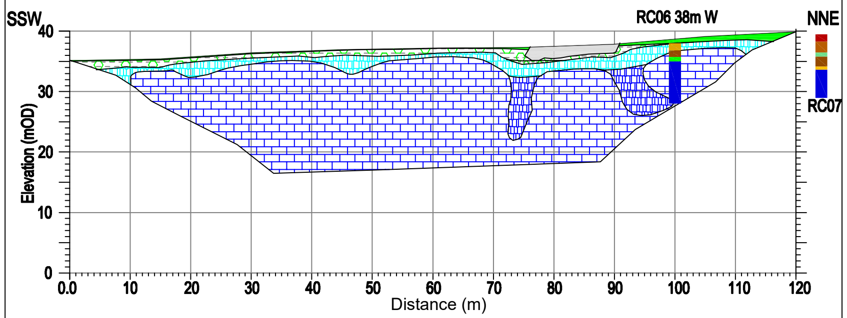
PROJECT:	LAURCLAVAGH WIND FARM GEOPHYSICAL SURVEY
CLIENT.:	GHRIAN ENERGY LIMITED
DRAWING 01:	AGP22050_T6a
SCALE:	AS INDICATED @ A4
DATE:	12-07-2023

Version:	Date:	Drawn By:	Checked:
01	12-12-2022	TL	IS
02	04-07-2023	TL	IS
03	17-07-2023	TL	IS

FIG. 1: TURBINE BASE T7a RESULTS AND INTERPRETATION T7aR1 & T7aS1

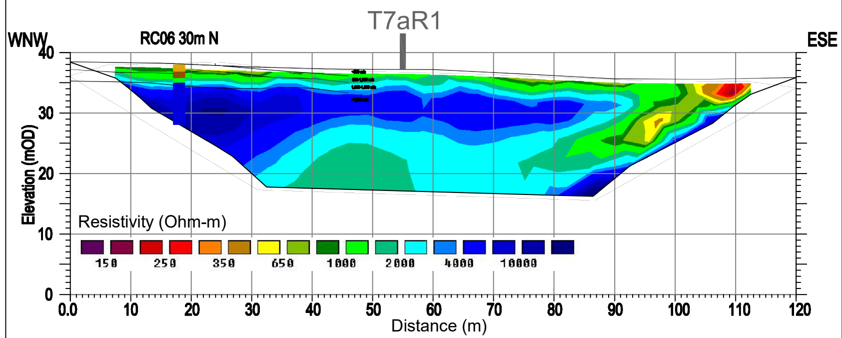
SCALE 1:1250

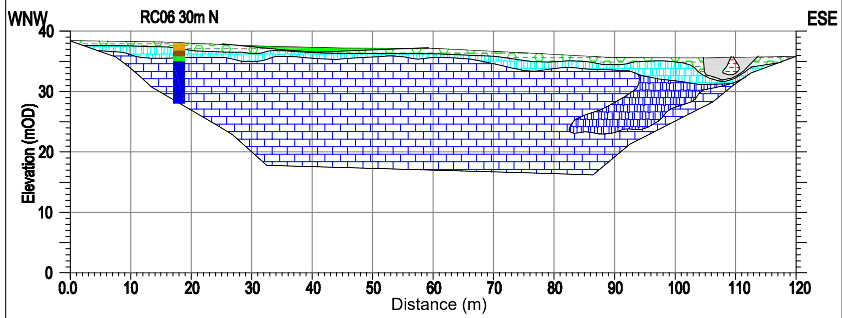




GIG. 2: TURBINE BASE T7a RESULTS AND INTERPRETATION T7aR2 &T7aS2

SCALE 1:1250

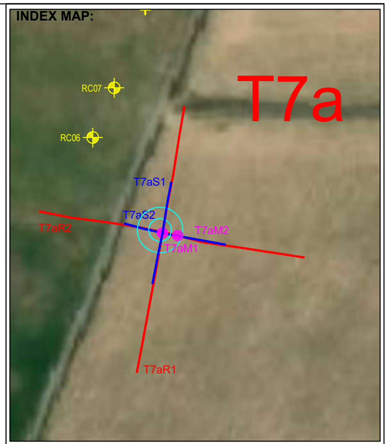




SUMMARY LOG LEGEND

- Sandy CLAY
- Firm to stiff sandy gravelly CLAY
- Stiff to very stiff Sandy gravelly CLAY
- CLAY
- Firm to stiff sandy gravelly SILT
- Sandy clayey GRAVEL
- GRAVEL
- COBBLES AND BOULDERS
- Gravelly clayey SAND
- STRONG DOLOMOTISED LIMESTONE
- MEDIUM STRONG TO STRONG LIMESTONE
- STRONG LIMESTONE

INDEX MAP:



LEGEND:

- Seismic Refraction layer with Vp velocity
- Soft sandy gravelly CLAY
- Soft-Firm sandy gravelly CLAY with cobbles & boulders
- Stiff sandy gravelly CLAY with cobbles
- Very stiff sandy gravelly CLAY with cobbles
- Firm sandy gravelly CLAY
- Stiff sandy gravelly CLAY
- Very stiff sandy gravelly CLAY
- Loose clayey sandy GRAVEL
- Medium dense clayey sandy GRAVEL
- Dense clayey sandy GRAVEL
- Very dense clayey sandy GRAVEL
- Dense-Very Dense GRAVEL/COBBLES/BOULDERS/ Highly-moderately weathered/fractured LIMESTONE
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