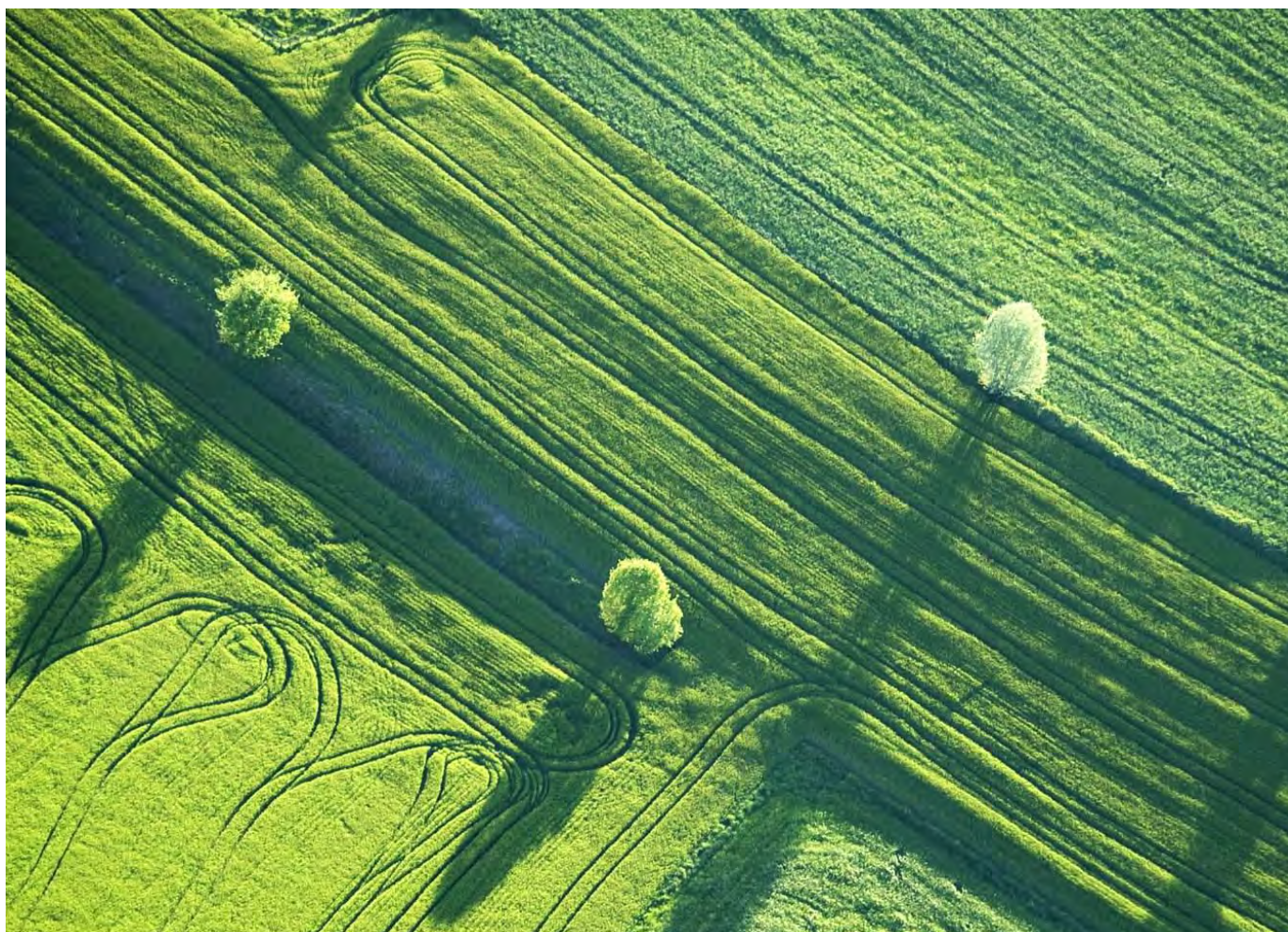




RWE Renewables UK Swindon Ltd.

Pen March

Turbine 1-6 Ground Conductivity Mapping

Turbine 6 Vertical Electrical Resistivity Sounding

Geophysical Report

Project no. 2190464

DECEMBER 2022





RSK GENERAL NOTES

Project No.: 2190464-R04(00)

Title: Geophysical Report, Pen March

Client: RWE Renewables UK Swindon Ltd.

Date: 1st December 2022

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Where field investigations have been carried out, these have been restricted to a level of detail required to achieve the stated objectives of the work.

This work has been undertaken in accordance with the quality management system of RSK Environment.

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EXECUTIVE SUMMARY

On the instructions of RWE Renewables UK Swindon Ltd., RSK Environment Ltd has carried out a geophysical investigation to determine the presence of any anomalous geophysical responses associated with potential shallow shakehole formations in order to inform the location and design of six turbines.

Project Findings

Site Setting and Current Usage	The site is located at Pen March, which can be found to the north of Merthyr Tydfil in South Wales. Six turbine locations have been proposed across the development site. The ground conditions across the site are predominantly undulating/hummocky grasslands with a number of marsh-like regions and gullies.
Survey Objectives	The objective of the survey is to determine the possible presence of any anomalous responses associated with potential shallow shakehole formations. A trial survey was carried out on 22nd February 2021, reference 2190464-LR01(00), covering a 1 Ha area surrounding Turbine 1. Subsequently, a survey covering 4 Ha across six proposed locations was carried out, reference 2190464-R02(00). A further survey was commissioned based on findings and recommendations from R02(00), consisting of surveys covering a 4 Ha area centred on revised positions of Turbine 1 and Turbine 2 (designated 1b and 2b), as well as additional geophysical testing at Turbine 6 to provide more information on anomalies identified in the prior works. The findings of these additional surveys were detailed in 2190464-R03(00). This revision, 2190464-R04(00), updates previous survey results to account for the final chosen locations. Only information relevant to these positions has been included in this report version.
Geophysical Techniques Employed	The geophysical techniques employed were that of Electromagnetic (EM) Mapping and electrical resistivity sounding. The fieldwork was carried out over several mobilisations • 22nd February 2021. • Between the 29th March and 9th April 2021. • Between the 6th May and 18th May 2021 The locations of the survey areas are shown in Figure 1. The EM survey utilised a GF Instruments CMD Explorer that samples the conductivity of the ground up to depths of approximately 6.7 mbgl. Data were collected along survey lines nominally spaced every 2 m and recorded at a 10 Hz frequency. There were a small number of areas that could not be surveyed due to waterlogged, marsh-like conditions. The instrument was integrated with a dGPS to provide location data. The electrical resistivity survey utilised an Ohmega resistivity meter. Eight soundings were collected. Data were collected to a maximum depth of approximately 30 m. Positional data was recorded using a Leica dGPS.
Geophysical Investigation Findings	The general range of shallow bulk conductivity measurements recorded over Turbines 1 to 5 do not indicate the potential presence of shallow sink holes within the survey areas. However, the variations observed in the proximity of Turbine 6 could relate to the presence of sink holes and were recommended for further investigation. The results of

the subsequent electrical resistivity survey at Turbine 6 have been used to create a model of resistivity with depth. The data are all relatively consistent and there is no significant variation within the depth of investigation that might indicate variable ground conditions associated with shake holes.

It is noted that the EM technique deployed is limited in the depth of investigation and that features of interest may be present, but undetected, at depths greater than ~7 mbgl.

1 INTRODUCTION

1.1 Introductions

On the instructions of RWE Renewables UK Swindon Ltd., RSK Environment Limited carried out a geophysical site investigation as part of the feasibility study of a proposed wind farm development. The purpose of the survey was to seek to determine the presence of any anomalous responses that may relate to the location of potential shakeholes in the shallow subsurface.

1.2 Details of the Project

A trial survey (reference 2190464-LR01(00)), covering a 1 Ha area centred on a proposed location for Turbine 1 was commissioned. A follow up survey covering 4 Ha across six proposed locations was subsequently carried out (reference 2190464-R02(00)). Based on recommendations and revised locations for Turbine 1 and 2, an additional survey was commissioned, consisting of surveys covering a 4 Ha area centred on revised positions of Turbine 1 and Turbine 2 (designated 1b and 2b), as well as additional geophysical testing at Turbine 6 to provide more information on anomalies identified in the prior works. The findings of these additional surveys were detailed in 2190464-R03(00).

This revision, 2190464-R04(00), updates previous survey results to account for the final chosen locations. Only information relevant to these positions has been included.

1.3 Limitations

Non-intrusive geophysical techniques seek to locate boundaries across which there is a marked contrast in physical properties. Such a contrast may be detected remotely because it gives rise to a geophysical anomaly, which is indicative of variation in a physical property relative to some background value. Insufficient contrast (including high levels of cultural noise) can result in masking of the sought anomaly. Therefore, there may be other conditions prevailing at the site which have not been revealed by this investigation and which have therefore not been taken into account in this report.

The response of the ground to different physical forces can be highly variable. Interpretation of the responses contained in this report is based on experience in similar environments and site conditions.

The materials encountered and samples obtained during on-site intrusive investigations represent only a small proportion of the materials present on-site. It should be accepted, therefore, that the interpretation from remotely sensed geophysical data may be inconsistent with that arising from direct methods of investigation.

2 THE SITE

2.1 Location and Regional Setting

The survey site is located at Pen March, which can be found to the north of Merthyr Tydfil in South Wales. All six locations for the proposed wind turbines are located on predominantly undulating/hummocky grasslands with a number of localised marsh-like regions and gullies.

The site is located at National Grid reference SO 086 106. An extract of the 1:50,000 Ordnance Survey map showing the location of the site and survey areas is given in **Figure 1**. The central black circles within each survey grid indicate the final proposed turbine locations.

2.2 Geology

The online BGS geology maps show the survey area is underlain by the Millstone Grit Group and Pennine Lower Coal Measures Formation. Previous site reconnaissance and reporting undertaken by others for the Client suggests the potential for shakehole formations across the site.

3 THE SURVEY

3.1 Objective and Geophysical Approach

The objective of the survey was to seek to determine the presence of any anomalous responses within the geophysical data associated with potential shallow shakehole formations.

The geophysical techniques employed were that of Electromagnetic (EM) Conductivity and Electrical Resistivity Sounding. The geophysical fieldwork was conducted out over several mobilisations:

- 22nd February 2021.
- Between the 29th March and 9th April 2021.
- Between the 6th May and 18th May 2021

3.2 The Electromagnetic Technique

In electromagnetic surveying the electrical properties of the ground are measured as a function of depth and/or horizontal distance. Different rocks (and buried structures/objects) exhibit different values of electrical conductivity. Mapping variations in electrical conductivity can identify anomalous areas worthy of further geophysical or intrusive investigation.

3.2.1 Theory

The electromagnetic method is based on the induction of electric currents in the ground by the magnetic component of electromagnetic waves generated at the surface (**Figure 2A**). An alternating current, of variable frequency, is passed through a coil of wire (a transmitter coil, TX). This process generates an alternating primary magnetic field which, in turn, induces very small eddy currents in the earth, the magnitude of which is directly proportional to the ground conductivity in the vicinity of the coil. These eddy currents then generate a secondary magnetic field, a part of which is intercepted by a receiver coil (RX). The interaction between the primary and secondary magnetic flux and the receiver coil generates a voltage that is linearly related to the electrical conductivity of the subsurface.

Two types of measurements may be recorded in electromagnetic surveying: the quadrature component and the in-phase response. The quadrature response measures the bulk electrical properties of the ground. The electrical properties are expressed as

an apparent electrical conductivity in millisiemens per metre (mS/m). The in-phase response is essentially metal detector mode and is expressed in units of parts per thousand (ppt) of the primary transmitted field.

In electromagnetic mapping, individual measurements are recorded across a site at a suitable density and plotted as a contoured map (**Figure 2C**). Measurements may also be recorded at different depths according to the orientation (either vertical or horizontal) of the transmitter and receiver coils.

3.2.2 Application to Site

Theoretically, differences in water content, compaction, rock type and superficial deposits exhibit different values of electrical conductivity. Typically, voids or loose, uncompacted ground may generate localised areas of higher or lower conductivity depending on the fill material of the void (water, air or rubble filled) and the type of surrounding ground material. By mapping variations in electrical conductivity across the survey area, any subsurface material changes caused by shakehole formations should manifest itself in the EM data.

3.2.3 Equipment

CMD Explorer

The equipment used was the CMD Explorer (see **Appendix A** for equipment specifications). This consists of a transmitter and receiver separations of 1.48 m, 2.82 m, and 4.49 m, mounted on a single beam. The coil separation is such that the measurements recorded represent ground conditions at three different depth ranges down to an effective depth of approximately 6.7 m. The CMD Explorer has the facility to record two types of measurement as the secondary field may be separated into the quadrature component and the in-phase response.

3.2.4 EM Survey Design

The layout of the geophysical survey is shown in **Figure 1**. A 4Ha grid was centred on the proposed locations of the 6 no. Turbines.

Table 1 below indicates the final positions for the proposed turbine locations.

Table 1 Final Turbine Locations

ID	Easting	Northing
Turbine 1	307733	210855
Turbine 2	308300	210948
Turbine 3	308089	210116
Turbine 4	309105	210563
Turbine 5	308632	210633
Turbine 6	308565	210077

In certain areas the ground conditions were such that data could not be collected. These are labelled where applicable.

The data were monitored in real time to ensure its quality. The data collected with the CMD was recorded every 0.1 second with the inter-line spacing being approximately 2 m. Lines were collected by walking alternate lines in a North to South or East to West orientation across the survey areas as vegetation allowed (orientation depended on the topography and elevation change at each turbine location).

Positioning data were recorded using a dGPS linked to the instrument. The location of the survey lines was also surveyed using a Leica GS08 SmartRover, providing accurate location data referenced to the Ordnance Survey OSGB36 National Grid system.

3.3 The Electrical Resistivity Sounding Technique

An electrical resistivity sounding examines the electrical properties of the ground as a function of depth and/or horizontal distance. Different rocks often exhibit different values of electrical resistivity. Variations in subsurface resistivity can be measured at the surface, and layer thicknesses and resistivities calculated.

3.3.1 Theory

An electrical resistivity sounding investigates the ground resistivity as a function of depth. For any single measurement of ground resistance, an alternating electric current is injected into the subsurface via two metal stakes (electrodes) planted into the ground. One electrode behaves as the current source, whilst the current is returned to the surface to complete the electrical circuit through a second electrode. The current passing through the ground sets up a distribution of potential in the subsurface which is sampled by two additional electrodes (potential electrodes) across which a voltage is measured. The ratio of voltage to current is the resistance, R , of the ground through which the current has passed (**Figure 3A**).

To perform a Wenner resistivity sounding, the electrode spacing, a , is progressively increased between measurements while keeping the centre of the electrode arrangement fixed (**Figure 3B**). This introduces the current into the earth at greater and greater depths so permitting an examination of ground resistance with increasing depth. The resulting resistances are then converted to values of apparent resistivity, ρ_a , using the equation $2\pi a RA$, where a is the spacing in metres and RA is the average resistivity in Ω . This equation can be used where the depth that the electrodes are inserted into the ground is small compared to the distance between electrodes. Generally, the burying depth must be less than 5% of the electrode separation (a).

The values calculated (plotted on a sounding curve) are intimately related to the geometry of the electrodes used to obtain them and hence are termed *apparent*, not true, resistivities. In order to produce one-dimensional models of the true ground resistivities and thicknesses, the data set is interpreted using a modern computer software package (**Figure 3C**).

3.3.2 Application to Site

The Wenner array was deployed at Turbine 6 for the measurement of the ground resistivity. The locations of the VES acquisition points are shown in **Figure 10**. The Wenner array maintains an equal separation between each of the four electrodes such that the total length of the array is three times the electrode separation.

The resistivity soundings were recorded with the Wenner array at the following 'a' spacing: 1 m, 2 m, 3 m, 5 m, 7 m, 10 m, 15 m, 20 m, 25 m, and 30 m.

3.3.3 Equipment

The instrument used to complete the resistivity sounding was the Ohmega resistivity meter manufactured by Allied Associates Ltd.

The serial no. of the equipment used was 0259. See equipment specifications in **Appendix A**.

3.3.4 Electrical Resistivity Survey Design

Eight vertical soundings were measured within the 4 Ha survey area centred on the proposed location of Turbine 6. The profiles were designed to cover anomalous areas identified in 2190464-R02(00) as well as areas showing uniform conditions to provide a baseline set of values.

As per accepted standards for such tests (BS1377:9 section 5.1 and BS7430 section 9.4) the electrodes were inserted into the ground no greater than 5% of the electrode spacing ('a' spacing). For each measurement at least 12 individual cycles were

acquired, by collecting 3 sets of at least 4 cycles at each measurement interval. The readings were monitored during acquisition with readings being accepted if the error between subsequent cycles was less than 4%.

3.4 EM Data Processing and Presentation

CMD Explorer data were downloaded from the logger using the CMD Transfer software and then exported as DAT format.

Data were imported into Geosoft's specialist software Oasis Montaj. Within this software data are manipulated in a number of ways. Positional data are transformed from WGS84 format to British National Grid Co-ordinates before data are filtered to remove spurious or bad data points and interrogated to remove or correct for other sources of 'noise'.

The final data for each depth range sampled are contoured to produce colour filled grids. The CMD Explorer ground conductivity data for two coils are shown in **Figures 4-9** to show conductivity data for moderate (4.2 m) and deeper (6.7 m) effective depths. High conductivity values are displayed with shades of red and pink, through yellows and greens, with shades of blue and purple representing low conductivity values. See **Table 2** for a summary of processing methods.

The additional survey area at Turbine 2 has been combined with the previous 4 Ha survey and presented as one plot.

The topography of the survey area has also been presented as an inset on each figure.

Table 2 Summary of EM processing methods

Method	Justification
Instrument nulling	An area of the site free of metallic objects is identified and the instrument is nulled. The location is marked and returned to prior to commencement of survey works in the survey area.
Data download	Following completion of each section of the survey area the data was downloaded to a laptop to allow completion of quality control check.
Co-ordinate transform	Positional data was transformed from Geographic projection to OSGB (1936), British National Grid projection, for mapping and presentation.
Data filtering	Spurious data points were filtered from the datasets.
Gridding & contour plotting	Data is gridded and plotted as a contour plot in Oasis Montaj, the various datasets can then be displayed using optimised colour palettes.

3.5 Electrical Resistivity Data Processing and Presentation

The average resistance for each of the measurement intervals was determined which then went on to be used in calculating a value of apparent resistivity. These values were then used in creating the resistivity models for each of the profiles shown in Figure 10. The resistivity sounding data are shown in this figure as a series of graphical plots and tabulated data. For each set of graphs, the purple line represents the sounding curve plotted over the observed data points. The red line shown the 1D resistivity model that would generate the purple sounding curve.

Best fit layered models were created using Interpex 1-D Sounding Inversion software program (IX1D). The model is generated by inversion to generate the model with the fewest layers that will best fit the observed data.

Anomalous data points could be masked within the programme where appropriate, and therefore ignored during the inversion calculations. The models were generated with an RMS fit error of between 0.84% and 3.80%. The RMS provides a qualitative measure of the fit of the model to the observed data. 3.80% represents a model with a low error fit, and all sounding curves present a good fit, which gives confidence to the models.

4 DATA INTERPRETATION

4.1 Data Quality

The electrical resistivity data is of good quality, with a high repeatability between soundings.

The EM dataset is generally of good quality and suitable from which to make interpretations.

4.2 EM Results

The EM data are presented in **Figures 4-9** for the six turbine locations. Each turbine has two displays, one each for a different coil separation. The two coil separations displayed measure bulk conductivity to an approximate depth of 4.2 m and 6.7 m depth respectively. The benefit of comparing data from multiple coil separations is that variations in conductivity with depth can also be evaluated. Three broad types of anomaly have been identified in the data:

- **Low conductivity** anomaly (<4mS/m): area of lower conductivity indicative of an area of thinner superficial cover, decreased saturation, or lower clay content. There is possibility this response can also relate to presence of shallow voids.
- **Higher conductivity** anomaly discrete area of high conductivity indicative of an area of thickening of superficial cover, increased saturation, or clay content; may relate to preferential fluid pathway which may relate to subsurface voids.
- **Very high conductivity** anomaly: response most likely to manifest from surface metal e.g. fences, scrap metal, or shallow buried metallic features, such as structures of buried utilities. These areas of very high conductivity resulting from surface or buried metal are not targets of interest in this survey but may be of interest for later development of the site.

The results of the EM survey are summarised below:

- **Turbine 1:** General trend from moderate to low apparent conductivity from north to south, no notable anomalous areas that are likely to manifest from the presence of shallow solution features.
- **Turbine 2:** Moderate conductivity across the survey area, continuing into additional survey area around the proposed turbine location. Further processing was carried out to remove artefacts present in the north west quadrant. No features are observed that are indicative of the expected response from a shallow shakehole or void.

- **Turbine 3:** A number of low conductivity anomalies are found in the north of the survey area. It is possible that these features may relate to subsurface voids, but the features are not consistent between the two coil separation data sets and it is more likely that the variations relate to changes in composition of shallow material and possible buried man made material. There is a difference between the east and western sides of the survey area, this potentially relates to a change in the shallow geology and depth of bedrock. The change is less pronounced in the second coil data, suggesting that at greater depth the bulk difference in material is less distinct. The topography also broadly mirrors the conductivity trends.
- **Turbine 4:** Broadly uniform conductivity values across the survey area in the data set imaging to greater depth. There are no anomalies in the deeper data set to suggest the presence of shallow shakehole features. The smaller coil separation data shows some subtle variation local to the proposed turbine location, but this is most likely related to shallow material composition and not related to shallow voiding. A high conductivity anomaly in the southeast corner of the survey area may indicate the position of shallow buried metal.
- **Turbine 5:** Broadly uniform conductivity values recorded across the survey area, with conductivities increasing between the two coil separation measurements. Higher conductivities in the centre of the area would suggest that the turbine location is positioned on shallow bedrock relative to the north east and south west quadrants – or else that the data are reflecting shallow geological boundaries. No anomalous areas in the proximity of the proposed turbine location to suggest the presence of shallow shakehole features.
- **Turbine 6:** Conductivity values across this area are more variable than observed within the other areas. In the shallow data there is a more extensive area of lower conductivity in the vicinity of the proposed turbine location. In the wider coil separation data, which images to greater depth, there remain three notable areas in proximity to the proposed turbine location – in addition to two other areas in the north and north east quadrants of the survey area. These variations do not tie with the general variation in topography across the survey area. It is possible that the three areas highlighted relate to potential shallow shakehole features or variations in shallow bedrock composition. There are three A high conductivity anomaly along the northern edge of survey area is representative of surface or shallow buried metal.

With the exception of Turbine 6, the general range and trends of shallow bulk conductivity measurements recorded would not indicate the presence of shallow shake holes within the survey areas. The results for Turbine 6 led to the commissioning of the Electrical Resistivity survey.

4.3 Electrical Resistivity Results

The resistivity sounding data have been presented in **Figure 10**.

For each model the table shows the resistivity (ρ) and the thickness of each layer, plus the accumulative depth to the base of the layer. As a consequence of having a half space at the base of the mode, there is no thickness or maximum depth associated with the lowest layer. As the “a” spacing between electrodes is increased, the measurement is recorded over a larger volume of ground, and thus to a greater depth. The maximum “a” spacing used was 30 m, which equates to a maximum depth of ~30 m. It should be noted that although a number of the graphs extend to 100 m this is due to the logarithmic axis display used in the software. The data are only collected to ~30 m, so this is not an indication that ground conditions are constant to 100 m.

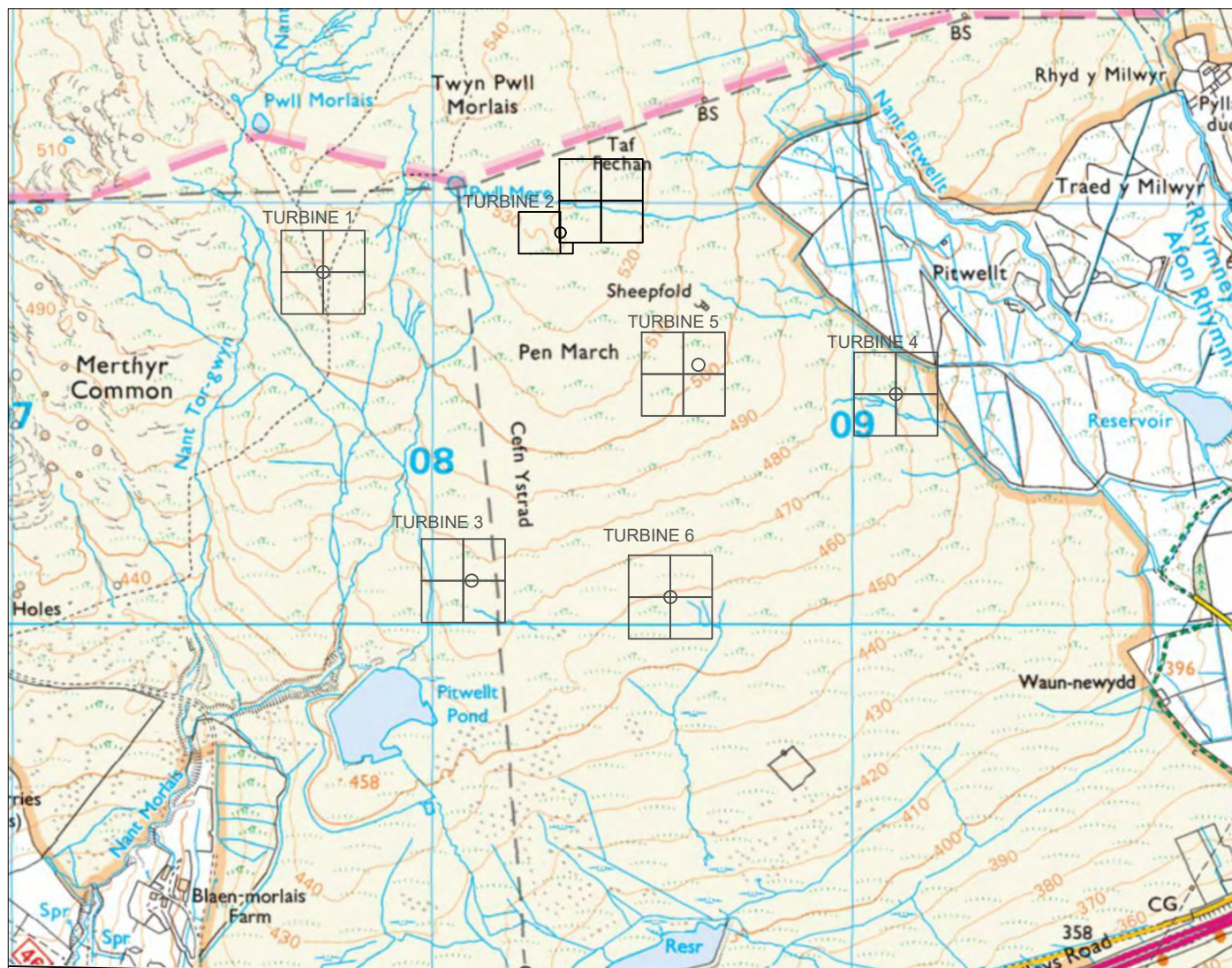
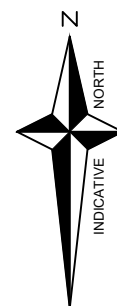
Generally, the resistivity soundings have shown relatively similar bulk resistivities. Whilst there are some shallow and localised variations that may be associated with the shallow geology and the surface variations observed in the conductivity survey, there are no significant increases in resistivity observed that may indicate the presence of solution feature / shake holes at depth.

5 CONCLUSIONS

- On the instructions of RWE Renewables UK Swindon Ltd., RSK Environment Ltd has carried out a geophysical investigation to determine the presence of any anomalous sub-surface areas associated with potential shakehole formations in order to inform the design of six turbine locations.
- The geophysical techniques employed were that of Electromagnetic (EM) Mapping and Electrical Resistivity Sounding.
- The fieldwork was carried out over several mobilisations between February and May 2021.
- A trial survey was carried out on 22nd February 2021, reference 2190464-LR01(00), covering a 1 Ha area surrounding Turbine 1. Subsequently, a survey covering 4 Ha across six proposed locations was carried out, reference 2190464-R02(00). A further survey was commissioned based on findings and recommendations from R02(00), consisting of surveys covering a 4 Ha area centred on revised positions of Turbine 1 and Turbine 2 (designated 1b and 2b), as well as additional geophysical testing at Turbine 6 to provide more information on anomalies identified in the prior works. The findings of these additional surveys were detailed in 2190464-R03(00).
- The EM surveys utilised a GF Instruments CMD Explorer that samples the conductivity of the ground to depths of up to 6.7 mbgl. Data were collected along survey lines nominally spaced every 2 m as access allowed. EM conductivity data is presented in **Figures 4-9**.
- The electrical resistivity survey utilised an Ohmega resistivity meter. Eight profiles were collected. Data were collected to a maximum depth of approximately 30 m. Data is presented in **Figure 10**.
- EM data: The general range and trends of shallow bulk conductivity measurements recorded would not indicate the presence of shallow shakeholes within the survey areas. However, it must be appreciated that the technique deployed is limited in depth of investigation and that features may be present beyond the depth of detectability with this method. As such this survey can not rule out the presence of features at depths greater than 7 mbgl.
- Resistivity data: The data are generally consistent and there is no significant variation within the depth of investigation that might indicate ground conditions associated with shake holes.

FIGURES

Figure 1	Site Location Plan
Figure 2	The Electromagnetic Technique
Figure 3	The Electrical Resistivity Technique
Figure 4	EM Results: Turbine 1
Figure 5	EM Results: Turbine 2
Figure 6	EM Results: Turbine 3
Figure 7	EM Results: Turbine 4
Figure 8	EM Results: Turbine 5
Figure 9	EM Results: Turbine 6
Figure 10	VES layout and results



NOTES

- (1) Extract from Ordnance Survey 1 : 50000 scale map.
- (2) Reproduced from Ordnance Survey mapping with the permission of the Controller of Her Majesty's Stationery Office. Crown Copyright reserved (Licence No:AL100002620).



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Client

**RWE RENEWABLES
UK SWINDON LTD**

Project Title

PEN MARCH

Drawing Title

SITE LOCATION

National Grid Reference: SO 086 106

Drawn
LW

Date
01/12/22

Checked
TG

Date
01/12/22

Approved
TG

Date
01/12/22

Orig Size
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Dimensions

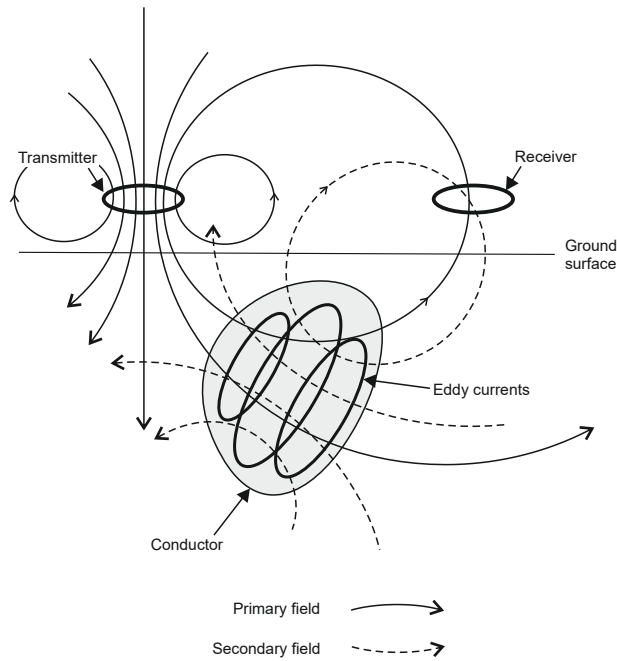
Project No.
2190464

Drawing File
2190464_R04 Figure 1

Drawing No.
2190464_R04 Figure 1 Sheet 1 of 1

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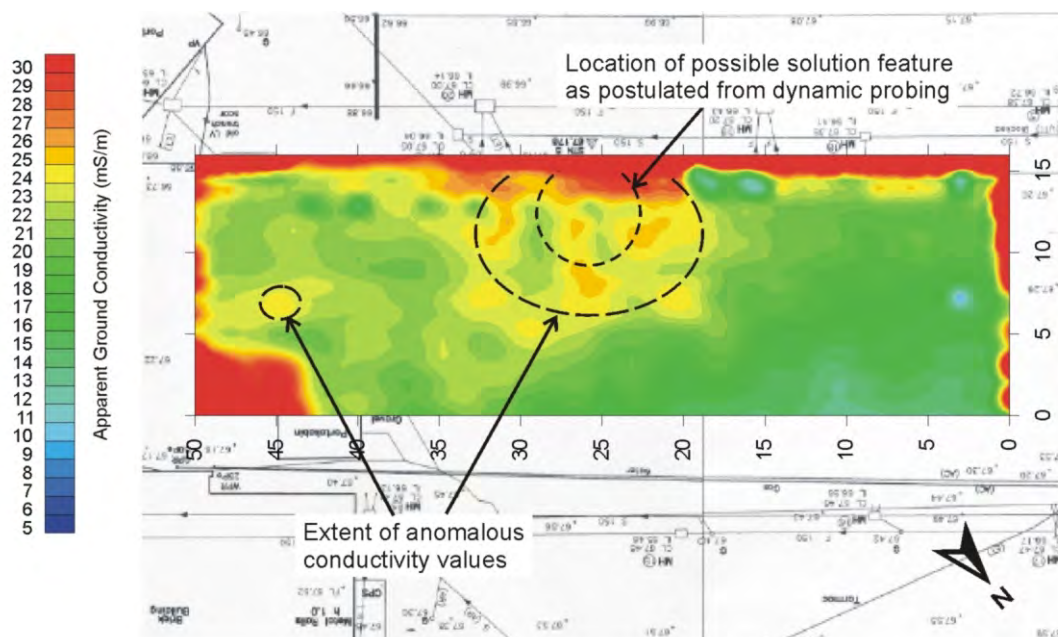
A The principle of electromagnetic induction



B The GF Instruments CMD Explorer



C An example of electromagnetic data collected over voided/solution feature ground



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**THE
ELECTROMAGNETIC
TECHNIQUE**

Client:
**RWE RENEWABLES UK SWINDON
LTD.**

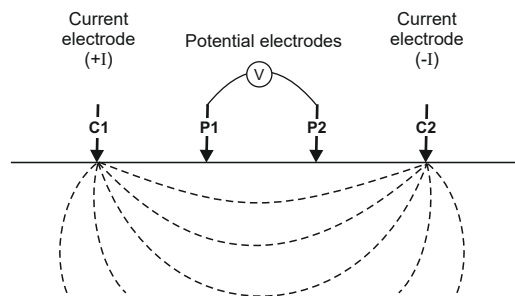
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Job: 2190464

Site/Project:
PEN MARCH

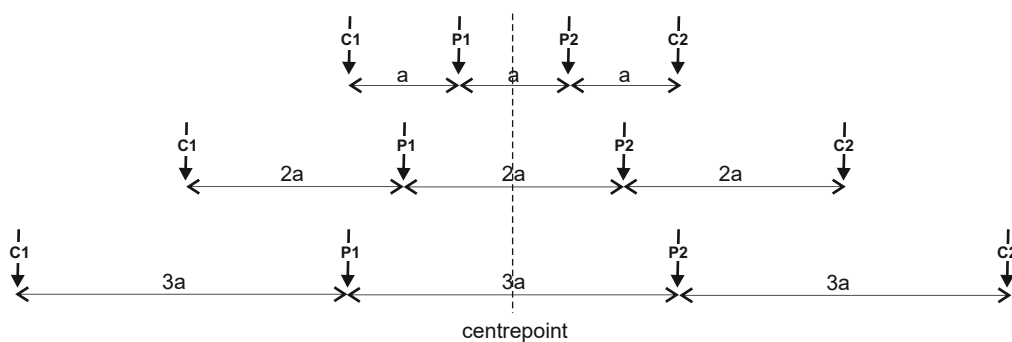
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DATE
DECEMBER 2022

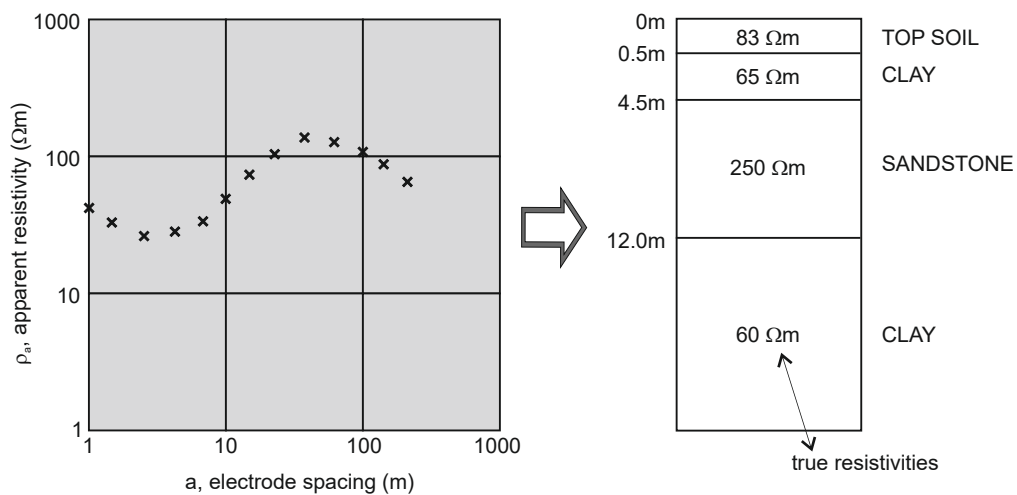


A Obtaining a measurement of ground resistance

B Conducting a sounding using the Wenner electrode array



C A 4-layer sounding curve and interpreted model of the subsurface



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THE ELECTRICAL RESISTIVITY SOUNDING TECHNIQUE

Client:
RWE RENEWABLES UK SWINDON LTD.

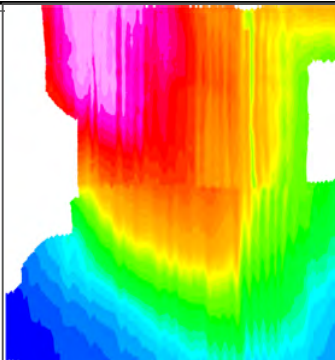
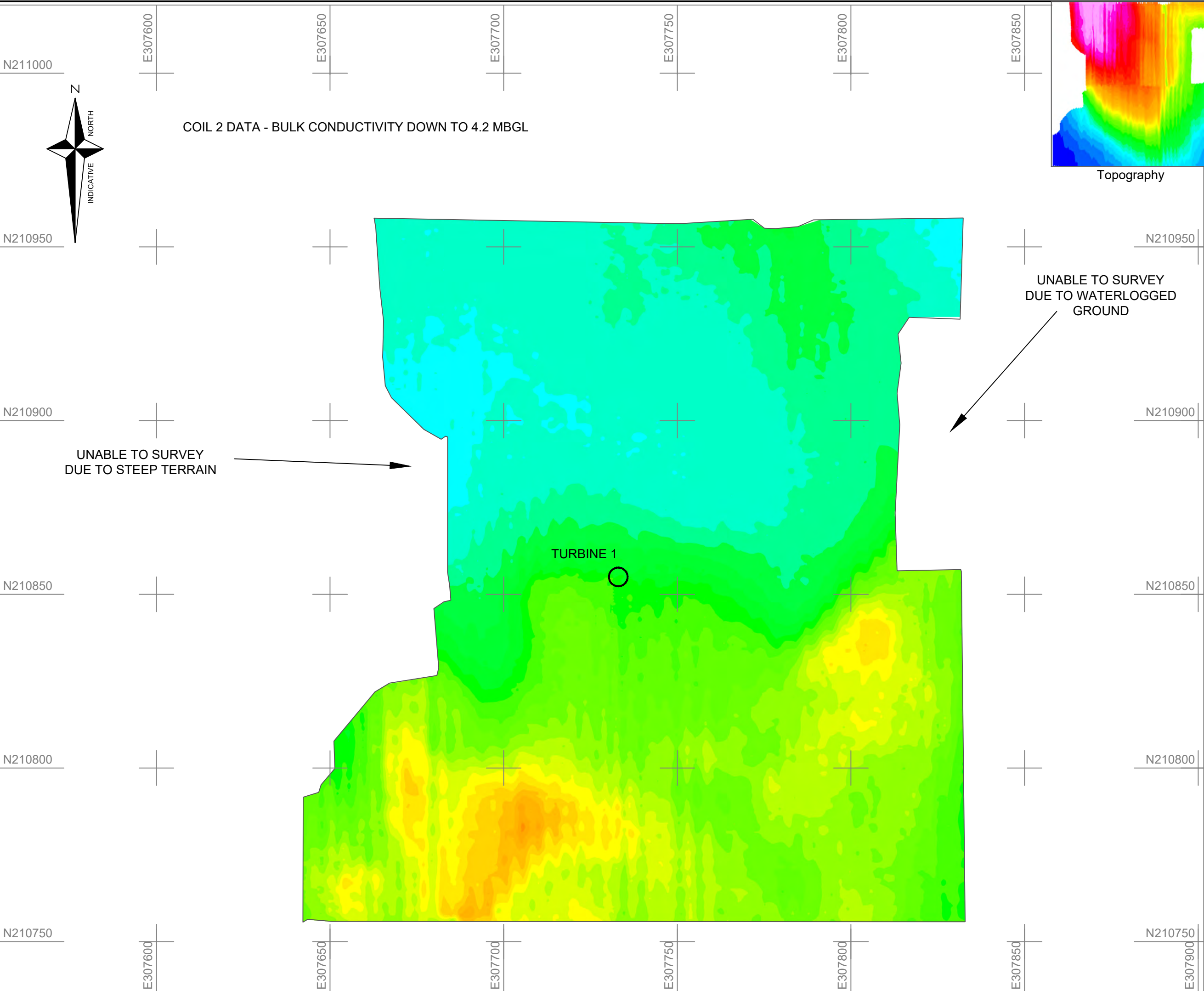
Figure: 3

Job: 2190464

Site/Project:
PEN MARCH

SCALE
N/A

DATE
DECEMBER 2022



NOTES

The specific risks associated with the content of this drawing are considered to be:-

(1) It is recommended that the Client should confirm the location of the geophysical anomalies with hand dug pits within 0.5m to confirm the cause of the anomalies prior to the commencement of works.

(2) Although every reasonable effort has been made to locate features associated with voided ground using EM mapping techniques, RSK Environment Ltd cannot guarantee that every feature has been located.

Apparent Conductivity mS/m

KEY

- TURBINE 1 PROPOSED LOCATION (Pen_March_Turbine_Locations)
- ANOMALY A - LOW CONDUCTIVITY AREA (<4 mS/m)
- ANOMALY B - HIGH CONDUCTIVITY AREA (>14 mS/m)
- ANOMALY C - METAL (ABOVE GROUND OR BURIED)

Rev.	Date	Amendment	Drawn	Chkd.	Appd.

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www.environmental-geophysics.co.uk

Client
RWE RENEWABLES UK SWINDON LTD.

Project Title
PEN MARCH - TURBINE 1

Drawing Title
RESULTS OF THE ELECTROMAGNETIC SURVEY - 4.2M EFFECTIVE DEPTH

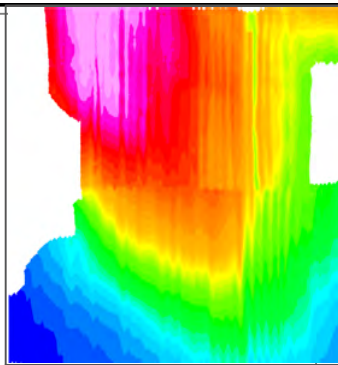
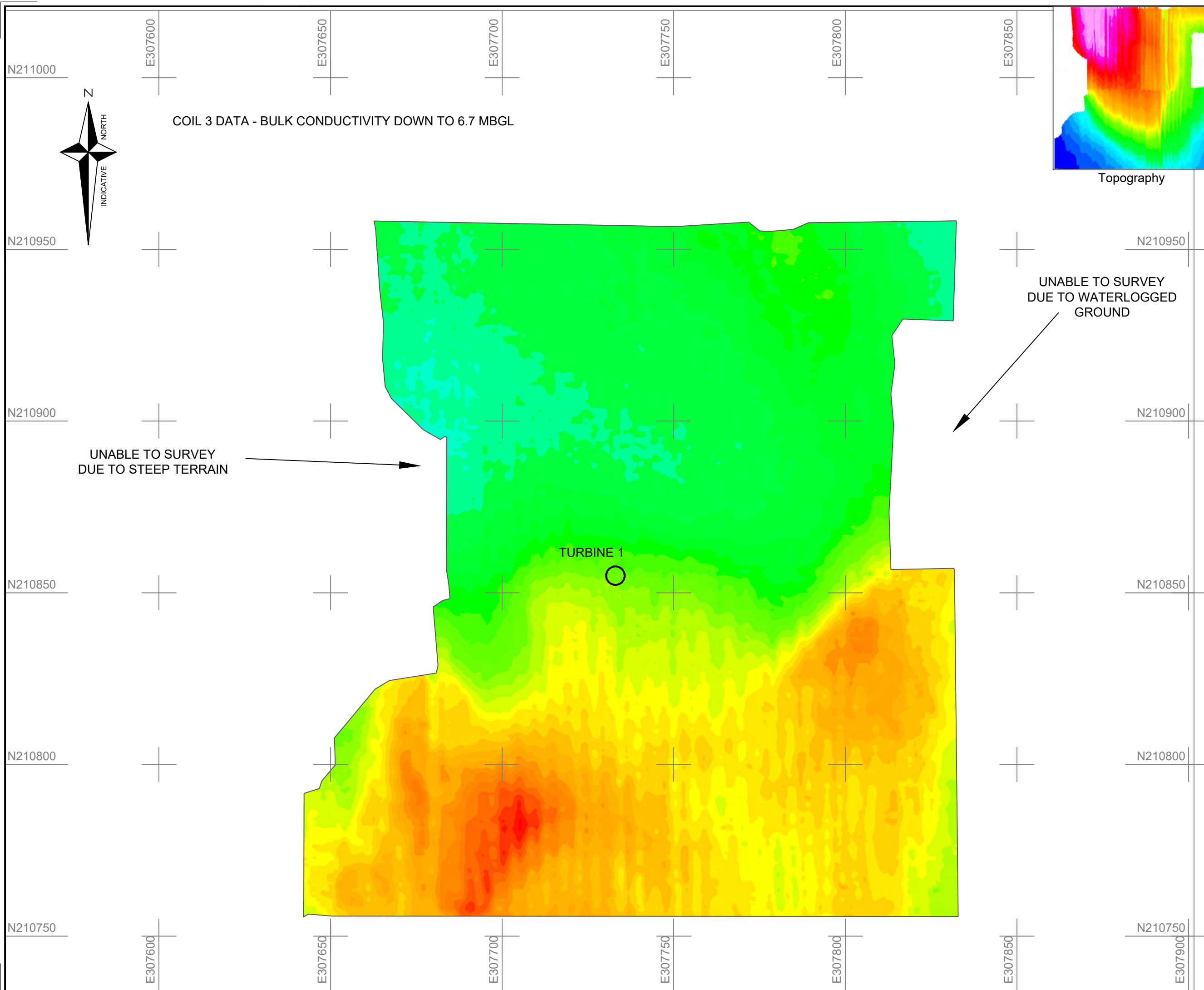
Drawn	Date	Checked	Date	Approved	Date
LW	01/12/22	TG	01/12/22	TG	01/12/22

Scale	Orig Size	Dimensions
1:1000	A3	

Project No.	Drawing File
2190464 R04	2190464 R04 Fig. 4A

Drawing No.	Rev.
2190464 Fig.4 Sheet 1 of 2	

Scale
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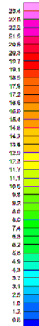


Topography

NOTES

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Apparent Conductivity
mS/m



KEY

- TURBINE 1 PROPOSED LOCATION (Pen_March_Turbine_Locations)
- ANOMALY A - LOW CONDUCTIVITY AREA (<4 mS/m)
- ANOMALY B - HIGH CONDUCTIVITY AREA (>14 mS/m)
- ANOMALY C - METAL (ABOVE GROUND OR BURIED)

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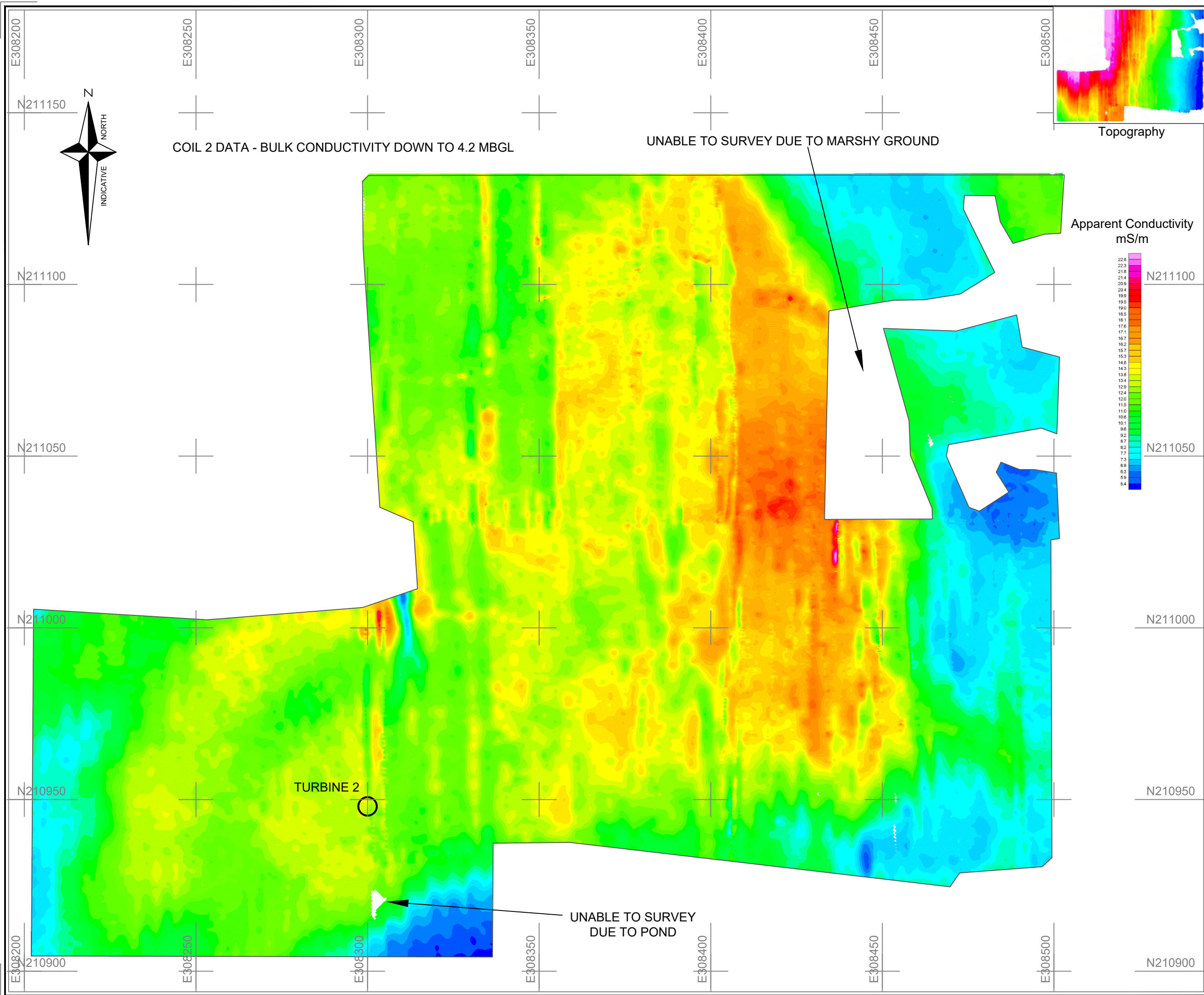
Client
**RWE RENEWABLES UK
SWINDON LTD.**

Project Title
PEN MARCH - TURBINE 1

Drawing Title
**RESULTS OF THE
ELECTROMAGNETIC SURVEY -
6.7M EFFECTIVE DEPTH**

Drawn LW	Date 01/12/22	Checked TG	Date 01/12/22	Approved TG	Date 01/12/22
Scale 1:1000	Orig Size A3	Dimensions			
Project No. 2190464 R04				Drawing File 2190464 R04 Fig. 4B	
Drawing No. 2190464 Fig.4 Sheet 2 of 2					Rev.

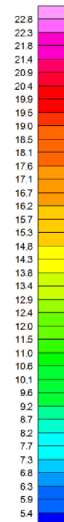




COIL 2 DATA - BULK CONDUCTIVITY DOWN TO 4.2 MBGL

UNABLE TO SURVEY DUE TO MARSHY GROUND

Apparent Conductivity
mS/m



Topography

NOTES

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KEY

- TURBINE 2 PROPOSED LOCATION (Pen_March_Turbine_Locations)
- ANOMALY A - LOW CONDUCTIVITY AREA (<4 mS/m)
- ANOMALY B - HIGH CONDUCTIVITY AREA (>14 mS/m)
- ANOMALY C - METAL (ABOVE GROUND OR BURIED)

Rev.	Date	Amendment	Drawn	Chkd.	Appd.

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Client
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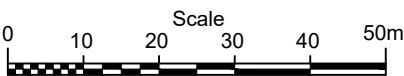
Project Title
PEN MARCH - TURBINE 2

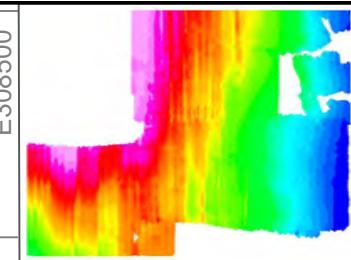
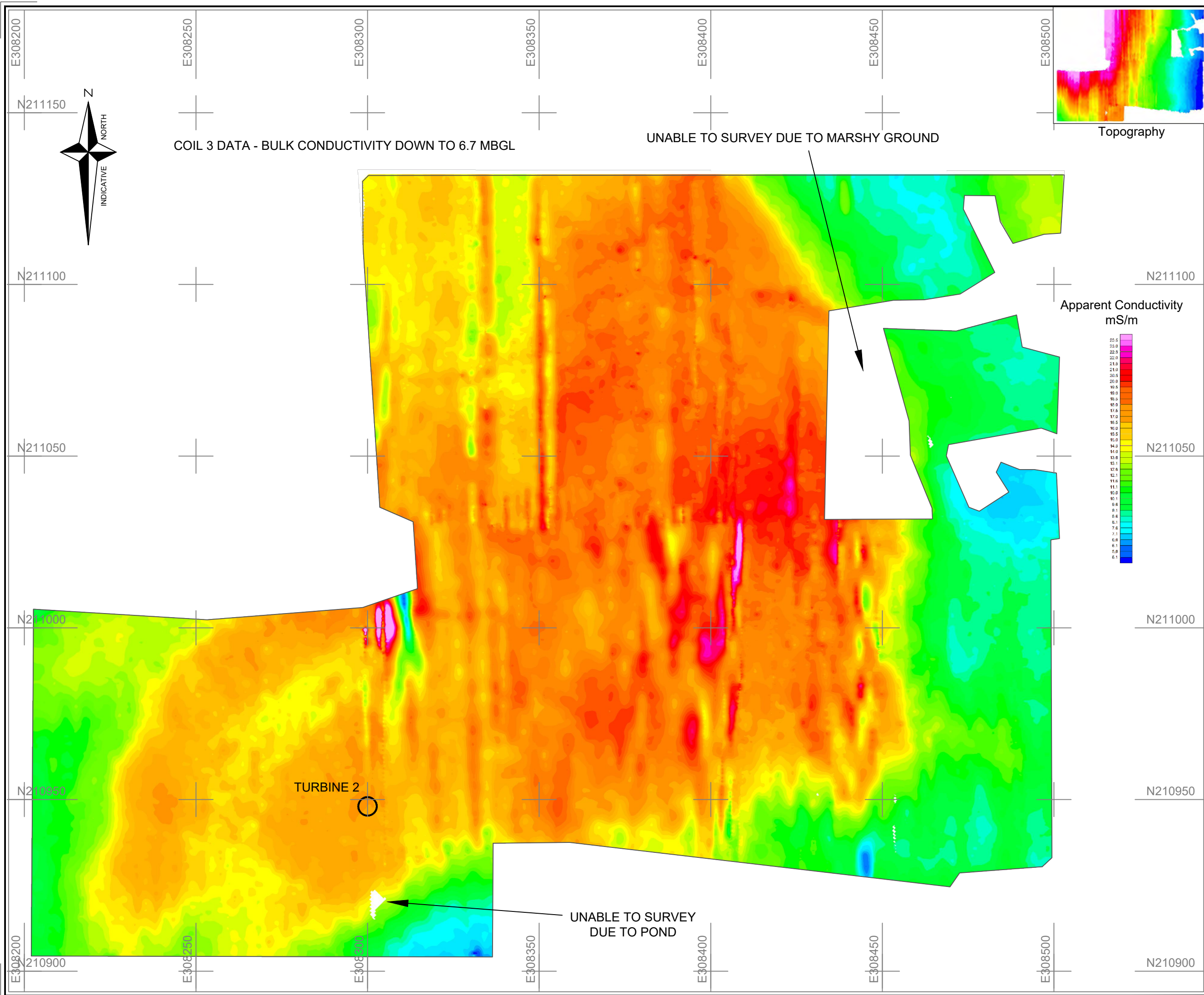
Drawing Title
**RESULTS OF THE
ELECTROMAGNETIC SURVEY -
4.2M EFFECTIVE DEPTH**

Drawn LW	Date 01/12/22	Checked TG	Date 01/12/22	Approved TG	Date 01/12/22
Scale 1:1000	Orig Size A3	Dimensions			

Project No. 2190464 R04	Drawing File 2190464 R04 Fig. 5A
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Drawing No. 2190464 Fig.5 Sheet 1 of 2	Rev.
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Topography

NOTES

The specific risks associated with the content of this drawing are considered to be:-

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KEY

- TURBINE 2 PROPOSED LOCATION (Pen_March_Turbine_Locations)
- ANOMALY A - LOW CONDUCTIVITY AREA (<6 mS/m)
- ANOMALY B - HIGH CONDUCTIVITY AREA (>14 mS/m)
- ANOMALY C - METAL (ABOVE GROUND OR BURIED)

Rev.	Date	Amendment	Drawn	Chkd.	Appd.



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Client

**RWE RENEWABLES UK
SWINDON LTD.**

Project Title

PEN MARCH - TURBINE 2

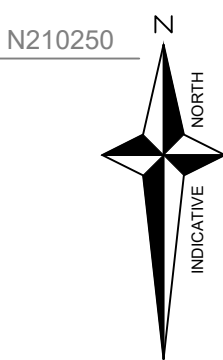
Drawing Title

**RESULTS OF THE
ELECTROMAGNETIC SURVEY -
6.7M EFFECTIVE DEPTH**

Drawn	Date	Checked	Date	Approved	Date
TG	01/12/22	TG	01/12/22	TG	01/12/22
Scale	Orig Size	Dimensions			
1:1000	A3				

Project No.	Drawing File
2190464 R04	2190464 R04 Fig. 5B
Drawing No.	Rev.
2190464 Fig.5 Sheet 2 of 2	





N210250

N210200

N210150

N210100

N210050

N210000

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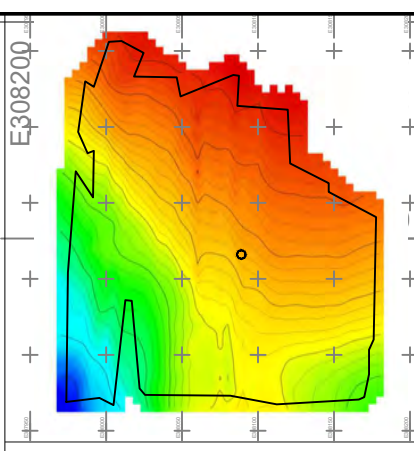
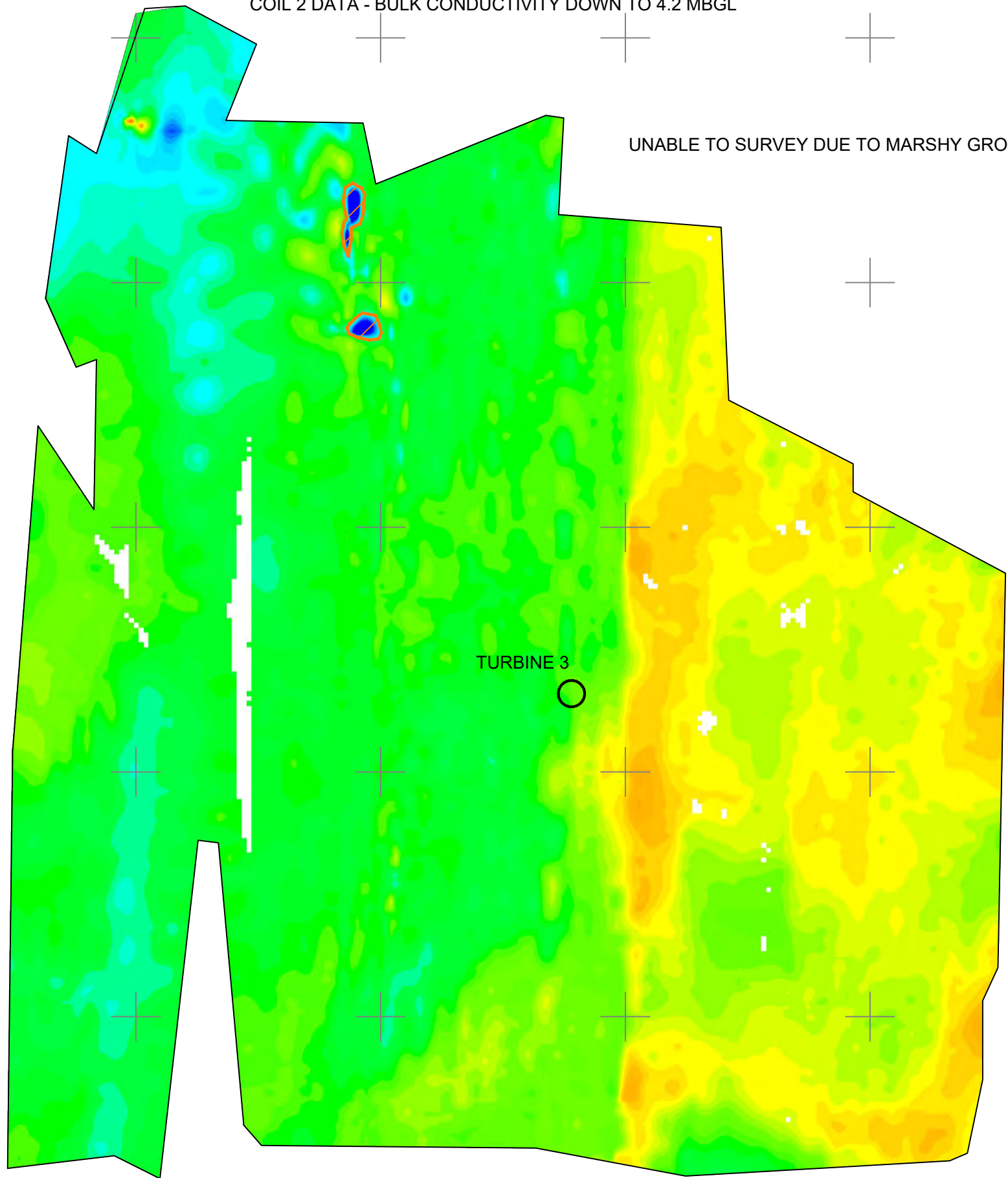
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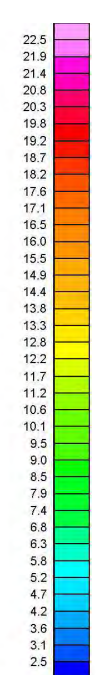
E308250

COIL 2 DATA - BULK CONDUCTIVITY DOWN TO 4.2 MBGL

UNABLE TO SURVEY DUE TO MARSHY GROUND



Topography



Apparent Conductivity
mS/m

NOTES

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KEY

- TURBINE 3 PROPOSED LOCATION (Pen_March_Turbine_Locations)
- ANOMALY A - LOW CONDUCTIVITY AREA (<6 mS/m)
- ANOMALY B - HIGH CONDUCTIVITY AREA (>14 mS/m)
- ANOMALY C - METAL (ABOVE GROUND OR BURIED)

Rev.	Date	Amendment	Drawn	Chkd.	Appd.



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Client
**RWE RENEWABLES UK
SWINDON LTD.**

Project Title
PEN MARCH - TURBINE 3

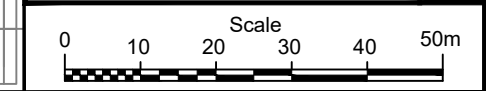
Drawing Title
**RESULTS OF THE
ELECTROMAGNETIC SURVEY -
4.2M EFFECTIVE DEPTH**

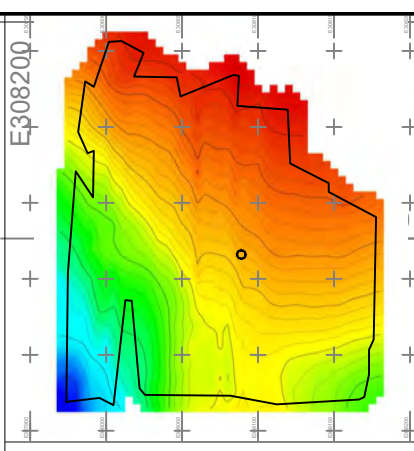
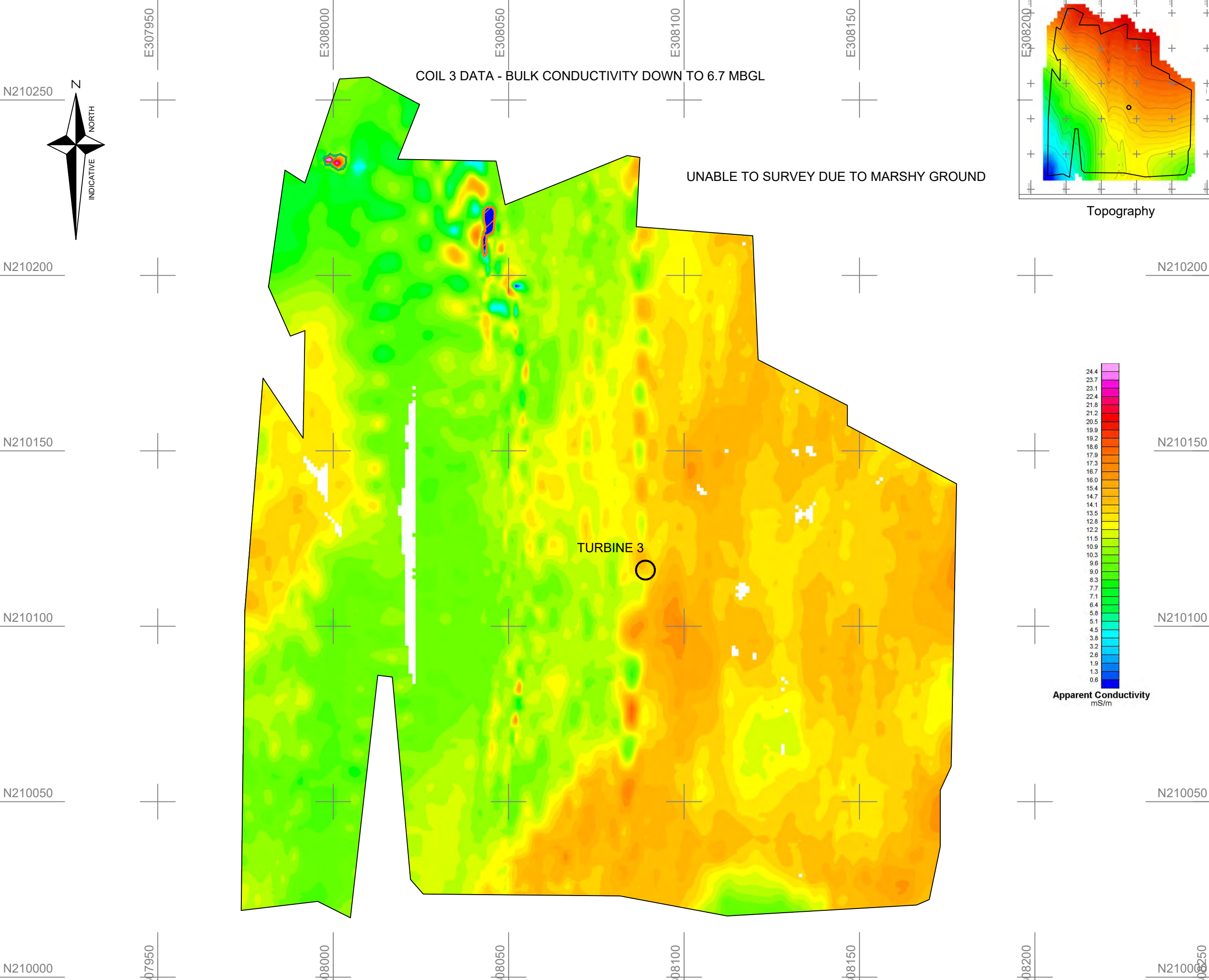
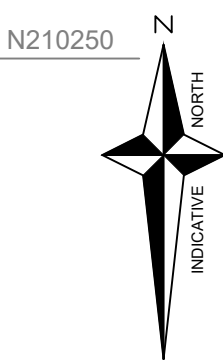
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Scale 1:1000	Orig Size A3	Dimensions
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Project No. 2190464 R04	Drawing File 2190464 R04 Fig. 6A
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Drawing No. 2190464 Fig.6 Sheet 1 of 2	Rev.
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NOTES

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- KEY**
- TURBINE 3 PROPOSED LOCATION (Pen_March_Turbine_Locations)
 - ANOMALY A - LOW CONDUCTIVITY AREA (<6 mS/m)
 - ANOMALY B - HIGH CONDUCTIVITY AREA (>14 mS/m)
 - ANOMALY C - METAL (ABOVE GROUND OR BURIED)

Rev.	Date	Amendment	Drawn	Chkd.	Appd.



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Client

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SWINDON LTD.**

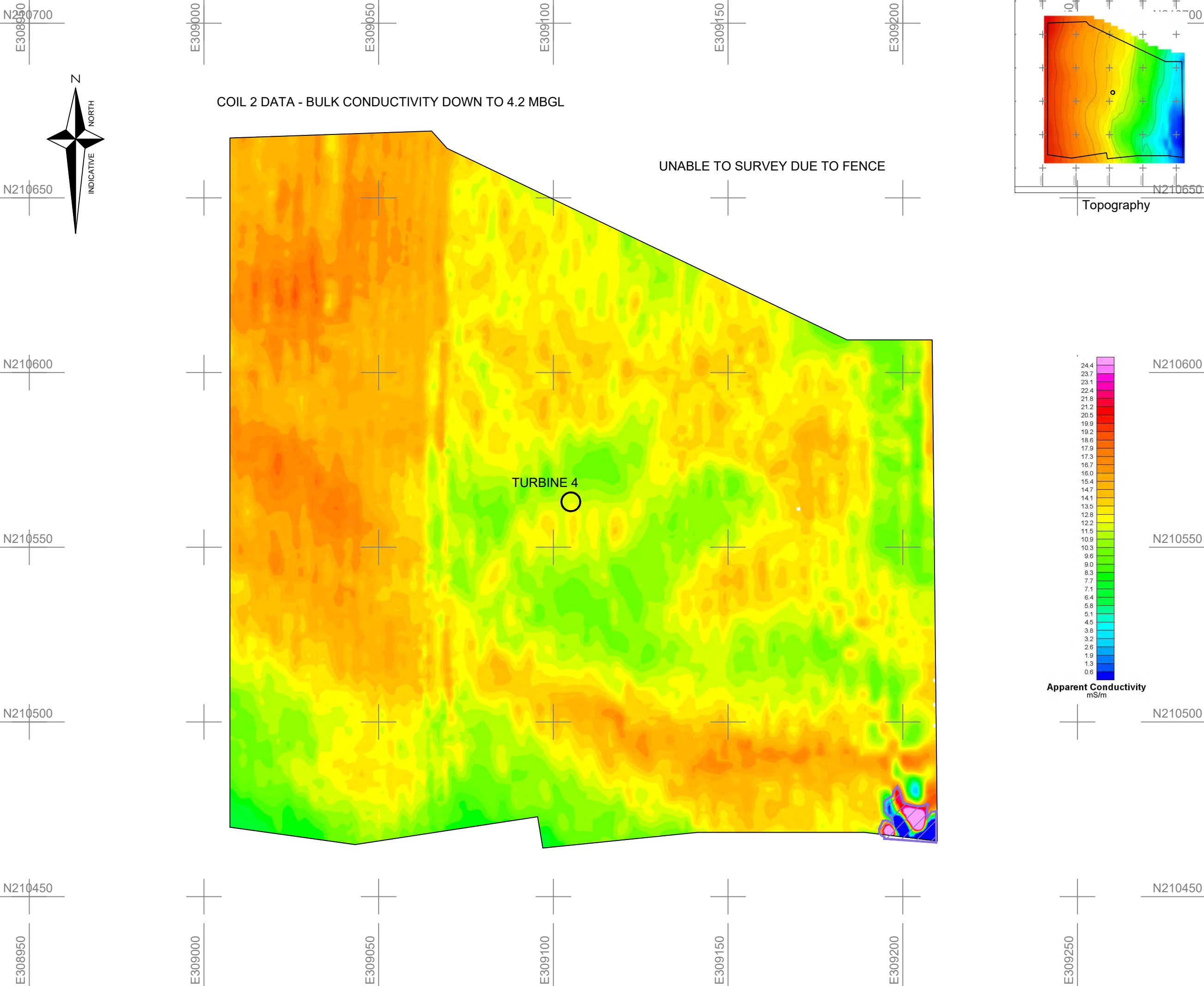
Project Title

PEN MARCH - TURBINE 3

Drawing Title

**RESULTS OF THE
ELECTROMAGNETIC SURVEY -
6.7M EFFECTIVE DEPTH**

Drawn LW	Date 01/12/22	Checked TG	Date 01/12/22	Approved TG	Date 01/12/22
Scale 1:1000	Orig Size A3	Dimensions			
Project No. 2190464 R04		Drawing File 2190464 R04 Fig. 6B			
Drawing No. 2190464 Fig.6 Sheet 2 of 2					Rev.
Scale 0 10 20 30 40 50m					



NOTES

The specific risks associated with the content of this drawing are considered to be:-

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- KEY**
- TURBINE 4 PROPOSED LOCATION
(Pen_March_Turbine_Locations)
 - ANOMALY A - LOW CONDUCTIVITY AREA (<6 mS/m)
 - ANOMALY B - HIGH CONDUCTIVITY AREA (>14 mS/m)
 - ANOMALY C - METAL (ABOVE GROUND OR BURIED)

Rev.	Date	Amendment	Drawn	Chkd.	Appd.



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Client

**RWE RENEWABLES UK
SWINDON LTD.**

Project Title

PEN MARCH - TURBINE 4

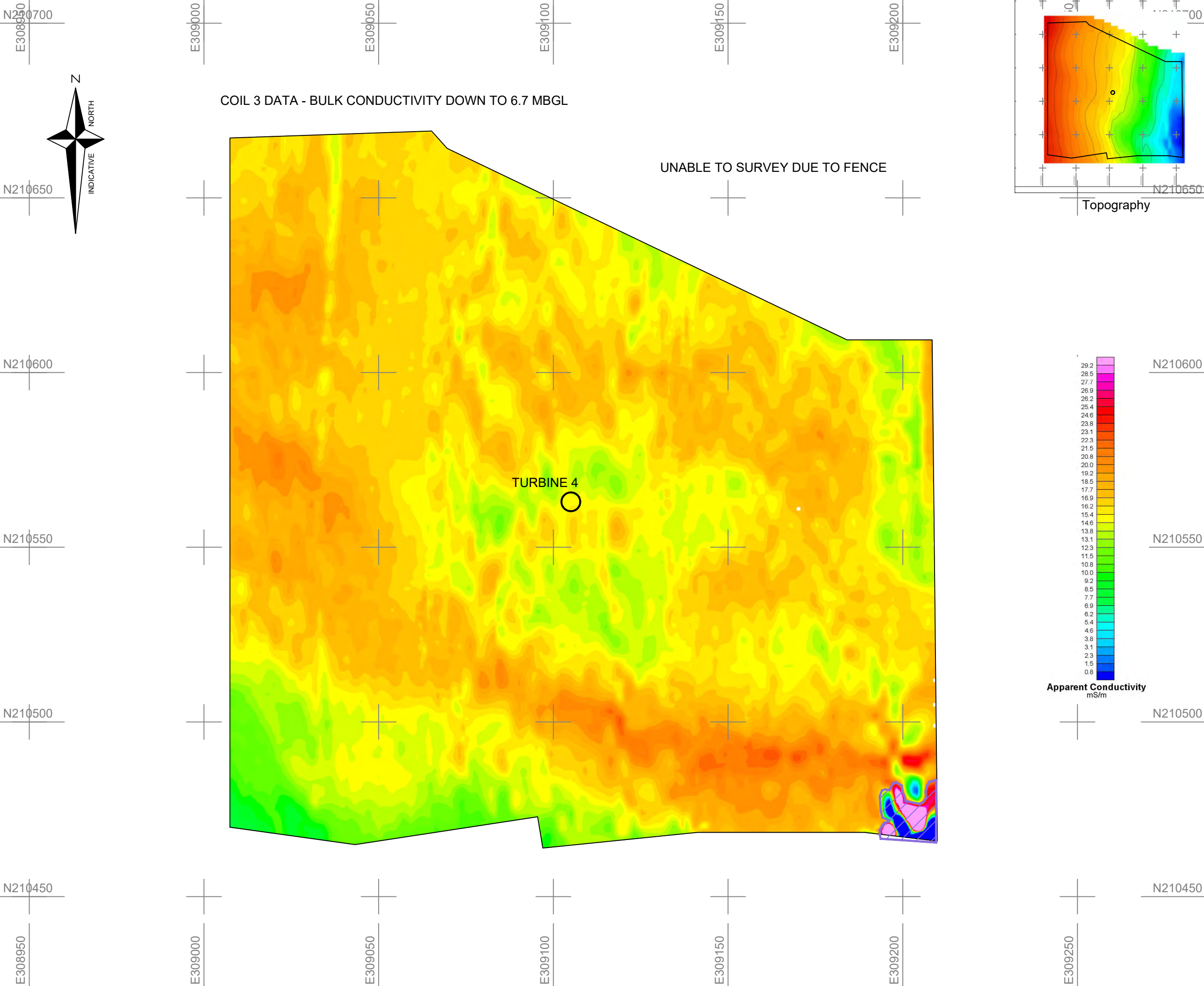
Drawing Title

**RESULTS OF THE
ELECTROMAGNETIC SURVEY -
4.2M EFFECTIVE DEPTH**

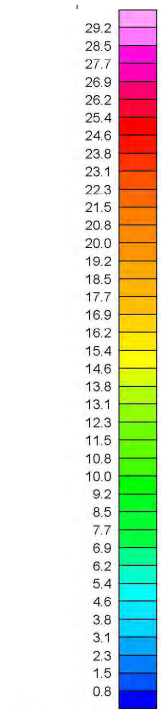
Drawn LW	Date 01/12/22	Checked TG	Date 01/12/22	Approved TG	Date 01/12/22
Scale 1:1000	Orig Size A3	Dimensions			
Project No. 2190464 R04		Drawing File 2190464 R04 Fig. 7A			
Drawing No. 2190464 Fig.7 Sheet 1 of 2					Rev.

0 10 20 30 40 50m

Scale



Topography



NOTES

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KEY

- TURBINE 4 PROPOSED LOCATION (Pen_March_Turbine_Locations)
- ANOMALY A - LOW CONDUCTIVITY AREA (<6 mS/m)
- ANOMALY B - HIGH CONDUCTIVITY AREA (>14 mS/m)
- ANOMALY C - METAL (ABOVE GROUND OR BURIED)

Rev.	Date	Amendment	Drawn	Chkd.	Appd.

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Client

**RWE RENEWABLES UK
SWINDON LTD.**

Project Title

PEN MARCH - TURBINE 4

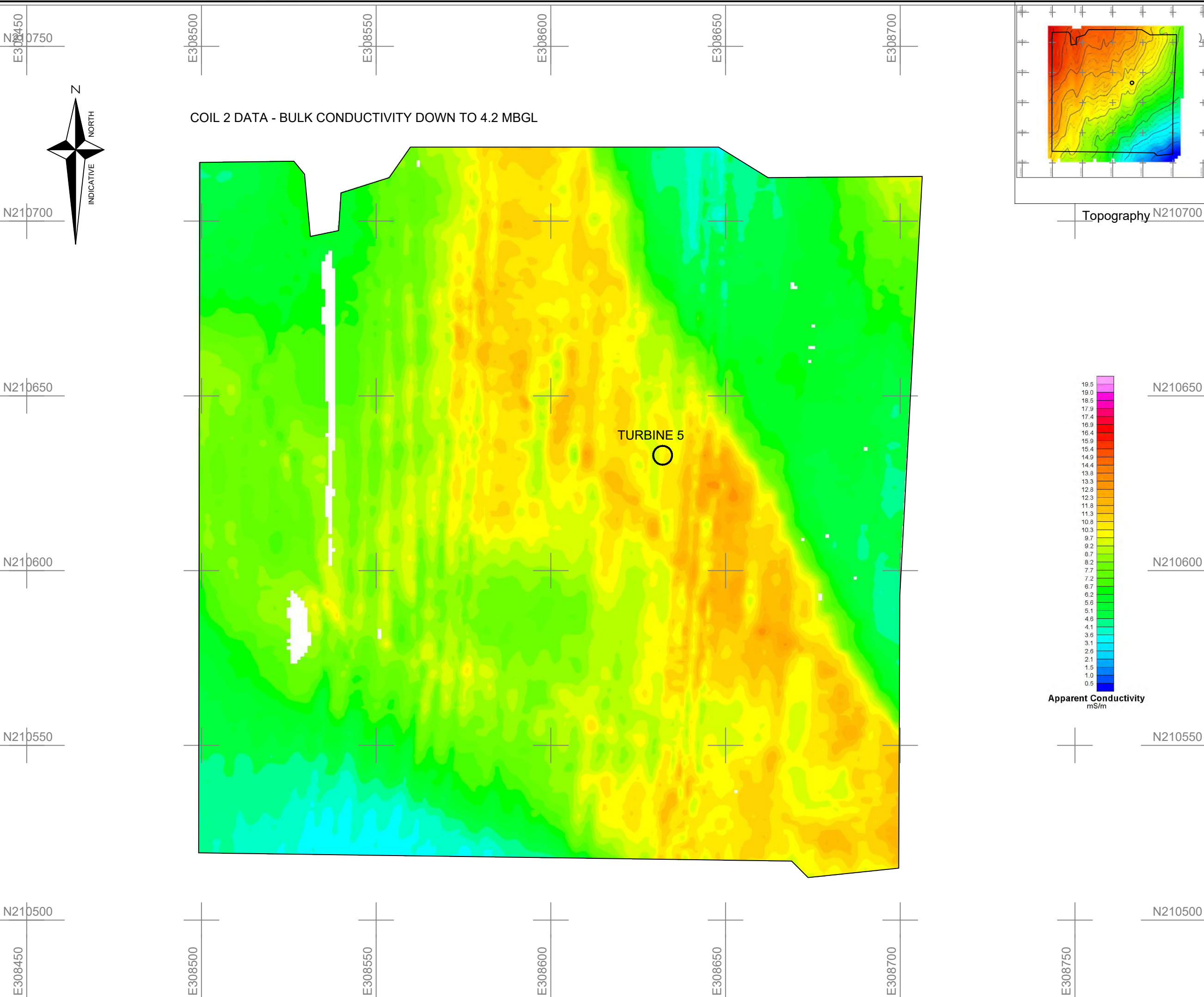
Drawing Title

**RESULTS OF THE
ELECTROMAGNETIC SURVEY -
6.7M EFFECTIVE DEPTH**

Drawn LW	Date 01/12/22	Checked TG	Date 01/12/22	Approved TG	Date 01/12/22
Scale 1:1000	Orig Size A3	Dimensions			
Project No. 2190464		Drawing File 2190464 R04 Fig. 7B			
Drawing No. 2190464 Fig.7 Sheet 2 of 2					Rev.

0 10 20 30 40 50m

Scale



NOTES

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KEY

TURBINE 5 PROPOSED LOCATION (Pen_March_Turbine_Locations)

ANOMALY A - LOW CONDUCTIVITY AREA (<6 mS/m)

ANOMALY B - HIGH CONDUCTIVITY AREA (>14 mS/m)

ANOMALY C - METAL (ABOVE GROUND OR BURIED)

Rev.	Date	Amendment	Drawn	Chkd.	Appd.

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Client

RWE RENEWABLES UK SWINDON LTD.

Project Title

PEN MARCH - TURBINE 5

Drawing Title

RESULTS OF THE ELECTROMAGNETIC SURVEY - 4.2M EFFECTIVE DEPTH

Drawn	Date	Checked	Date	Approved	Date
LW	01/12/22	TG	01/12/22	TG	01/12/22

Scale
1:1000

Orig Size
A3

Dimensions

Project No.
2190464

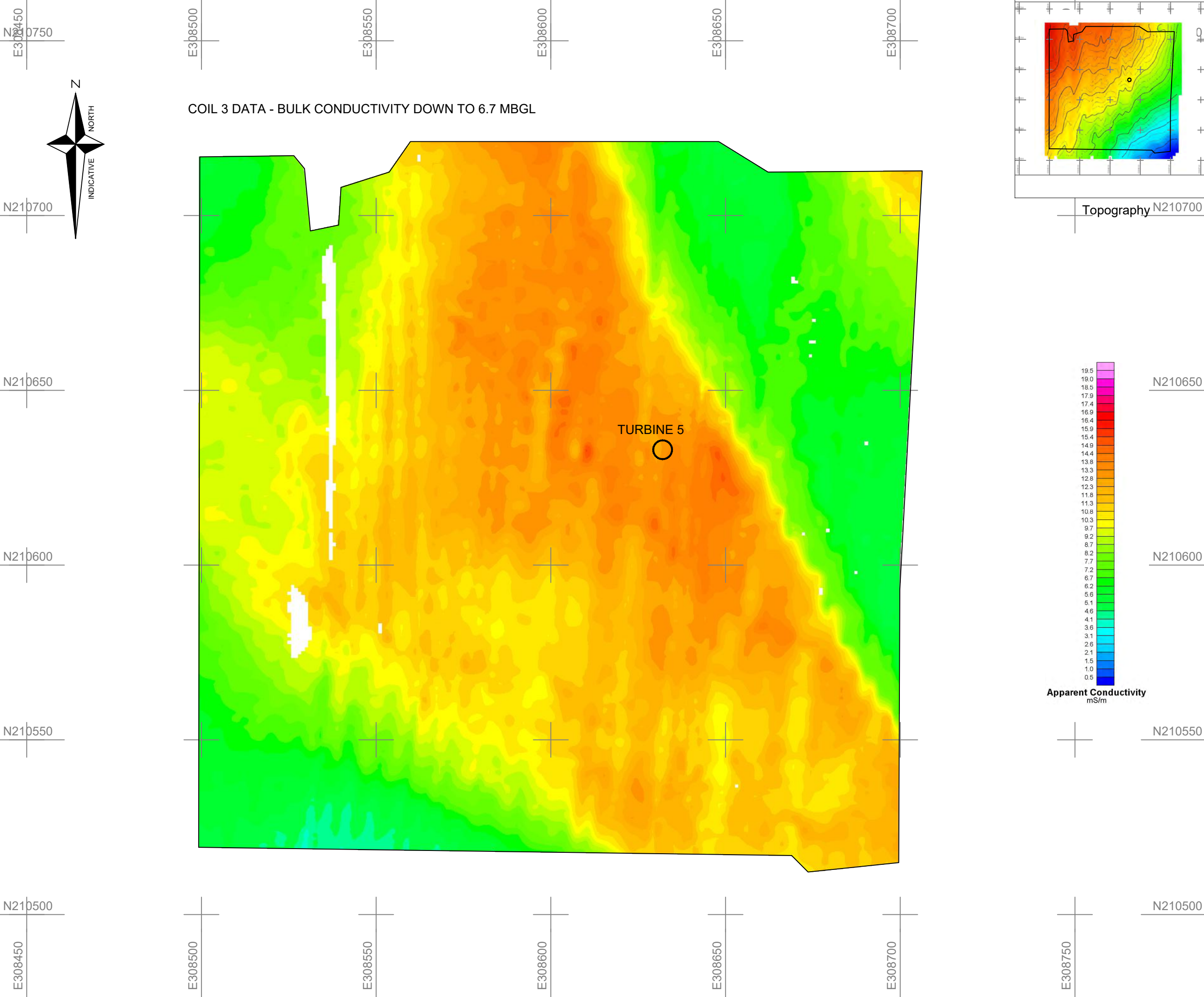
Drawing File
2190464 R04 Fig. 8A

Drawing No.
2190464 Fig.8 Sheet 1 of 2

Rev.

0 10 20 30 40 50m

Scale



NOTES

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KEY

- TURBINE 5 PROPOSED LOCATION (Pen_March_Turbine_Locations)
- ANOMALY A - LOW CONDUCTIVITY AREA (<6 mS/m)
- ANOMALY B - HIGH CONDUCTIVITY AREA (>14 mS/m)
- ANOMALY C - METAL (ABOVE GROUND OR BURIED)

Rev.	Date	Amendment	Drawn	Chkd.	Appd.

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Client

RWE RENEWABLES UK
SWINDON LTD.

Project Title

PEN MARCH - TURBINE 5

Drawing Title

RESULTS OF THE
ELECTROMAGNETIC SURVEY -
6.7M EFFECTIVE DEPTH

Drawn	Date	Checked	Date	Approved	Date
LW	01/12/22	TG	01/12/22	TG	01/12/22

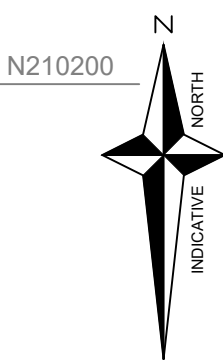
Scale	Orig Size	Dimensions
1:1000	A3	

Project No.	Drawing File
2190464	2190464 R04 Fig. 8B

Drawing No.	Rev.
2190464 Fig.8 Sheet 2 of 2	

0 10 20 30 40 50m

Scale



N210200

N210150

N210100

N210050

N210000

N209950

E308450

E308500

E308550

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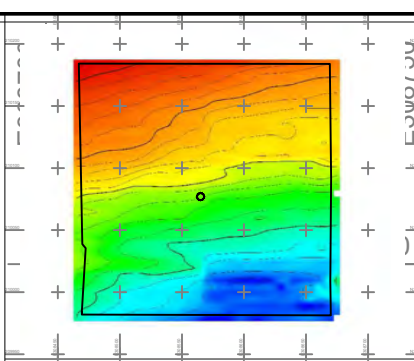
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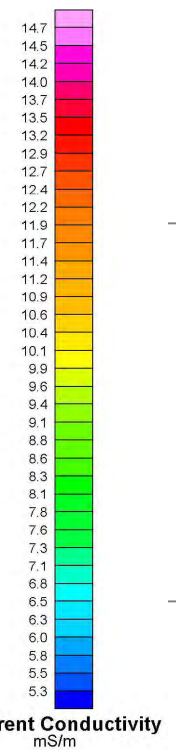
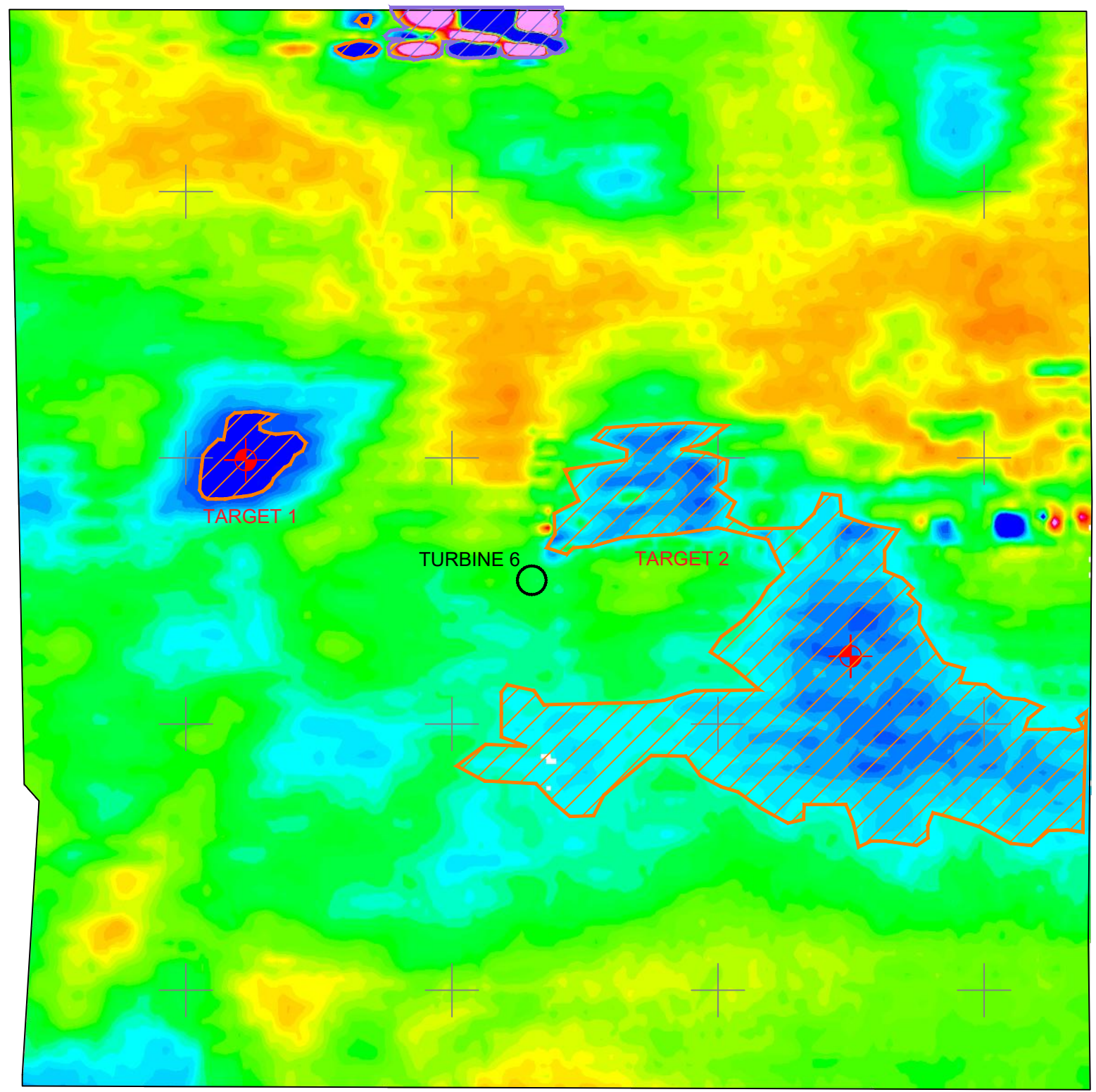
E308600

E308650



Topography

COIL 2 DATA - BULK CONDUCTIVITY DOWN TO 4.2 MBGL



Apparent Conductivity
mS/m

NOTES

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SUGGESTED INTRUSIVE TARGET CO-ORDINATES

Target	Eastings	Northings
1	308511.152	210099.805
2	308625.201	210062.586

KEY

- TURBINE 6 PROPOSED LOCATION (Pen_March_Turbine_Locations)
- SUGGESTED INTRUSIVE INVESTIGATION TARGETS
- ANOMALY A - LOW CONDUCTIVITY AREA (<6 mS/m)
- ANOMALY B - HIGH CONDUCTIVITY AREA (>14 mS/m)
- ANOMALY C - METAL (ABOVE GROUND OR BURIED)

Rev.	Date	Amendment	Drawn	Chkd.	Appd.



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Client

**RWE RENEWABLES UK
SWINDON LTD.**

Project Title

PEN MARCH - TURBINE 6

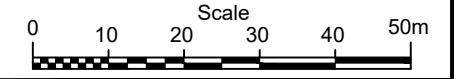
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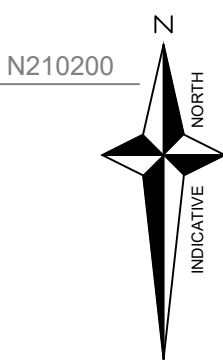
**RESULTS OF THE
ELECTROMAGNETIC SURVEY -
4.2M EFFECTIVE DEPTH**

Drawn LW	Date 01/12/22	Checked TG	Date 01/12/22	Approved TG	Date 01/12/22
Scale 1:1000	Orig Size A3	Dimensions			

Project No. 2190464	Drawing File 2190464 R04 Fig. 9A
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Drawing No. 2190464 Fig.9 Sheet 1 of 2	Rev.
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N210200

N210150

N210100

N210050

N210000

N209950

E308450

E308500

E308550

E308600

E308650

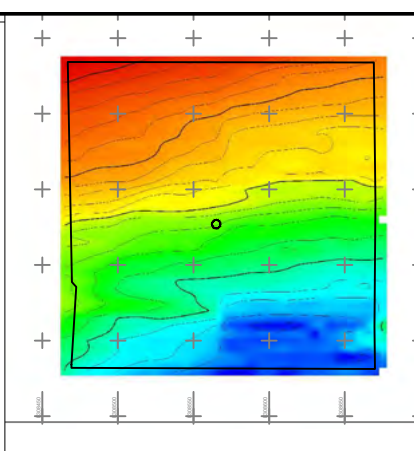
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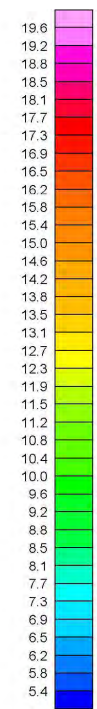
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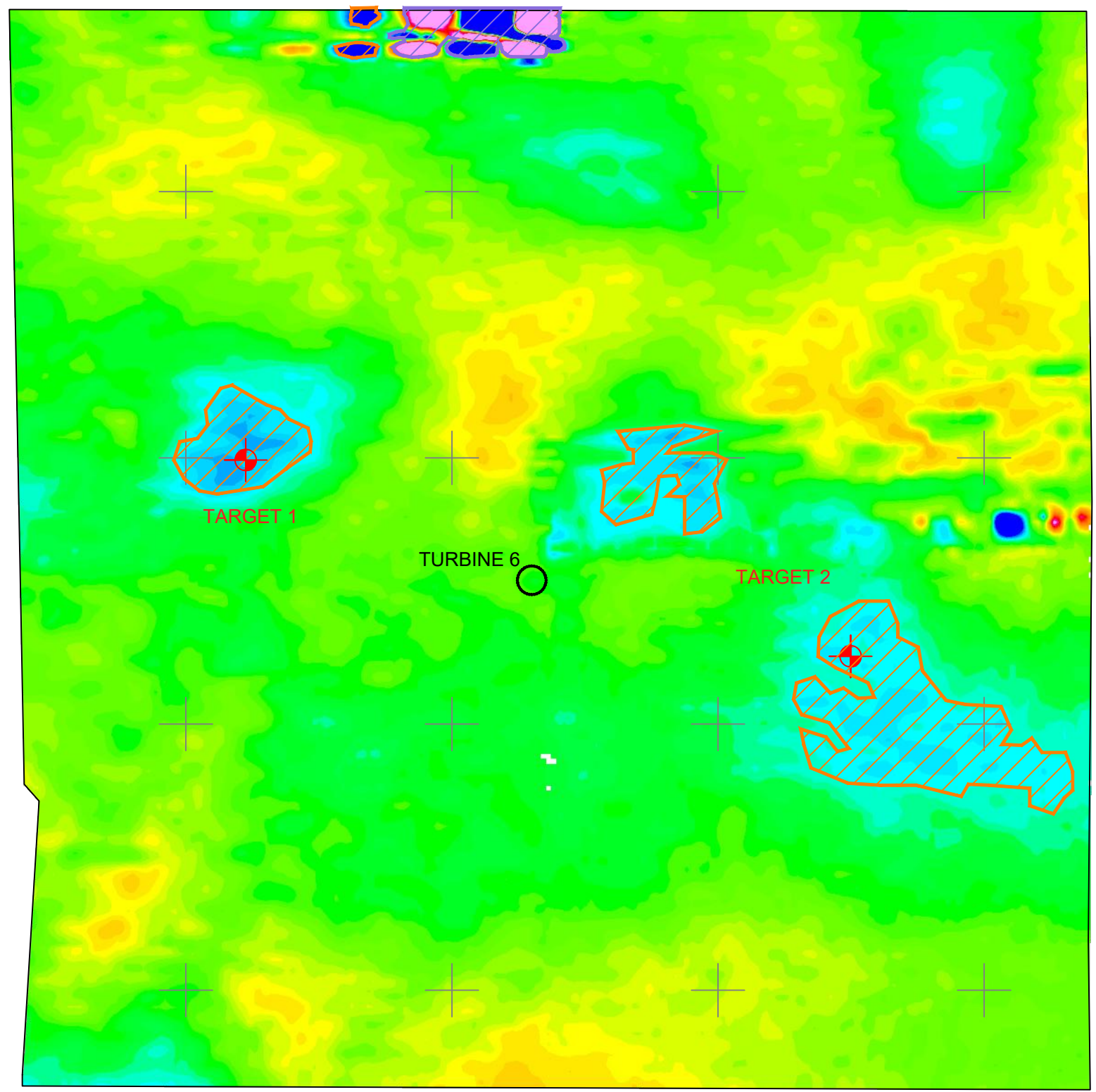


Topography



Apparent Conductivity mS/m

COIL 3 DATA - BULK CONDUCTIVITY DOWN TO 6.7 MBGL



NOTES

The specific risks associated with the content of this drawing are considered to be:-

(1) It is recommended that the Client should confirm the location of the geophysical anomalies with hand dug pits within 0.5m to confirm the cause of the anomalies prior to the commencement of works.

(2) Although every reasonable effort has been made to locate features associated with voided ground using EM mapping techniques, RSK Environment Ltd cannot guarantee that every feature has been located.

SUGGESTED INTRUSIVE TARGET CO-ORDINATES

Target	Easting	Northings
1	308511.152	210099.805
2	308625.201	210062.586

- KEY**
- TURBINE 6 PROPOSED LOCATION (Pen_March_Turbine_Locations)
 - SUGGESTED INTRUSIVE INVESTIGATION TARGETS
 - ANOMALY A - LOW CONDUCTIVITY AREA (<6 mS/m)
 - ANOMALY B - HIGH CONDUCTIVITY AREA (>14 mS/m)
 - ANOMALY C - METAL (ABOVE GROUND OR BURIED)

Rev.	Date	Amendment	Drawn	Chkd.	Appd.



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Client

**RWE RENEWABLES UK
SWINDON LTD.**

Project Title

PEN MARCH - TURBINE 6

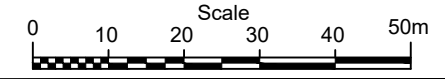
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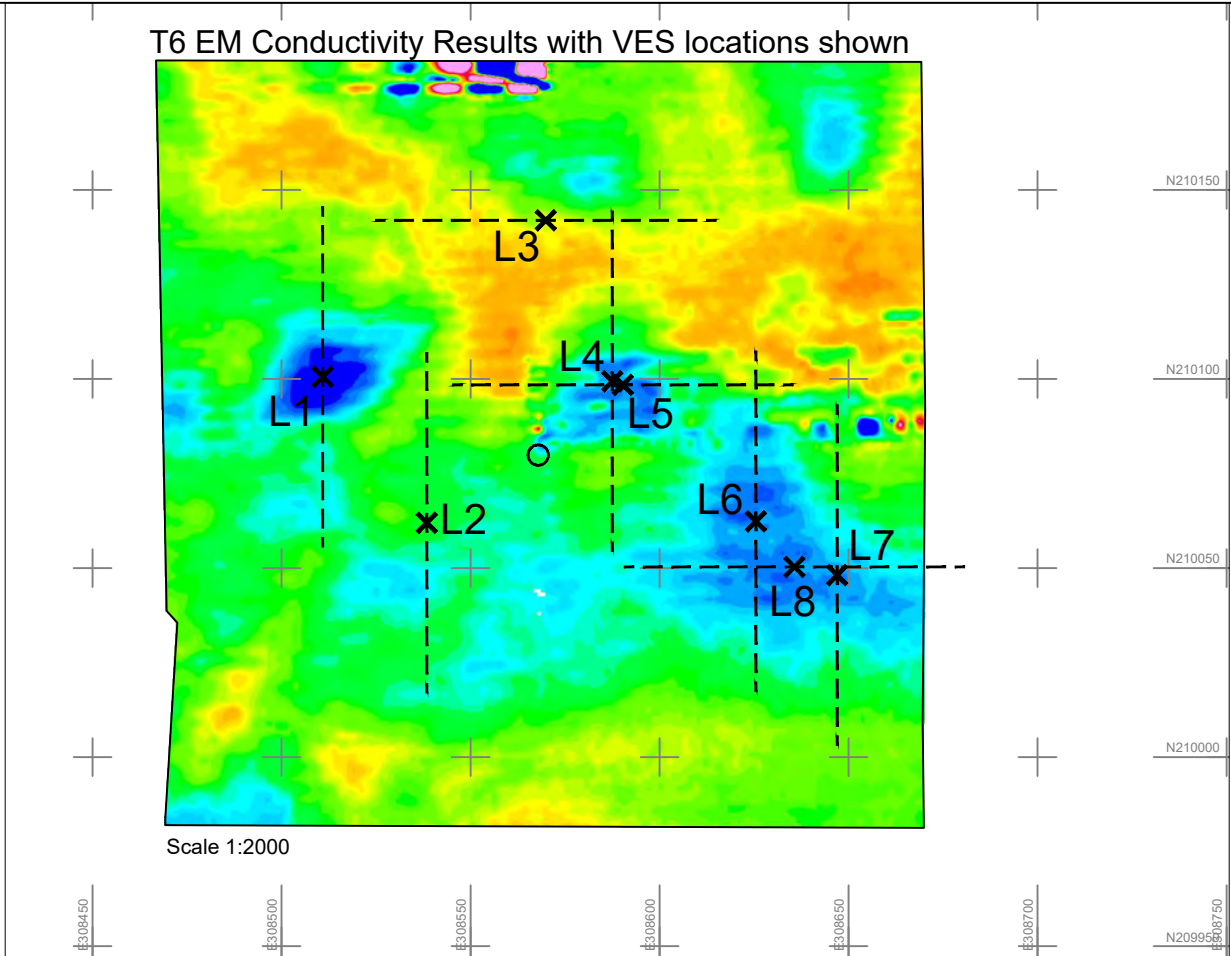
**RESULTS OF THE
ELECTROMAGNETIC SURVEY -
6.7M EFFECTIVE DEPTH**

Drawn LW	Date 01/12/22	Checked TG	Date 01/12/22	Approved TG	Date 01/12/22
Scale 1:1000	Orig Size A3	Dimensions			

Project No. 2190464	Drawing File 2190464 R04 Fig. 9B
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Drawing No. 2190464 Fig.9 Sheet 2 of 2	Rev.
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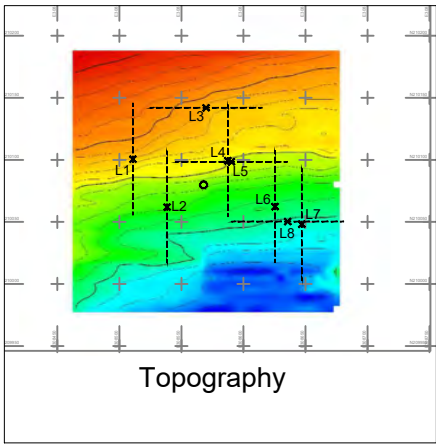


VES Survey Location co-ordinates

Loc. ID	Easting	Northing	Elevation
1	308510.9	210100.6	464.4
2	308538.4	210062.0	459.4
3	308569.9	210142.0	465.9
4	308587.5	210099.4	461.9
5	308590.4	210098.5	461.6
6	308625.5	210062.4	458.0
7	308646.9	210048.2	456.7
8	308635.8	210050.3	456.8

VES Results Model Details

Location 1				Location 2			
Layer	Rho	Thickness	Depth	Layer	Rho	Thickness	Depth
1	235.94	1.09	1.09	1	435.44	1.27	1.27
2	968.86	2.02	3.11	2	69.65	0.33	1.60
3	109.13	4.62	7.73	3	272.72		
4	449.24						
Location 3				Location 4			
Layer	Rho	Thickness	Depth	Layer	Rho	Thickness	Depth
1	82.15	2.90	2.90	1	145.29	3.49	3.49
2	1021.7	7.55	10.45	2	727.19	3.14	6.63
3	160.73			3	189.16	3.05	9.68
				4	68.53	5.44	15.12
				5	1241.5		
Location 5				Location 6			
Layer	Rho	Thickness	Depth	Layer	Rho	Thickness	Depth
1	91.724	2.15	2.15	1	446.39	1.33	1.33
2	791.02	3.09	5.23	2	89.78	1.48	2.81
3	185.52	3.05	8.28	3	299.32		
4	66.94	5.62	13.90				
5	1139.0						
Location 7				Location 8			
Layer	Rho	Thickness	Depth	Layer	Rho	Thickness	Depth
1	280.72	1.40	1.40	1	268.69	1.85	1.85
2	67.68	1.49	2.89	2	48.34	1.41	3.26
3	375.56			3	927.27	7.82	
				4	145.31		

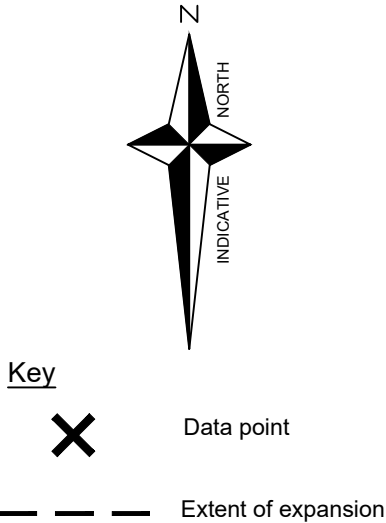


NOTES

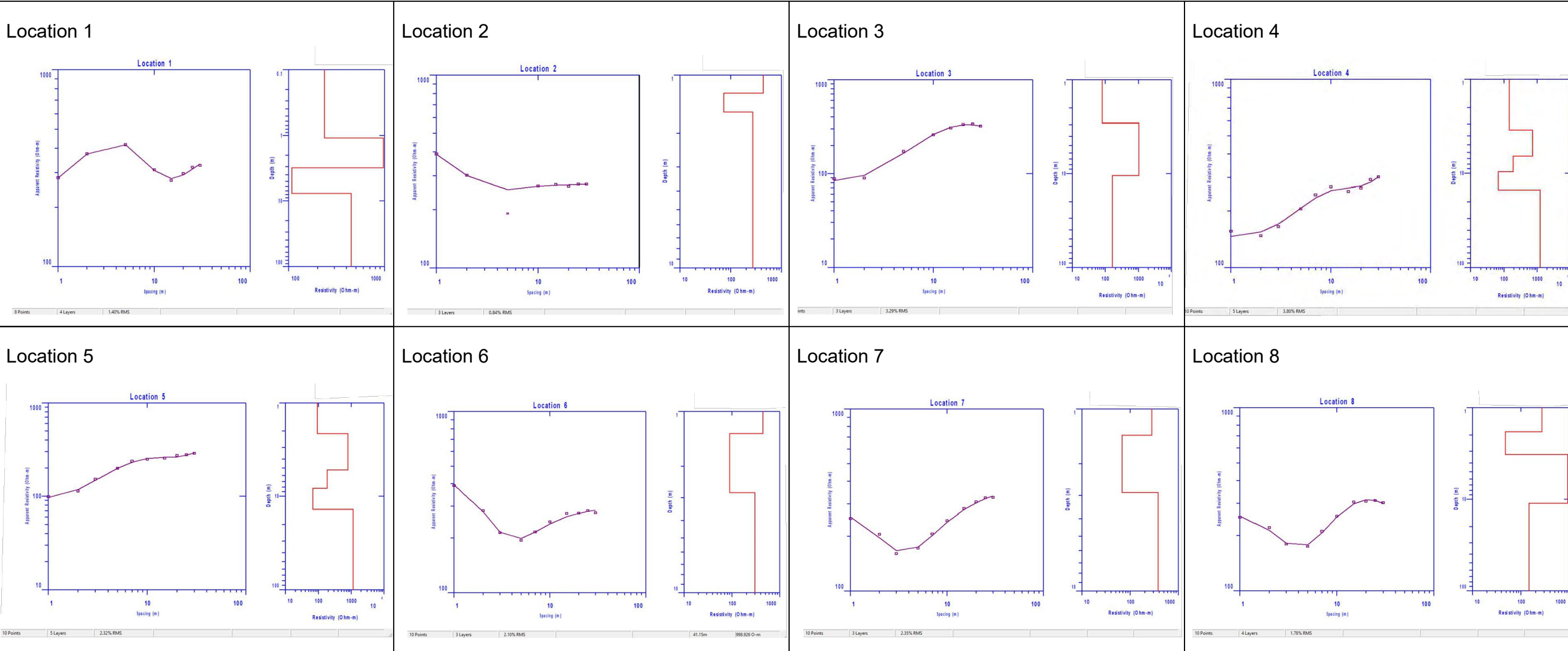
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VES Survey Results - 1D Inversion Models



Rev.

Date

Amendment

Drawn

Chkd.

Appd.

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Client

RWE RENEWABLES UK
SWINDON LTD.

Project Title

PEN MARCH - TURBINE 6

Drawing Title

RESULTS OF THE ELECTRICAL
RESISTIVITY SURVEY

Drawn
LW

Date
01/12/22

Checked
TG

Date
01/12/22

Approved
TG

Date
01/12/22

Scale
As Shown

Orig Size
A3

Dimensions

Project No.
2190464 R04

Drawing File
2190464 R04 Fig. 10

Drawing No.
2190464 Fig.10 Sheet 1 of 1

Rev.

APPENDIX A

Equipment Specification Sheets

GF Instruments CMD Explorer

A portable, lightweight, multi receiver ground conductivity instrument designed for a broad range of environmental, geotechnical, geological and engineering applications.



The GF Instruments CMD Explorer maps geological variations, groundwater contaminants or any subsurface feature associated with changes in ground conductivity, using the electromagnetic induction technique that allows measurement without electrodes or ground contact. With this inductive method, surveys can be carried out under most conditions including those of high surface resistivity such as sand, gravel and asphalt.

Ground conductivity (quad-phase) and magnetic susceptibility (in-phase) measurements are read directly from a digital display. A choice of 5 different data collection modes are available including manual measurement, continuous measurement and GPS correlated data.

The effective depth of exploration is a maximum of about 6.7m, making it ideal for geotechnical and environmental site characterization. Important advantages of the CMD Explorer over conventional resistivity methods are the speed with which surveys can be performed, the precision in which small changes in conductivity can be measured and the continuous read out and data collection while traversing the area. Additionally, the in-phase component is particularly useful for the detection of buried metallic structure and waste material. The advantage of the CMD Explorer over other electromagnetic instruments is its ability to record data from multiple depths during a single survey traverse, providing a greater amount of information about the subsurface with no increase in collection times.

Specifications;

<i>Measured quantities:</i>	1. Apparent conductivity in millisiemens per metre (mS/m) 2. In-phase ratio of secondary to primary magnetic field in parts per thousand (ppt)
<i>Intercoil spacing:</i>	1.48m, 2.82m, 4.49m
<i>Power supply:</i>	Internal Exchangeable rechargeable Li-Ion battery pack; (approx 24-32 hours continuous measurement.
<i>Measuring Ranges:</i>	Conductivity: 1000mS/m; In-phase: ± 80 ppt
<i>Measurement Resolution:</i>	Conductivity: 0.1mS/m; In-phase: 10ppm
<i>Measurement Accuracy:</i>	$\pm 4\%$ at 50mS/m
<i>Weights:</i>	Instrument: 8kg Handset/Logger: 0.7kg

**GF INSTRUMENTS
CMD EXPLORER**



OHMEGA RESISTIVITY SOUNDING SYSTEM



Output current:	0.5 – 200mA
Output Voltage:	360V peak to peak
Cycle time:	2.1, 4.2 & 8.4 sec
No. of cycles:	1, 2, 4, & 16
Input impedance:	22 MOhms
Measurement range:	0.001 Ohms – 360 kOhms
Power supply:	Internal rechargeable 12v battery or external 12v source
Display:	4 line alphanumeric LCD
Weight [Ohmega]:	4kg
Weight [Shipping]:	36kg
Dimensions:	270 x 240 x 175 mm

**OHMEGA RESISTIVITY
SOUNDING SYSTEM**

