

GeoEnergy NI

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Project Summary Report

V3 Final

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Appendix A – Greenmount Survey Works Specification

ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
AR	Augmented Reality
XR	Extended Reality
MT	Magnetotelluric
TRT	Thermal Response Test

1.0 INTRODUCTION

Geothermal energy is a low carbon, natural, and renewable energy source from beneath the Earth's surface and is already widely used successfully across the world. The GeoEnergy NI Demonstrator project, led by the Department for the Economy, was commissioned to explore the geothermal energy potential at two demonstrator sites in Northern Ireland and raise awareness by showcasing the potential for geothermal energy to contribute to decarbonising the Northern Ireland economy and increase our security of energy supply, for all our benefit.

Further information about the geothermal demonstrator project can be found at www.GeoEnergyNI.org.

The project comprised the following key components:

- Exploration of the Stormont Estate in Belfast through the drilling and testing of 5 No boreholes aimed at investigating the geological / hydrogeological setting and assessing options for the development of shallow geothermal energy systems at the site.
- Assessment of the deep geothermal resource potential at the College of Agriculture, Food and Rural Enterprise (CAFRE) Greenmount Campus near Antrim, through geophysical surveying and updated interpretation of the deep geological setting and associated geothermal properties.
- Public, educational and wider stakeholder engagement to raise awareness of geothermal through multi-strategy campaign including:
 - Roadshows to the general public, educational establishments and other stakeholder groups incorporating the use of a mobile visitor centre designed and built to support the project objectives;
 - Development of multi-media VR animation and other multi-media content for wide stakeholder engagement;
 - Development of teaching resources to support relevant schools curricula including 'Earth and Universe' and 'Movement and Energy';
 - Production of a documentary showcasing existing use of geothermal in Northern Ireland and its future potential;

This report provides an overview of the works completed over the project life cycle and includes reference to learnings from implementing the various project elements which will be of value to the industry when developing geothermal systems in Northern Ireland and further afield.

The different project outputs and datasets are also referenced in the relevant sections.

2.0 GREENMOUNT GEOPHYSICAL SURVEY (PLANNING AND IMPLEMENTATION) AND OUTPUTS

2.1 OVERVIEW

The project specification required the acquisition and interpretation of new geophysical survey data for the area at and in the vicinity of the CAFRE Greenmount site in Antrim, Northern Ireland.

The geophysical surveys consisted of 3 No. types of ground-based surveys which were undertaken between 15th and 25th of July 2023.

2.2 WORKS SPECIFICATION

The project specification was for a geophysical survey to be completed of CAFRE and the surrounding area south of Antrim town. Further detail on the specification is presented at Appendix A. The surveys were to include a 3.5km² gravity survey, a high-density seismic reflection survey and a magnetotelluric survey as outlined below. Tetra Tech was responsible for securing all relevant governmental and Local Authority permits for the surveys and obtaining landowners' permission to work on each site. The selection of survey sites was to be discussed/agreed with GSNI. DAERA / CAFRE had to be advised in advance of any communications made to landowners to make sure project messaging was aligned.

2.3 SEISMIC SURVEY OVERVIEW

The seismic survey was undertaken across 9 No. days between 16/06/23 to 24/06/23 and involved the acquisition of 3No. 2D lines with a total length of 15,440m. The survey is a low-impact survey which sends low-frequency acoustic waves into the earth with the resultant vibration signals collected by receivers placed a few centimetres into the ground. The acoustic waves are generated by a pad which is temporarily lowered onto the ground and vibrated below a specially designed vibroseis truck.

The vibroseis truck (Insert 2.1) operated along public roads and some private tracks through and around the Greenmount site. Nimble Stryde nodal receivers (Insert 2.2) were placed adjacent to the roadside at an approximate 4m spacing along the route of the survey (Insert 2.3). Points with visible obstacles (roads, paths, buildings) were skipped. As the vibroseis truck moved along the planned route, the receivers were progressively collected and moved to new locations along the route. The ground surface was vibrated to introduce seismic energy into the underlying ground at a 16 m spacing (Insert 3). Vibration at each location took place for a few of minutes, before moving on to the next successive location.

Insert 2.1 - Vibroseis Truck (HEMI-60)



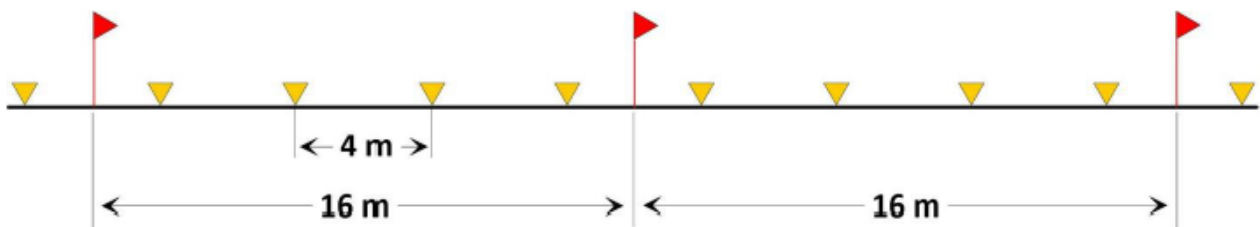
Insert 2.2 - Seismic Receiver (~ 13cm (H) 4cm (D))



Permission was secured from the relevant authorities (e.g DfI Roads Service) to allow the works to proceed. Consultation and pre-notification of those potentially affected by the temporary works was also undertaken in advance of the survey taking place. Due to heavy traffic use of the roads in the survey area and the potential for intense noise associated with this traffic, the survey was performed during late evenings/nights with the assistance of a specialist traffic management/ control company.

Traffic control facilitated the safe passage of traffic around the vibroseis truck when it was temporarily stationary and safeguarded the supporting field staff.

Insert 2.3 Set up of receiver and shot point location set up



2.4 MAGNETOTELLURIC (MT) SURVEY OVERVIEW

Magnetotelluric (MT) surveys were completed across 8 No. days between the 16/06/23 and 23/06/23. MT is a geophysical data acquisition technique with minimal associated ground disturbance. The MT equipment is designed to collect information on the electrical resistivity distribution in the Earth and was deployed at 19 No. locations across an area of approximately 20 km², centred around the Greenmount site.

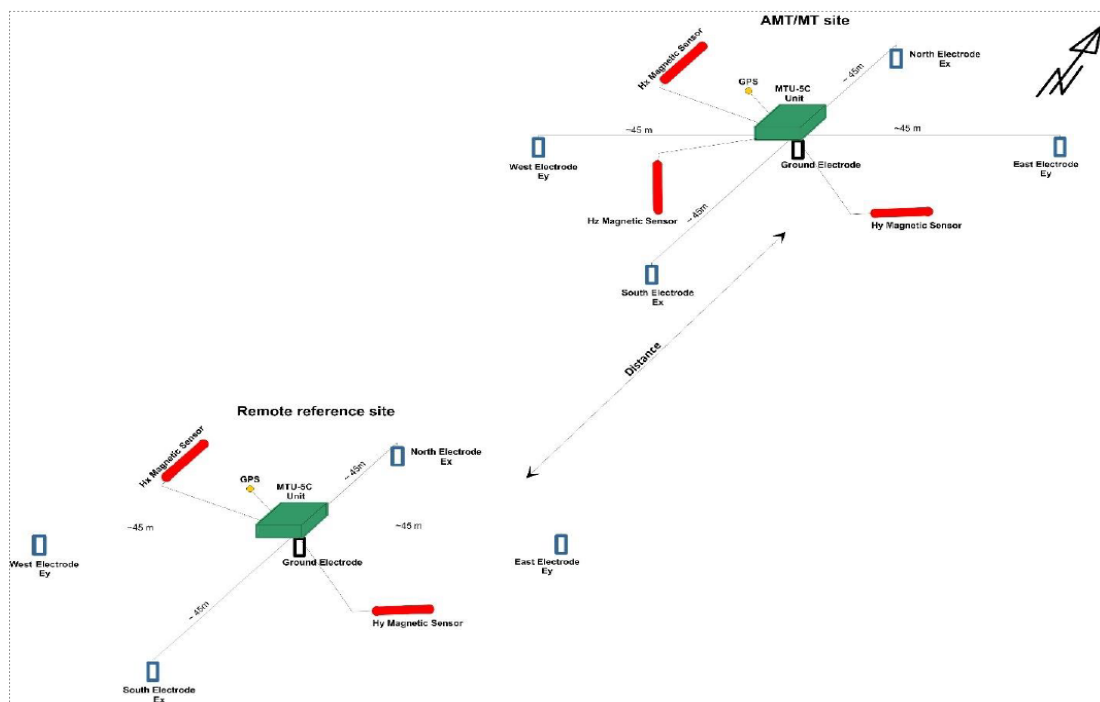
The MT survey involved laying out four 50-metre long plastic coated wires on the ground and burying four small sensors (non-polarizing electrodes) in shallow hand excavated holes. Two tubes (magnetic sensors) are also buried in a shallow trench. These electrodes and sensors are connected to a data receiver, GPS and

small lead-acid battery in a secure metal box. The equipment was then left in place for a minimum 14 hours (overnight). Following the survey the equipment was retrieved and the ground made good, replacing any grass/topsoil removed during the excavation. The equipment used collects the data. No electrical current is pumped into the ground, no electromagnetic fields are emitted, and no noise is created.

All MT receivers and magnetic sensors were calibrated on site prior to the survey completion. The calibration site was positioned on grassland away from electric power lines and other sources of Electromagnetic (EM) noise.

The precise location of each AMT/MT station was determined with the use of a hand-held GPS. A file with projected site locations was uploaded to handheld devices used by the field team. Each 5-channel magnetotelluric sounding array consisted of two perpendicular electric dipoles Ex and Ey, horizontal magnetic sensors: Hx, Hy and one vertical magnetic sensor Hz (Insert. 2.4)

Insert 2.4 – AMT/MT Set up



Lengths of electric dipoles were between 76 and 98 meters each, depending on terrain conditions. Electric dipoles were made of insulated cable and non-polarizing electrodes (Cu/CuSO₄). Electric dipoles (Ex and Ey) and the magnetic sensors (Hx and Hy) had the same azimuth for all measuring stations: $x = 0^\circ$, $y = 90^\circ$.

To eliminate or at least to reduce the effects of artificial electromagnetic noise, measurements were made with the magnetic remote reference point, where the horizontal magnetic component was recorded. The remote reference site was set up ca. 100 km in a straight line away from the survey area and signal to the noise level in a remote location was tested before starting the survey. Each day a remote reference operator

downloaded, reviewed and sent the measured time series to the server for Quality Control (QC) in-field processing.

Insert 2.5 Equipment Deployment example

Magnetic Sensors



MT recorder and sensors/wires



2.5 GRAVITY SURVEY OVERVIEW

A gravity survey was completed across 5 No days between 18/07/23 and 22/07/23. This is a geophysical data acquisition technique with no associated ground disturbance. Gravity surveys provide measurements of variations in the Earth’s gravitational field between different locations. These gravity variations represent changes in the density of the rock types below the measuring point and assist in interpreting changes in rock types at depth across a selected survey area.

Equipment designed to collect information on gravity at a specific location was deployed at 100No. locations across an area of ~20 km², centred around the Greenmount Campus site. On Average 20 gravity stations were deployed per day. For control gravity measurements 9No out of the 100No stations were resurveyed.

The survey locations were identified during the survey planning stage and relevant access permission was obtained prior to the deployment of any equipment. However, some gravity points had to be shifted due to the presence of physical obstructions and the lack of permission to enter local landowner’s property.

Gravity locations were simultaneously surveyed with standard GPS survey equipment. A local base station was established at St Jude’s Parish Church to assist with the calibration of data from other survey locations. The gravimetric method requires tying field measurements to local base points to determine the value of gravity acceleration at each measuring station and minimise the short-term drift related to the movement of the instrument.

Insert 2.6 Typical example of Surveying at Gravity Measurement Location and Gravity meter (SN 40878) during the survey



2.6 WORKS PREPARATION AND PLANNING

Upon appointment, Tetra Tech engaged with DfE/GSNI with respect to the design of the survey works.

The initial layout for the survey lines and survey stations had been developed by GSNI as part of the works specification. This was taken as the initial target design, to be adjusted and firmed up following:

- Input was provided by a specialist geophysical survey contractor Geopartner Geofizyka with regard to the practicalities of surveying and in respect of the requirements for working towards best quality data capture.
- On the ground engagement with CAFRE management, other private landowners and relevant authorities including Roads Service and Belfast International Airport, with respect to obtaining permission for access to land/surveying along public roads.

Land Access

A GIS project was set up for the study area to allow the compilation and review of relevant datasets which could influence the survey network design. This phase of works also included engagement with a range of public utility companies, including Northern Ireland Water (NIW), Northern Ireland Electricity Networks (NIE), Firmus Energy and BT Open Reach to obtain service information.

The data layers incorporated into the GIS project included:

- NIW- Manhole, Sewer & Water mains;
- Firmus Energy - Distribution pipes (low, medium and abandoned) and critical assets;
- NIEN- Cable lines;

- BT- Caution Area, Equipment Ducts, Structures and proposed plant.

The GIS analysis allowed consideration of factors that would influence final survey design. This included the:

- Location of underground services;
- Location of overhead power lines;
- Location of services where they cross the local road network;
- Location of potential structural and nuisance factors which could affect where the vibroseis truck operated (e.g. bridges, proximity to dwellings);
- Road classification and the requirement for traffic management/control.

In advance of mobilisation of the survey contractor (GeoPartner Geofizyka) and following consideration of the various factors, a phase of on-the-ground visits to local landowners/land agents was undertaken jointly by Tetra Tech and GSNI.

An access restricted database was established to record details of all site visits, compile contact details and record any special considerations/requirements for obtaining access to the desired survey locations on private land. For GDPR reasons the database was only held for the duration of the works.

This was an iterative process and required dedicated time on-the-ground visiting properties (sometimes multiple times) to confirm land ownership, seek permission to access lands and check for any limiting factors which may rule out a survey location (e.g. proximity to electrical fencing which would impact the quality of MT data collection, when access was limited due to silage cutting/presence of livestock).

For some parts of the study area, land access agreement could not be obtained. The significance of this depended on the scale of land under the same ownership in a particular area. In some cases, adjacent land under different ownership offered an alternative. In other cases, it resulted in a gap in survey coverage.

Public Roads

Through the design process it was established early on, due to the relatively heavy traffic movement on the local road network, that higher quality seismic data collection would best be achieved through surveying in the evening/overnight, when background traffic noise/vibration disturbance would be least.

This required engagement with Roads Service and Antrim Newtownabbey Borough Council (ANBC). This was mostly managed by an appointed traffic management company to obtain the necessary permits for public road working. This included, on smaller roads around the CAFRE Greenmount site. A small number of temporary road closures/diversions both to allow the operation of the vibroseis truck on the road, where passing by other vehicles is not possible and also for the protection of survey workers engaged in installing

and recovering the roadside seismic receivers. In terms of the timing of future geophysical survey works, consideration should be given for public roads where works have already been booked in by other contractors (e.g. utility works). Where this is the case, a request for road work can be turned down until such works are complete. Where specialist contractors are being employed and travelling from distance it is important that all permissions are secured in advance to ensure works can be undertaken efficiently in the available time.

Local Community Engagement

Prior to the mobilisation of the survey contractor to site, a public awareness campaign was conducted.

This incorporated:

- Notification of works in local press;
- Development of content for the project website, where stakeholders and local people could access more detailed information;
- Production of a non-technical summary of the proposed works and the objectives of the project, along with summary notes on the different survey techniques. These were available to be issued as part of engagement with local landowners and also as information for properties and businesses which were located in proximity to the survey lines. Dwellings close to the seismic survey lines were targeted for information leaflet drops in advance of the seismic road survey, with a mobile contact number and email address made available. To make sure all properties in proximity to the works were contacted Tetra Tech requested a land registry search of the area, with assistance provided by Gravis Planning.

2.7 SURVEY PHASE

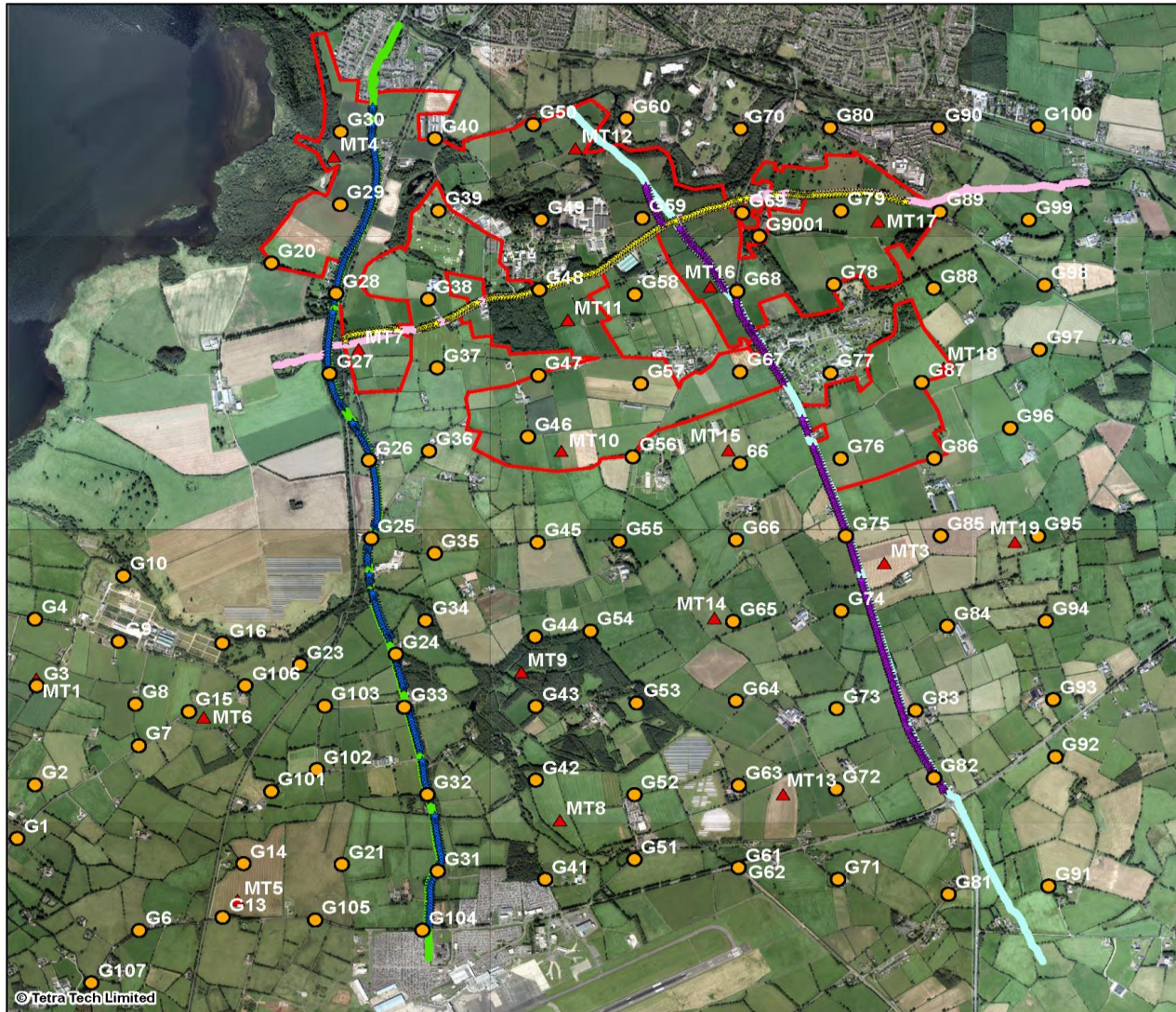
2.7.1 Overview

In advance of the surveys a fieldwork base was established at the CAFRE Greenmount site on 13/07/23 (at IGR 316555, 384876) where equipment, vehicles, site office and welfare facilities were located. Geopartner Geofizyka the specialist survey team partner mobilised to site on 14/7/23 and the vibroseis truck arrived on 15/07/23.

A programme of works was implemented from 16/7/23 to 24/7/23. Initial tasks included the start of installation of seismic receivers along the roadside of the first seismic line to be run (Line 1) and establishment of a remote MT base station in Donegal, which was deployed on 16/07/2023.

A map of the completed geophysical survey is provided in Figure 1

Figure 2.1 Completed Geophysical Survey Map



Geophysical Survey Locations

Site: CAFRE, Greenmount
Client: Department for the Economy



Legend

- ▭ CAFRE Boundary
- ★ Seismic Shot Line 3
- ★ Seismic Shot line 2
- ★ Seismic Shot Line 1
- Receiver Point Line 3
- Receiver Point Line 2
- Receiver Point Line 1
- Gravity Stations
- ▲ MT Stations

Notes:

Drawn by: EMcA
Checked by: PMcC
Office: Belfast

Drawing No.
Revision No. 3

0 70 140 210 Meters
Scale @A3

02 October 2023
NGR: 315743E 383311N

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TETRA TECH
1 Locksley Business Park,
Montgomery Road,
Belfast,
BT6 9UP

2.7.2 Seismic Survey

The seismic survey included data acquisition along three 2D lines with a total length reaching 15,440 m. Line_1 and Line_3 were oriented N-S, while Line_2 was perpendicular to them, with a general W-E direction. The receiving channel was a single Stryde nodal receiver – piezometric accelerometer. As a seismic source a vibroseis HEMI-60 vehicle was used.

As noted elsewhere the data collection phase of the survey was undertaken during the evening/night when less ambient noise/vibration from traffic was occurring. The placement and recovery of receivers occurred in advance and following completion of different survey sections.

Inset 2.7 Stryde Nodal receiver (on left) and vibroseis HEMI-60 (on right)



The new data (2023) was acquired with a shot point spacing of 16 meters and a receiver spacing of 4 meters along all three lines. There were 3 standing sweeps on each source point. Active spread was fixed and consisted of all channels on the given line. The data was processed as crooked lines according to the acquisition geometry, with bin size 4m. Sampling interval was 2ms and record length 4s.

While acquiring seismic data, execution of the vibe QC was performed by an Observer using Source Link software. The Observer verified each shot point position correctness using a GPS receiver mounted on the vibroseis truck. Constant control of vibe parameters (correlation phase, correlation force etc.) was conducted at each shot point.

At the end of the data acquisition on each line, nodal sensors were retrieved from the seismic lines. The data harvesting process was conducted in the Stryde server and nest. Once the data was downloaded, the operator obtained field records with the use of timestamps, which were acquired for each sweep. Finally

shot gathers (correlated and uncorrelated) were produced for each sweep separately. Amplitudes of seismic traces were prepared as a SEG-D file format in acceleration and then transformed into SEG-Y files in velocity.

The data was processed by Geopartner Geofizyka using the ProMAX/SeisSpace suite software. Near surface statics were computed with GeoTomo software.

In addition to the newly acquired data, data from 2011, held by GSNI, was also reprocessed by Geopartner Geofizyka as part of this project.

The datasets processed are summarised in Table 2.1

Table 2.1 Seismic Line Summary

Survey Line Reference	Data Collection Date	Data Processing Date	Length in km	No of channels
Line 1000	2023	2023	4.82	1310
Line 2000	2023	2023	3.55	1052
Line 3000	2023	2023	4.43	1320
INFA-11-01	2011	2023	20.38	320
INFA-11-01	2011	2023	16.58	320
INFA-11-01	2011	2023	28.58	320
INFA-11-01	2011	2023	16.62	320

The historical data (2011) was acquired with a shot point spacing of 25 meters and a receiver spacing of 25 meters. On each shot point 2 sweeps were recorded individually with move up 6.25 meters between them. The data was processed as crooked lines also. Two geometry approaches were used to process legacy data: - First, based on the geometry provided by the Client, where one shot was every 25 meters as the sum of two sweeps. The source coordinates were represented by COG (Central of Gravity) of two sweeps with the move up 6.25 meters. - Second, new geometry for the source points was prepared by Geopartner Geofizyka. The two sweeps with move up were used as a separate shot points (one sweep on shot point). The new geometry

was prepared based on SPS file and the PSS data provided by Client. Finally, the second approach was chosen for reprocessing data.

The data analysis and processed seismic interpretation undertaken by Geopartner Geofizyka is reported in: *Geopartner Geofizyka GeoEnergy NI Processing and Reprocessing Report of Seismic Data, Greenmount 2023, Northern Ireland.*

2.7.3 Gravity Survey

The survey achieved 100 gravity station measurements over five working days. The gravimetric method requires tying field measurements to local base points with the aim of determining the value of gravity acceleration at each measuring station and minimise the short-term drift related to the movement of the instrument. The measurement sequence – A,1,2,3...A (where: A – gravity base, 1,2,3 – gravity field stations) is called a loop. To minimise the time taken for a loop and possible disturbances related to transfer of the gravity instrument from base to the area of works, one local base point was established in St. Jude Parish church in Muckamore adjacent to the survey fieldwork base. This new base station was tied with a gravity base station from previous gravity surveying, at St Patrick’s Church of Ireland, Templepatrick.

Gravity stations were located on a 350x350 m quasi grid on the basis of pre-plotted positions provided by the Client. Some gravity point locations were adjusted depending on physical obstructions or lack of permission to enter land. The locations of the gravity stations completed is shown on the survey map (Fig.2.1). Gravity and GPS measurements in the field were conducted simultaneously.

The main survey equipment used was:

- one (1) automated gravity meters SCINTREX CG-5 Autograv SN: 40878, tripod, manual ruler for gravimeter height determination, inclinometer;
- Leica Viva GS16 GNSS System for geodesy field work.

Data preprocessing of geodesy and gravity data were carried out using firmware instrumental software. To calculate, adjust and transform coordinates to local coordinate system and for map drawing SURFER Golden Software Inc. systems were used. For gravity data computation, i.e. gravity calculation, free air and Bouguer anomaly calculation geophysical software developed at Geopartner was used.

The data analysis and processed gravity interpretation undertaken by Geopartner Geofizyka is reported in: *Geopartner Geofizyka GeoEnergy NI Processing Report of Gravity Data, Greenmount 2023, Northern Ireland.*

2.7.4 Magnetotelluric (MT) Survey

A 5-component magnetotelluric survey was completed with the survey programme delivered in July 2023. The total number of sites achieved was 19 across the study area. A remote reference location was located ~ 100 km NW from the field area in County Donegal.

The equipment used was Phoenix Geophysics receiver MTU-5C. Five survey equipment sets were used. The works started with equipment calibration at the remote reference site and then calibration of the remaining equipment on the survey area. All MT receivers and magnetic sensors were calibrated on site before the survey. The calibration site was placed on a grassland area away from electric power lines and other sources of Electromagnetic (EM) noise. Magnetotelluric stations were measured by 5- component MT tensor – Ex, Ey, Hx, Hy and Hz.

The individual surveys were conducted over a minimum of 14 hours (incorporating overnight) prior to data download and moving to the next location.

Acquisition of data was made in a wide, broadband frequency range (both MT and AMT bands). Fieldwork consisted of recording the time series of the components of the natural electromagnetic field. Acquisition on the field site was performed and synchronised via GPS clock with the remote reference. Recording of the electromagnetic field components was carried out in the frequency range 0.001 – 10 000 Hz. Recording of time series was carried out in two bands: td_24k and td_150 with a sampling frequency respectively: 24000 Hz and 150 Hz. To keep files to reasonable size, the higher frequency band was 1 second every 60 seconds time window. The lower frequency was sampled continuously.

Information on the data collection and processing is reported in: *Geopartner Geofizyka GeoEnergy NI Processing Report of Magnetotelluric Data, Greenmount 2023, Northern Ireland.*

Geopartner Geofizyka concluded, from an assessment of the processed data, that 17 of the 19 sites had achieved high quality data collection, with the two of the sites considered to be affected by anthropogenic influences to such a degree that could not be adequately compensated for through processing techniques.

2.8 DATA ANALYSIS, PROCESSING AND OUTPUTS

Details of fieldwork and data processing completed are reported in:

- *Geopartner Geofizyka GeoEnergy NI Field Report of Seismic, Gravity and Magnetotelluric Survey, Greenmount 2023, Northern Ireland.*
- *Geopartner Geofizyka GeoEnergy NI Processing Report of Gravity Data, Greenmount 2023, Northern Ireland.*

- *Geopartner Geofizyka GeoEnergy NI Processing and Reprocessing Report of Seismic Data, Greenmount 2023, Northern Ireland.*
- *Geopartner Geofizyka GeoEnergy NI Processing Report of Magnetotelluric Data, Greenmount 2023, Northern Ireland.*

Digital datasets of the data collected were transferred to GSNI for archiving on their information management system.

3.0 GREENMOUNT GEOLOGICAL MODEL DEVELOPMENT

3.1 OVERVIEW

Newly acquired datasets (19 MT sites, 100 gravity sites and 3 seismic lines) from the geophysical surveys completed in July 2023 were combined with a range of existing datasets including:

- Historical geophysical surveys undertaken in the general area (133 MT sites completed in 2009, 11740 legacy gravity stations from GSNI and 4 legacy 2D seismic lines);
- Information from the nearest deep boreholes drilled previously (4No wells drilled to depths of between 1371m to 2272m) ;
- Existing geological mapping; and
- Previous research on the geological setting.

This data was held by the Geological Survey of Northern Ireland and was provided for use on the project.

The data was used to produce a 3-D subsurface model of the geological setting below the Greenmount area.

During the data processing and interpretation phase regular meetings were held to update the client team on progress with the key phases of the model development and to obtain feedback on interpretation.

In addition, an expert's workshop was held in Belfast at the Tetra Tech office on 20/02/24. The purpose of the meeting was to allow a wider range of feedback and knowledge of the geological setting and data interpretation to be captured and to inform the model development process. This included members of research institutions, university academics and industry personnel.

Future potential work involves not only expanding the survey coverage but also refining processing and interpretation techniques to build a detailed and accurate model of the wider geothermal resource in the Antrim area.

3.2 WORKS SPECIFICATION

The specification for using the range of existing and new datasets to develop an updated geological model for the study area was to:

- Report and model data in an agreed format.
- The report/s to include details of the interpretation methodology, error estimates, the auxiliary geophysical and geological well log data integrated, and maps and cross-sections demonstrating the results.

- To provide an interpretation of the MT data based on 2D and 3D inversion, integrating the MT data with auxiliary borehole logs picked seismic horizons (depth sections) and newly acquired geological data to constrain the inversion and interpretation. The report is to contain:
 - A summary and details of the processed data.
 - A list and map of survey lines, sites, and station locations.
 - A summary of logistics, operations, equipment, instrumentation, procedures, and personnel.
 - All final processed results plotted in a format agreed by Contractor and GSNI.
 - Details of the 1D, 2D and 3D modeling methodology, error estimates and the modeled resistivity on a representative selection of horizontal and vertical slices through the model.
 - Digital copies of all interpretation products

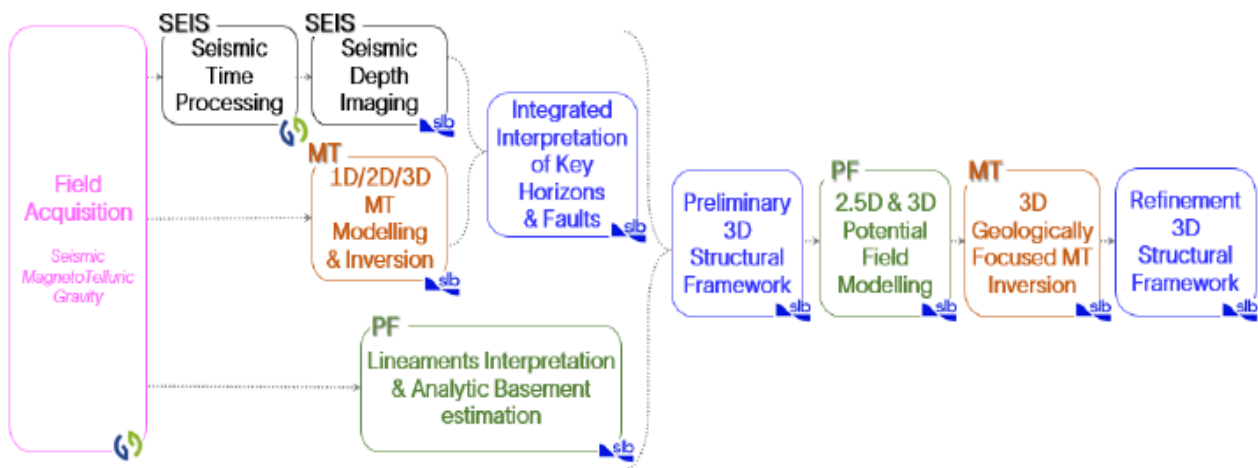
3.3 DATA ANALYSIS, PROCESSING AND OUTPUTS

Project team member SLB undertook the interpretation and integration of datasets ahead of developing a 3-D conceptual geological model for the assessment area.

SLB developed a fully integrated workflow to create and geophysically validate a 3D volumetric structural model of the subsurface geology at the site. All geological models are interpretations, they are non-unique solutions, and while many models may be a valid interpretation of any one single dataset, the integration of multiple datasets reduces the range of possible interpretations, to produce a more robust final solution.

The SLB approach aimed to maximise the value of each single acquired dataset in an integrated manner and the full report explains how the analysis, modelling and interpretation of gravity, MT, and seismic data led to the construction of the resultant structural models. The integration of lineament mapping, 3D MT inversion, and Simultaneous Joint Inversion (SJI), along with knowledge input from GSNI and other geologists familiar with the area and 2.5D gravity forward modelling, significantly helped in the consolidation of the structural model, the overall reduction of the subsurface uncertainty and mapping of key geological features (Figure 3.1).

Figure 3.1: SLB Multiphysics Workflow



The full integrated interpretation process was highly iterative, interrogation of one dataset providing constraints on interpretation of others, allowing the generation of a more robust final geological model and improving confidence in a potential drilling location for future geothermal wells. However, it is important to acknowledge that even the final model is not a unique solution. The workflow was complex because the geological setting is challenging to unravel, and while the integrated workflow does provide a more robust model, the seismic imaging remains sub-optimal and alternative interpretations remain possible. The opportunity exists to improve further the interpretation of the geological setting of the study area through additional data acquisition.

Example outputs included in the SLB 2025 report are shown in Figure 3.2.

Figure 3.2 Example Outputs from SLB 2025 report.

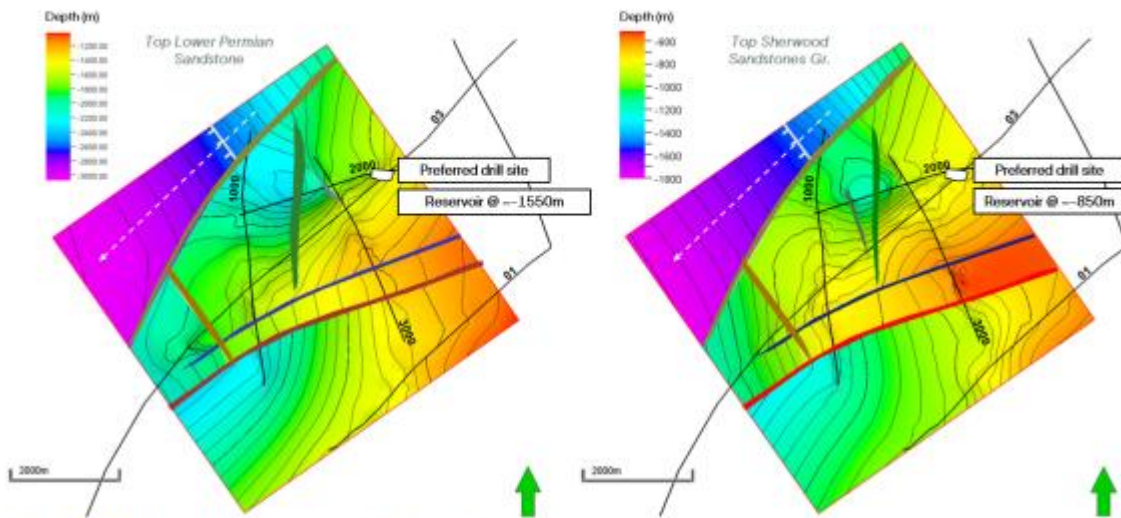


Figure 4.171 Final structural maps for the top Sherwood and Enler sandstones
Final structural maps showing the expected depths for the top of Sherwood Sandstone Group (right) and Enler Group sandstones (left). The location of the preferred drill site is highlighted for reference.

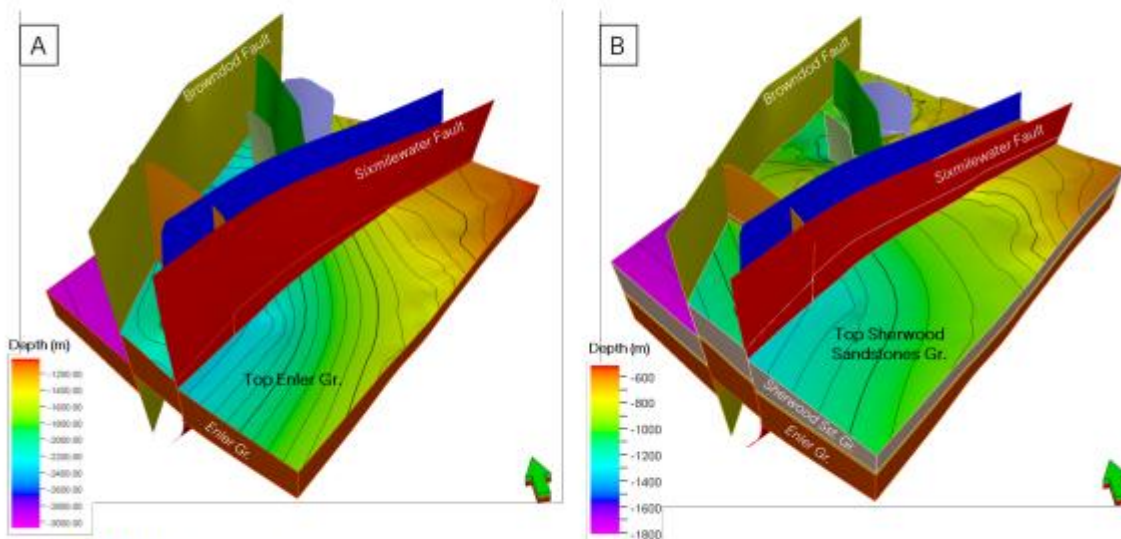


Figure 4.172 Final 3D model
Final 3D structural model view clipped to the Top Enler Group (A) and the Top Sherwood Sandstones Group (B) showing the main faults interpreted in the area of interest.

For this phase of the works the following reports have been produced which provide an overview and the detail of the assessment and interpretation of datasets through the model development process:

- Tetra Tech 2025. GeoEnergy NI Greenmount Multiphysics Non Technical Summary;
- SLB 2025. *Multiphysics study for Geothermal Demonstrator Project* Contract number: 861675.

All digital datasets produced were transferred to GSNi for archiving on their information management system.

3.4 SUPPORTING REPORTS

Supplementary to the above works, DfE commissioned additional studies to inform the assessment of the deep geothermal resource potential at Greenmount and how this might be investigated further through drilling of deep wells. These additional studies comprised:

- Causeway Energies, 2024. *Antrim Deep Geothermal, Heat Potential from a deep geothermal installation*. Report for Northern Ireland Department for the Economy Document Number: CWY-2412-NIR-DFE-REP-0-240426.
- SI Ltd. 2024. *Estimates of Heat Potential from a Deep Geothermal Installation, Northern Ireland*. Report for: Northern Ireland Department for the Economy.
- Tetra Tech, 2024 *Preliminary Well Design and Costings for Greenmount Deep Boreholes*. Report for: Northern Ireland Department for the Economy.
- Tetra Tech, 2025 *Greenmount Geothermal Feasibility Report*. Report for: Northern Ireland Department for the Economy.

3.5 LESSONS LEARNED

From the works completed the following considerations are relevant to the undertaking of similar type studies related to wider area geophysical surveying and data assessment:

- Pre-planning and preparation for engagement with landowners is essential to maximise the benefit of follow-on face to face meeting with landowners and other local stakeholders.
- Sufficient time should be allowed for landowner engagement and typically multiple visits and/or visits at suitable times outside of normal working hours will be required for some land-holdings to secure time with the appropriate person.
- Development of non-technical summary descriptions of the work proposed assists significantly with engagement.
- Ongoing engagement with landowners throughout the study assists with anticipating and management of last-minute changes to access arrangements, which minimises the loss of time to the contracted specialist surveyors whilst on-site.
- For working on public access areas including road networks, early engagement with relevant bodies is important to understand the requirements for gaining permission for the works. Use of companies with expertise in dealing with such activities on a regular basis (i.e. Traffic Management Companies) is of value.

- For surveys which require local, non-technical staff support (for example to deploy seismic receivers), a sufficiently flexible team of persons should be assembled to adapt to varying daily workloads, including overnight working.
- Seismic surveying along preferred straight lines (for best data analysis) is typically not possible in most settings and the implications of this should be considered in survey design.
- Even in semi-rural areas background disturbance from local traffic and other ambient noise can have an influence on data quality and this can require overnight works to minimise potential influence.
- Interpretation of collected, processed data is an iterative process. The interpretation of data will also be influenced by the range of experience of the specialists undertaking the work and typically there is not 'single solution' for deep geology interpretation. Benefits are gained by having sufficient allowance for multiple review stages in the interpretation work programme where key elements of model development can be considered in detail by the client team, in a collaborative approach with the contractor. This does have implications for timeframes and for costs that should be allowed for by both client and contractor.

4.0 GREENMOUNT PLANNING PROCESS

4.1 OVERVIEW

Following initial assessment of the new survey data and progression in the development of the 3-D geological model and based upon previous assessment of the deep geothermal potential in the general Antrim area, the decision was made to progress with submission of a planning application for the drilling and testing of two deep geothermal wells within the CAFRE Greenmount land ownership boundary.

This process was managed through the project team member Gravis Planning in conjunction with the client, with technical support provided by Tetra Tech.

Contact was made with Antrim and Newtownabbey Borough Council (ANBC) to inform them of the intention to submit an application and to provide the opportunity for any initial feedback.

A scoping report ([hyperlink](#)) was prepared and submitted to ANBC in August 2024, to seek feedback on the development proposals and proposed nature and scope of impact assessments that should be included in the Environmental Statement.

Based upon the nature of the development it was concluded that the application fell within Category 2D of Schedule 2 of the Planning EIA Regulations (NI) 2017, specifically:

Schedule 2 (2d) Deep drillings, in particular—

(i) geothermal drilling;

meeting threshold (ii) in relation to geothermal drilling and drilling for the storage of nuclear waste material only, drilling is to be undertaken within 100 metres of any waterway or water in underground strata.

The application would therefore be required to be supported by an Environmental Statement.

Following submission of the scoping report a Pre-Application Community Consultation (PACC) event was organised for the 22/11/24. This was held at Antrim Forum.

Subsequently, a Pre application Development (PAD) meeting with ANBC planning officers and invited consultees was held at ANBC Mossley Mills offices on 10/1/25. Due to the relatively novel nature of the application (first deep geothermal well application in Northern Ireland) this was taken as an opportunity to explain directly to the various parties/stakeholders who attended, the concept and design of the proposed development, and provide further information on the scope of impact assessments to be undertaken and to be informed by any initial feedback from planning officers and consultees on what information and risk assessment they will be expecting to accompany the planning application.

4.2 SITE SELECTION

Selection of the potential drill site within the CAFRE Greenmount land ownership area was informed by a range of considerations including:

- The analysis of the deep geology setting below the study area;
- Existing land use constraints identified by CAFRE management and potential future land use strategies;
- Potential environmental and ecological constraints including presence of sensitive features, proximity to watercourses etc.:
- Consideration of historical landuse and archaeological setting;
- Presence of underground and overground services;
- Access for the range and scale of equipment needed for the works.

Following initial mapping using GIS of constraints and the application of buffer zones around sensitive features where relevant, buffer zones were set. These buffer zones were informed by knowledge of likely set-back requirements that would be requested by regulatory bodies. Based on a review of land parcels containing the least or no constraints a land area suitable for potential development was identified and agreed with CAFRE management (Figure 4.1). Subsequent to this, an area was defined for submission as the planning application boundary area. This is shown by the red line in Figure 4.2.

Figure 4.1 Constraints Mapping

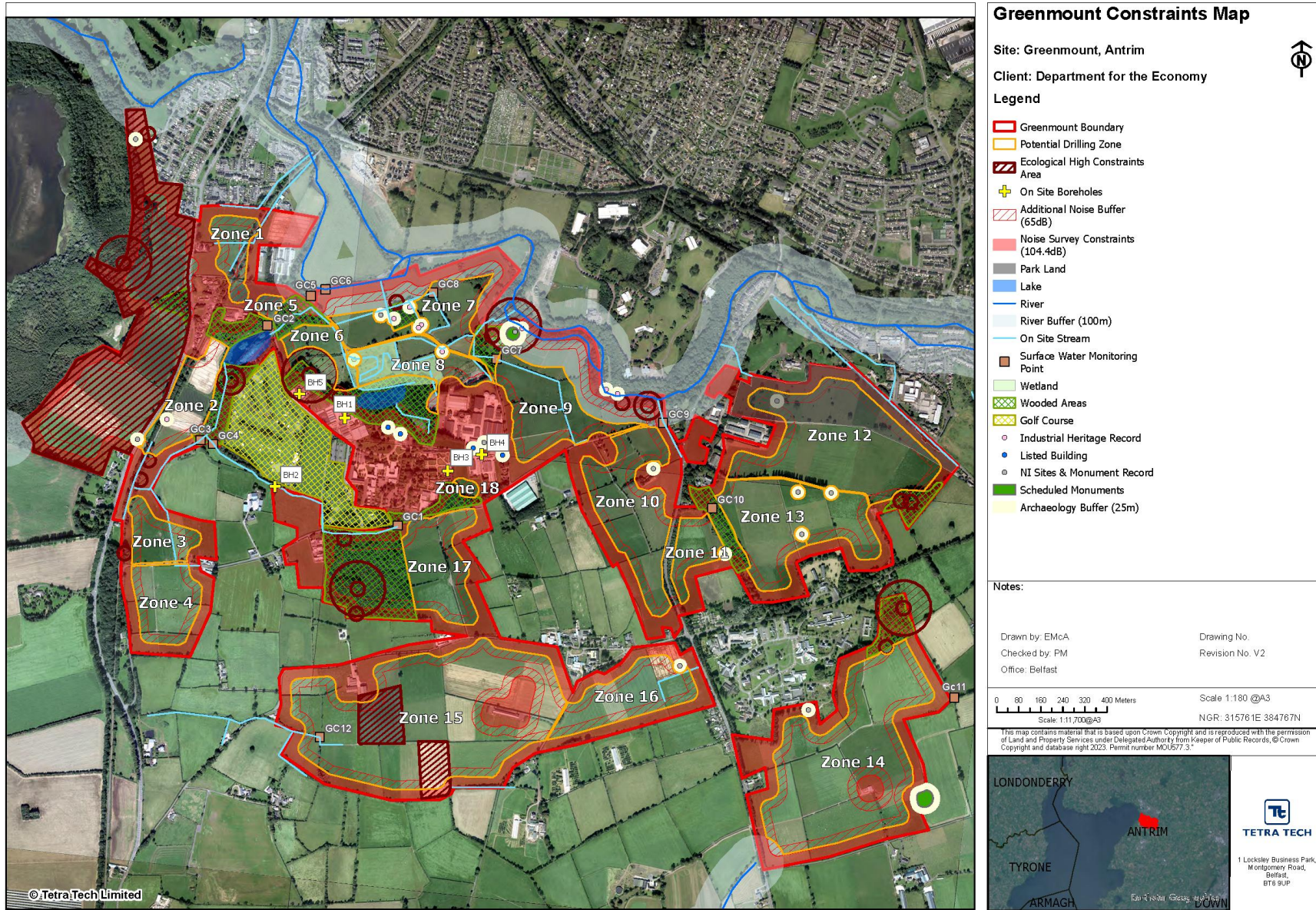
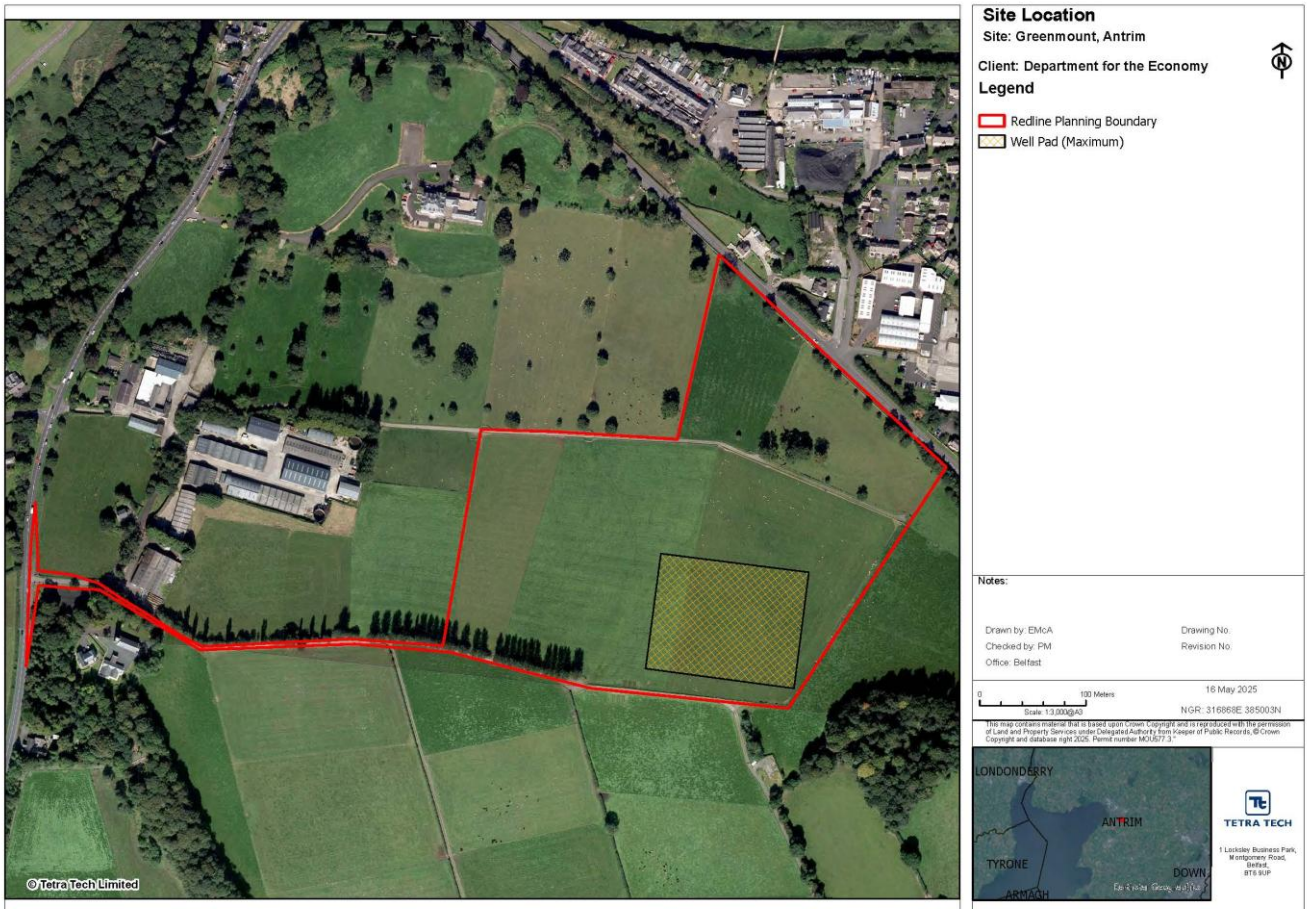


Figure 4.2 Planning Boundary Area



Following site walkover and taking into account land access routes and other factors, a sub-area in the southern part of the planning application area was identified as optimal for locating the drilling compound and soils storage area. The remaining area within the planning application area is retained to accommodate water management at and around the well compound and as a potential alternative access route.

4.3 PLANNING SUBMISSION

Subsequent to the scoping report and discussions with the planning authority a full planning application with supporting Environmental Statement was prepared and provided to DfE.

This included the following supporting assessments and documents:

- Non Technical Summary
- Chapter 1 Introduction
- Chapter 2 EIA approach and Methodology
- Chapter 3 Description of the Proposed Development
- Chapter 4 Scheme Development and Alternatives Considered

- Chapter 5 Soils and Geology
- Chapter 6 Ecology
- Chapter 7 Noise and Vibration
- Chapter 8 Landscape and Visual Impact Assessment
- Chapter 9 Archaeology and Cultural Heritage
- Chapter 10 Water Environment
- Chapter 11 Human Health
- Chapter 12 Lighting

Supporting Reports

- Transport Statement
- Soils Geology, Hydrology & Hydrogeology Baseline Report
- Greenmount Flood Risk & Drainage Assessment
- Greenmount Outline Construction Environmental Management Plan
- Greenmount Air Quality Assessment
- Ground Investigation Report
- Multiphysics Non Technical Summary
- Contaminated Land Risk Assessment PRA-GQRA
- Greenmount Drilling Platform Technical Note
- Background Seismicity Report
- Waste Management Report
- Preliminary Ecological Appraisal (PEA)
- Geophysical Survey Habitats Regulation Assessment Stage 1 June 2023
- Geophysical Survey Habitats Regulations Assessment Stage 1 Screening for Likely Significant Effect and Stage 2 Appropriate Assessment.
- Site Walkover & Landscape and Visual Assessment
- Greenmount Archaeological Constraints Assessment
- Archaeological Monitoring Report, gahananadlong, March 2025
- Arboricultural Impact Assessment & Method Statement (John Morris Arboricultural Consultancy, February 2025)

5.0 DRILL CUTTINGS ANALYSIS

As part of the overall project specification there was a work element to undertake photographic digitisation and inorganic geochemistry analysis of geological cuttings held by the GSNI. The cuttings were from two deep exploration wells previously drilled in the wider area around Antrim at:

- Ballymacilroy – 673 samples
- Ballynamullan-1 – 124 samples

The objective was to produce a unified and consistent dataset of lithological properties of available cuttings samples in the two nearby deep boreholes and to integrate the newly gathered dataset with existing well data held by GSNI. This information is considered valuable in the context of developing an understanding of the geological properties of the Permo-Triassic bedrock (the potential geothermal resource) below the Antrim area and the nature of the overlying strata.

This work was undertaken by a specialist contractor (RockWash Geodata) based in Wales.

The contractor undertook the following works:

- Digital Photography of samples

Inset 5.1 Example of sample photographic digitisation

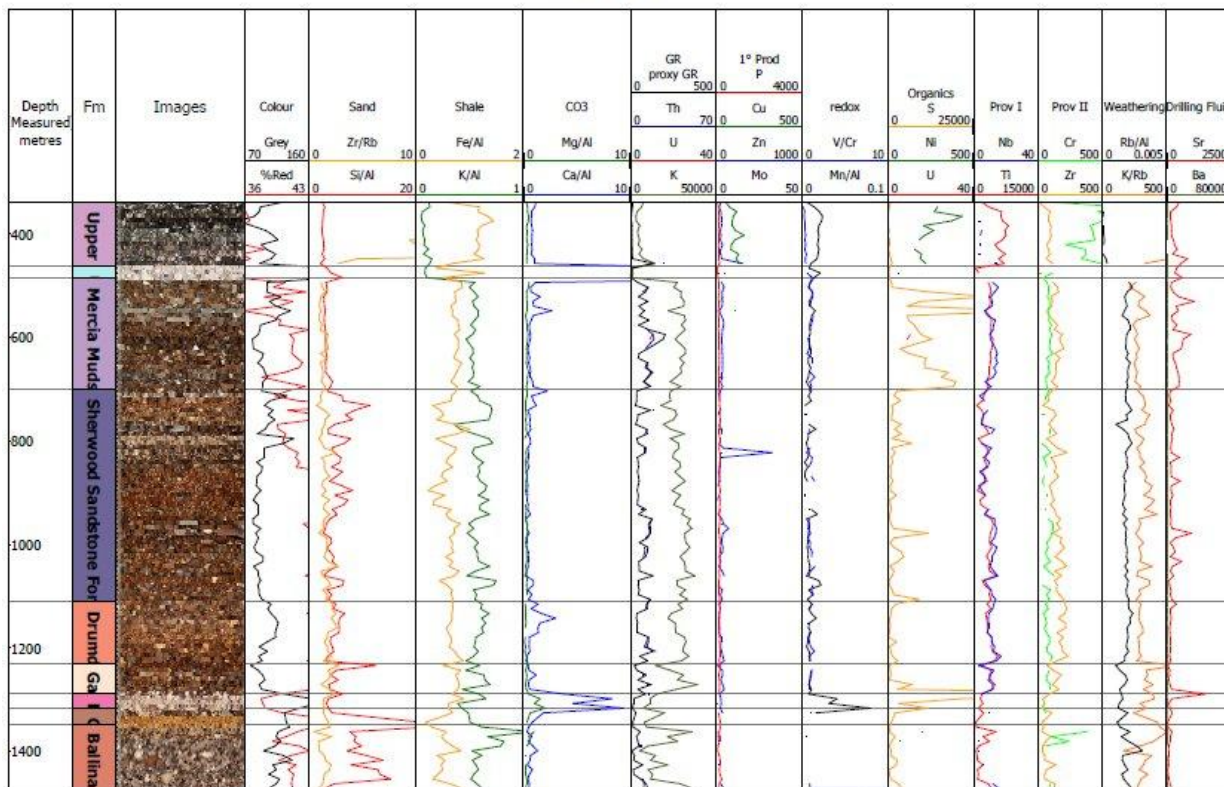


XRF analysis of sub-samples with analysis for:

- Sb
- Sn
- Cd
- Pd
- Ag
- Mo
- Nb
- Th
- Zr
- Sr
- U
- Rb
- As
- Se
- Au
- Pb
- W
- Zn
- Cu
- Ni
- Co
- Fe
- Mn
- Cr
- V
- Ti
- Ba
- Ca
- K
- Al
- P
- Si
- Cl
- S
- Mg
- Balance
- MgO
- Al₂O₃
- SiO₂
- K₂O
- CaO
- TiO₂
- Fe₂O₃
- Si/Al
- K/Al
- Ca/Al
- Fe/Al
- V/Cr
- V/Ni
- Cu/Ti
- K/Ti
- Mn/Al
- Rb/Sr
- Zr/Cr
- Zr/Rb
- TiO₂/Nb
- Cr/Nb
- Rb/Al
- K/Rb
- Mg/Al
- Red
- Green
- Blue
- %Red
- Brightness
- Grey
- Correlation of selected data with existing borehole log datasets.

Inset 5.2 PhotoSTRAT Summary

**Ballynamullan-1
1:7000**



The outputs from this work comprised:

- Ballynamullan_1 Photolog of samples
- Ballynamullan_1 Inorganic Analysis results.csv
- Ballynamullan_1 Compiled Borehole Log
- Ballymacilroy_1 Photolog of samples
- Ballymacilroy_1 Inorganic Analysis results.csv
- Ballymacilroy_1 Compiled Borehole Log

6.0 STORMONT WORKS (PLANNING AND IMPLEMENTATION) AND OUTPUTS LIST

6.1 OVERVIEW

A programme of geological, hydrogeological and geothermal investigation was specified for the Stormont Estate, Belfast.

The proposed works were located at Stormont Estate, Upper Newtownards Road, Belfast, BT4 3SH and the site is centred at Irish National Grid Reference J 40016 74509. The proposed development is located within the Belfast City Council jurisdiction. The overall site is comprised of Northern Ireland’s parliament building, government offices, and associated access and car-parking. It is surrounded by woodlands, gardens, parkland and walking trails. The site location is shown on Figure 6.1.

Figure 6.1 Site Location



This site was identified by DfE as a suitable candidate site for investigation taking into account the available information on geological setting, ability to facilitate access for works and with a range of different office buildings where a future full geothermal scheme could be implemented, as part of the overall demonstration of geothermal technology.

6.2 INVESTIGATION WORKS PLANNED

The specified works plan for Stormont comprised:

- Drilling of 4 No boreholes (EB1 – EB3, EB5) each to a depth of up to 250m;
- Drilling of 1 No cored borehole to the base of the Permian bedrock or up to a maximum depth of 500m (STRAT);
- Geophysical Logging of all boreholes;
- Potential packer testing of selected boreholes;
- Installation of closed loop pipework in one of the 250m deep boreholes and testing for thermal properties;
- Yield testing of several of the 250m deep boreholes.

The objectives of the investigation design were to:

- Assess the geological conditions across the site through intrusive borehole drilling, coring of rock and geophysical logging;
- Investigate the hydrogeological setting at the site through geophysical logging and water yield testing of selected boreholes and collection of water quality samples;
- Install closed loop pipework in one borehole and undertake a thermal response test to obtain site specific geological thermal properties to inform.

The data gathered would inform assessment of the options for implementing shallow geothermal at the site with the main options being:

- Open loop geothermal where groundwater is abstracted from boreholes, a portion of thermal energy transferred to a building heat pump for subsequent use for building heating. Such a system would also require re-injection of the abstracted groundwater back below ground into the same aquifer system using other ‘recharge’ boreholes.
- Closed loop geothermal where a multi-borehole scheme is implemented and heat extracted from the ground using closed loops in the boreholes, connected to a surface manifold system and transferred to a building heat pump.

6.3 REGULATORY REQUIREMENTS AND PLANNING

6.3.1 Planning Permission

In preparation for the works, consultation was undertaken with Belfast City Council (BCC) regarding the nature and scale of the works.

Following internal assessment of the proposal BCC indicated that a planning application for works would need to be made.

A Pre-Application Notice (Pre Application Notice), supported with a PAN Technical Briefing note was submitted on 21/03/2023 to BCC for a full planning application request. BCC subsequently confirmed that the PAN complied with Section 27 of the Planning Act (NI) 2011 subject to additional notification/consultation with the following :

- Neighbourhood Renewal Coordinator
- Tullycarnet Neighbourhood Collective
- Ardcam Residents Association
- East Side learning

BCC also recommended submitting a Pre Application Discussions (PAD) in line with the Council Published Operating Principles.

In May 2023, Tetra Tech sought a formal screening opinion from BCC under part 2, regulation 8 of the Planning (Environmental Impact Assessment (Northern Ireland) Regulations 2017 (“The EIA Regulations”) on the proposed project.

An EIA Determination Opinion report ([hyperlink](#)) was submitted to BCC by Gravis planning on 03/05/2023 to inform the screening opinion. This included the following information:

- A plan sufficient to identify the land;
- A brief description of the nature and purpose of the development and of its possible effects on the environment; and
- Such other information or representations as the person making the request may wish to make.

In order to fulfil the requirements of the EIA Regulations 2017, an EIA Screening request must cover all receptors which are likely to be impacted. The submission included consideration of potential environmental and ecological receptors and set out the potential effects and levels of significance.

Following feedback from BCC and statutory consultees a planning application was submitted and recorded as received by the council on 18/8/23.

LA04/2023/3856/F Short duration geothermal ground source heating demonstration project, comprising the shallow drilling, testing and completion of 5 no. exploratory boreholes, associated temporary access, compound areas and mobile public information kiosk. Lands at Stormont Estate, Upper Newtownards Road, Belfast BT14, 3SB

The planning application was supported with the following technical risk assessment and other reports:

- Preliminary Risk Assessment (PRA) and Desktop Study
- Generic Quantitative Risk Assessment (GQRA)
- Geology and Hydrogeology Report
- Noise and Vibration Constraints Assessment
- Archaeological and Heritage Rapid Assessment
- Preliminary Ecological Assessment Report
- Ecological Assessment Report
- Badger Survey Report
- Bat Survey Report
- Arboricultural Impact Assessment & Method Statements report
- Test Water Discharge Technical Note
- Construction Environmental Management Plan (CEMP)

A letter drop was sent on 19/05/2023 to local residents which invited the public to attend a Pre-Application Consultation Event (PACC) held at the Stormont Pavilion on 30/05/2023. The purpose of the event was for the public to provide feedback and questions about the proposal. The letter also sign-posted the public to the Gravis Planning website, the project email address (geoenergyni@gravisplanning.com), telephone service and an address for a letter submission where feedback could be submitted.

A PACC was held on 30/05/2023 at the Stormont Pavillion. In addition to the PACC

A response was received from BCC on 29/4/24 indicating:

As the development is within Category 02(d) – Extractive Industry of Schedule 2 of the Planning (Environmental Impact Assessment) Regulations (NI) 2017 the Councils is obliged under Regulation 12(1) of these Regulations to make a determination as to whether the application is for EIA development.

The Council has determined as such that the planning application does not require to be accompanied by an Environmental Statement.

Following assessment Planning Permission was issued by BCC on 30/4/24.

Two of the planning conditions applied to the permission (Condition 6 and Condition 10) required additional submissions to be made to allow the conditions to be discharged before any works at the site could begin. These related to further demonstrating that risks to groundwaters and surface waters from on-site contamination had been effectively assessed and provision of a Detailed Method Statement for vibration monitoring at Dundonald House.

These conditions were successfully discharged through submission of the following reports to the council:

- Tetra Tech 2024. Letter Report dated 30/4/24, with updated Risk Assessment
- Tetra Tech 2024. DfE Geothermal Demonstrator Dundonald House – Vibration Method Statement

and works were able to begin on-site in May 2025.

6.3.2 Other Permissions

6.3.2.1 Borehole Drilling

Under Section 4 of the Minerals (Miscellaneous Provisions) Act (Northern Ireland) 1959 [1959 c. 17] as amended by paragraph 5 of Schedule 3 to the Mineral Development Act (Northern Ireland) [1969 c.35 (NI)] there is a requirement to notify the Department for Economy (GSNI) of the intention *to sink a shaft, borehole or well or make an excavation intended to reach a depth of more than fifty feet below the surface or to extend any existing shaft, borehole, well or excavation (whether or not it has already reached that depth) to reach any greater depth beyond fifty feet*, at least two weeks in advance (unless a shorter notice period is agreed).

GSNI were formally notified in advance of the works, on 5/4/24.

6.3.2.2 Water Management – Abstraction for testing

DAERA were consulted with respect to the requirement for regulatory authorisation for the short duration yield testing of the boreholes by pumping of water. It was confirmed that a water abstraction licence would be required.

An application for a licence to abstract water under The Water Abstraction & Impoundment (Licensing) Regulations (Northern Ireland) 2006 was made on 2/11/23. An associated application fee was paid. A supporting technical note was provided with the application. This included further information on the drilling process and also a water features survey of the surrounding area to identify any water receptors which could potentially be affected by the proposed works, primarily in the context of temporary influence on local groundwater levels from the borehole yield testing.

Following receipt of the application DAERA sought additional details on the testing proposed and potential for impact on surrounding nearby receptors. An updated technical note was submitted to include further information and assessment of degree of potential impact and the monitoring and mitigation to be implemented. Taking into account the hydrogeological setting, the distance from nearby water receptors and the relatively limited duration of borehole testing proposed (up to 1 MLD volume, not exceeding 10 days at any borehole) the potential for influence was considered low. One exception to this was the borehole at the NISCCA Pavilion, within the Stormont Estate. This is a licensed water abstraction, with water pumped to storage tanks and subsequently used for intermittent watering of adjacent hockey pitches. As such monitoring of this borehole was proposed for any testing period with the option to reduce or curtail testing if an adverse impact on water use was considered to be occurring by the borehole user.

An abstraction licence (AIL/2024/0005) was issued for the yield testing on 14/8/24.

6.3.3 Water Management – Discharge

Several phases of the investigation works required consideration of managing of water/liquids discharge.

Borehole Drilling

As the drill sites for the investigation boreholes were in/adjacent to hard-standing areas, minimising the requirement to manage drill flush water (with high sediment loading) was an important factor in selecting the drilling method.

The main method of drilling at the site was selected to be mud rotary drilling. This ‘closed circuit’ method was selected to reduce the requirement to dispose of water encountered during drilling. The more typical method for drilling hard rocks and superficial cover in Northern Ireland is down the hole hammer with air flush. This is an efficient method of drilling where management of water flushed up from the borehole during drilling can be achieved at the drill site through natural settlement and soakage to surrounding ground.

With mud drilling the flush water can be recirculated up from and back down the borehole via a series of tanks/screens/shakers. At the end of drilling the residual flush water in the tanks was tankered off-site using a licensed waste contractor.

For water wells, once the borehole has been drilled to final depth, there is typically a period of development of the borehole which is designed to flush out remaining cuttings and muds until the water clears up (low suspended solids), after which yield testing can be undertaken. For this aspect of water management the drilling methodology agreed with DAERA included the requirement to capture the first flush borehole volume, which would contain the majority of residual drill mud, and for this to be tankered off-site. For boreholes EB1, EB3, EB5 and STRAT, any flush water after this could be pumped to nearby vegetated ground for settlement and natural soakaway. The areas for soakaway were selected following assessment and confirmation that there were no direct drainage routes (drains, ditches) to waterways or open water bodies and that there were no sensitive ecological features. At EB2 drill location there were no suitable nearby vegetated areas and all flush water would have to be tankered away. No discharge consent was required by DAERA for this temporary discharge of flush water to ground surface.

Borehole Yield Testing

Yield testing of the boreholes was planned to be up to 1MLD for up to 10 days at up to two of the borehole locations. There was the requirement to be able to discharge the clean groundwater during the testing to a suitable location. Given the potential volumes involved tankering of water off-site would be financially prohibitive.

DAERA were consulted and confirmed that no consent to discharge, Under the Water (Northern Ireland) Order 1999, would be required for the temporary discharge of clean groundwater from the boreholes during testing.

Two options for discharging the water were explored. One was to be able to discharge to the NI Water combined network. A Wastewater Impact Assessment application was made but due to insufficient capacity in the network was refused, even for the intended short duration of the discharge.

A Schedule 6 application was made to the Department for Infrastructure (DfI Rivers) in October 2023 for temporary discharge of the water to the on-site surface water drainage network which drains eventually to the nearby Knock River. A technical note was submitted to support the application. Permission (Ref:IN1-23-13279) for this was subsequently attained on 11/12/23. The permission required that the works (discharge) were such that it did not cause any physical impact on the watercourse and that monitoring of weather conditions during any phases of discharge take place such that the discharge could be stopped should there be any indication that it could influence risks from flooding.

6.4 INVESTIGATION WORKS

Following granting of planning permission of the works and discharge/implementation of planning conditions, active drilling investigation works got underway at the Stormont site in May 2024.

In advance of mobilisation of the drilling company assigned for drilling the deepest STRAT borehole (up to 500m) site enabling works were undertaken including:

- 6.1 Ground Penetrating Radar (GPR) surveys at all proposed drill locations to identify and map subsurface services. This is a non-invasive survey which assists with removing the risk of service strikes and interacting with any other underground structures.
- 6.2 Establishing a main site compound at EB2 and a drilling compound at the STRAT borehole location
- 6.3 Installation of below ground concrete chambers at STRAT, EB1 and EB2 borehole locations to facilitate drilling
 - Ecological bird nesting checks at STRAT borehole location in advance of drilling
 - Establishment of vibration monitor and noise monitor at Dundonald House adjacent to STRAT drill compound.

After drilling of STRAT borehole similar site enabling works were undertaken as required in advance of drilling at the other drill sites including:

- Established of fenced off drilling compounds at EB1, EB3 and EB5;
- Installation of a below ground concrete chamber at EB3 and EB5 borehole locations to facilitate drilling
- Ecological bird nesting checks at each borehole location in advance of drilling
- Establishment of vibration monitor Dundonald House in proximity to EB1 and EB2 drilling compounds.
- At EB5, permission was obtained from NIEA to allow closure of a disused outlier badger sett entrance in proximity to the drill site. This entailed a period of monitoring prior to closure to confirm no activity and ongoing checking for activity during the works.

A summary of the drilling and investigation works completed is provided in Tables 6.1 and 6.2.

Table 6.1 Summary of borehole details.

I.D.	Easting	Northing	Depth	Achieved Objective
STRAT	340455	374094	303m	Stratigraphic Sequence established, core recovery, geophysical logging of borehole
EB1	340436	374092	148m	Geological conditions verified. Single U closed loop install (failed)
EB2	340505	374262	110.4m	Geological and Hydrogeological Conditions established.
EB3	340127	374480	46m	Geological and Hydrogeological Conditions established, borehole geophysical logging completed, hydrogeological testing.
EB5	340448	374378	118m	Single U closed loop installed, Thermal Response Test completed.

Table below summarises the encountered geology at each investigation borehole. A description of the encountered geology at the Stormont site is as follows:

- Superficial Glacial Deposits: Silt and Sands dominated with gravel and cobbles/boulders in places
- Sherwood Sandstone: Reddish brown silty SAND, weathered.
- Permian Bedrock: Mudstone, Sandstone, Breccia
- Greywacke: Grey, brittle, indurated Sandstone
- Intrusive dykes/sills: Speckled white and grey DOLERITE, minor calcite.

Table 6.2 Summary of Geology Encountered at Investigation Locations

Borehole	Encountered Geology depths (mbgl)				Igneous Intrusions mbgl	Sherwood sst thickness (m)
	Superficials	Sherwood Sandstone	Permian	Greywacke		
STRAT	0 - 34.5	34.5 - 58.2	58.2 - 288.9	288.9 - 302.6	148.15-149.12 163.5-169.63	23.7
EB1	0 - 34.5	34.5 - 58.2	58.2 - 148	-	None	23.7
EB2	0 - 28	28 - 36.6	36.6 - 110.4	-	None	8.6
EB3	0 - 12.9	12.9 - 16.8	16.8 - 46	-	16.8 - 38.6 40.3-42.2 (in mudstone)	3.9
EB5	0 - 28	-	33 - 118	-	28-33	

After the drilling and logging of the boreholes, yield testing and water quality sampling and analysis was undertaken at borehole EB3.

At Borehole EB5, following installation of the single 40mm U ground loop, thermal response testing was undertaken to obtain site specific information on ground thermal properties.

Further specific detail on works can be found in the following reports:

- *Tetra Tech 2025 Stormont Borehole Drilling and Geophysical Logging*
- *Tetra Tech 2025 Stormont Hydrogeological Testing Report*
- *Tetra Tech 2025 Stormont EB5 Thermal Response Testing Report*

6.5 STORMONT GEOLOGICAL MODEL

Prior to investigation works beginning a geological model was developed based upon existing datasets and existing understanding of the local geological setting.

Version 2022.10 of Earth Volumetric Studio (EVS) software was selected for interpreting and depicting the regional geologic interpretation in 3D. Cross sections from the Geological Survey of the Stormont Estate Geothermal Demonstrator AOI (GSSEGDA) (Cooper et. al¹.) were imported into the model domain and displayed in 3D. Regional geology maps of the superficial deposits and bedrock geology were imported into EVS and overlain on the surface created based on elevations from Digital Elevation Maps (DEM).

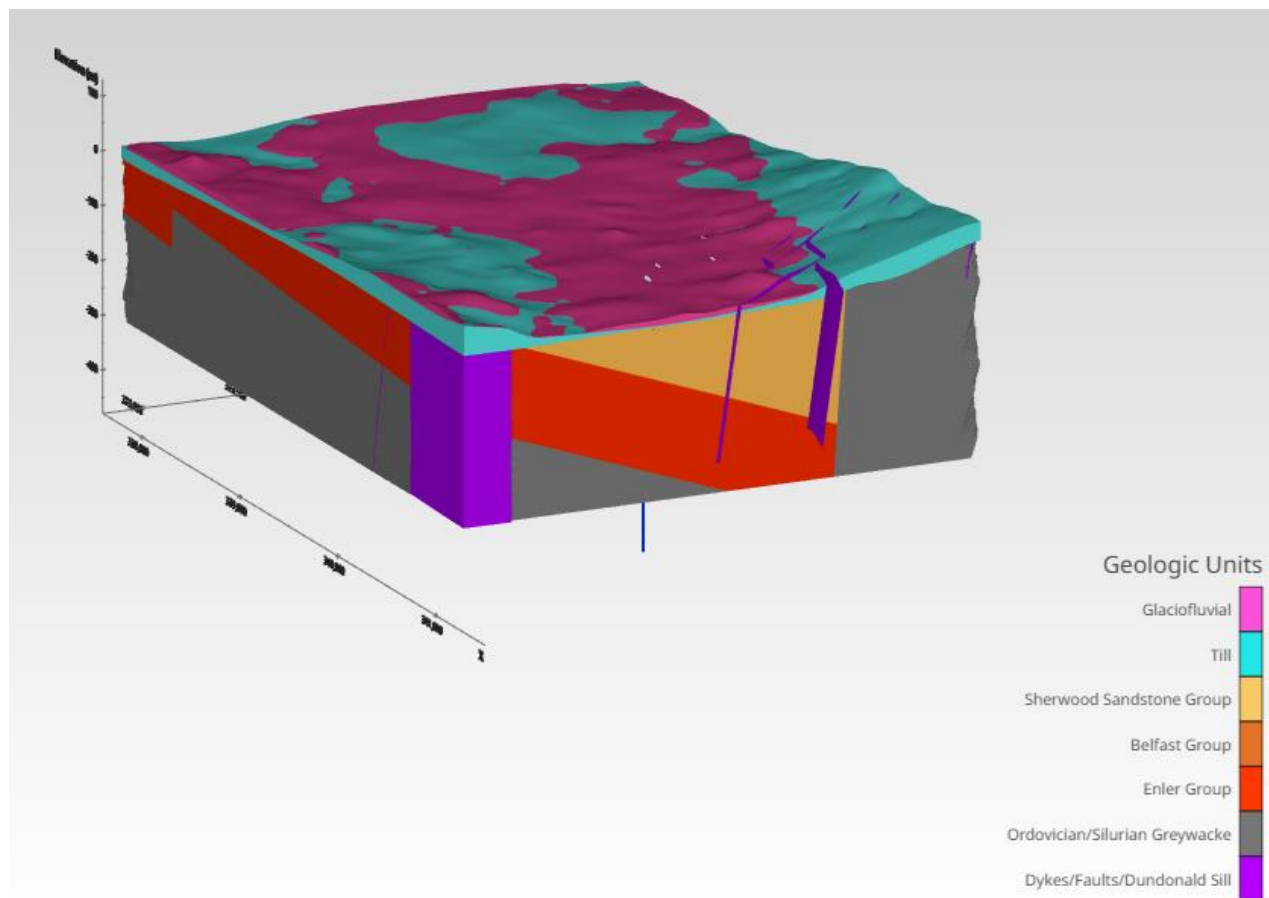
Using the cross-section data (GSSEGDA), a small-scale 3D geologic model, covering approximately 2 km², was created to identify the location of the superficial deposits and the location of the greywacke fault block in the vicinity of the Stormont Estate. The cross-section data depicted Sherwood Sandstone beneath the superficial deposits and was interpolated throughout the model domain. A fault plane between the Ordovician/Silurian Greywacke and the Sherwood was interpolated based on where the regional geology maps coincided with the cross sections.

A larger regional geology model, covering approximately 9 km², was constructed with EVS. The regional bedrock geology map was overlain on DEM data. The contact between the Ordovician/Silurian Greywacke and Permian Enler Group that represents the fault plane was interpreted with EVS. The hanging wall of the Permian Enler group was given a strike of N20W with a dip of 10 degrees. Thicknesses of each unit were selected based on historical and regional data from the AOI. A secondary normal fault to the southwest was depicted in the model. These inputs resulted in a sufficient match between regional geologic maps and the 3D regional geology model constructed in EVS.

Based upon available data the model indicated an expected thickening of the Sherwood Sandstone unit, dipping to the north, as is understood to occur to the east around Newtownards and with a thick Sherwood Sandstone sequence also found in the Lagan Valley to the west.

¹Cooper, M. R., Raine, R., Roberson, S. L., & ni Chonchubhair, R. (2023). *Geological Survey of the Stormont Estate Geothermal Demonstrator AOI*. Draft V2_8-3-2023. Geological Survey of Northern Ireland

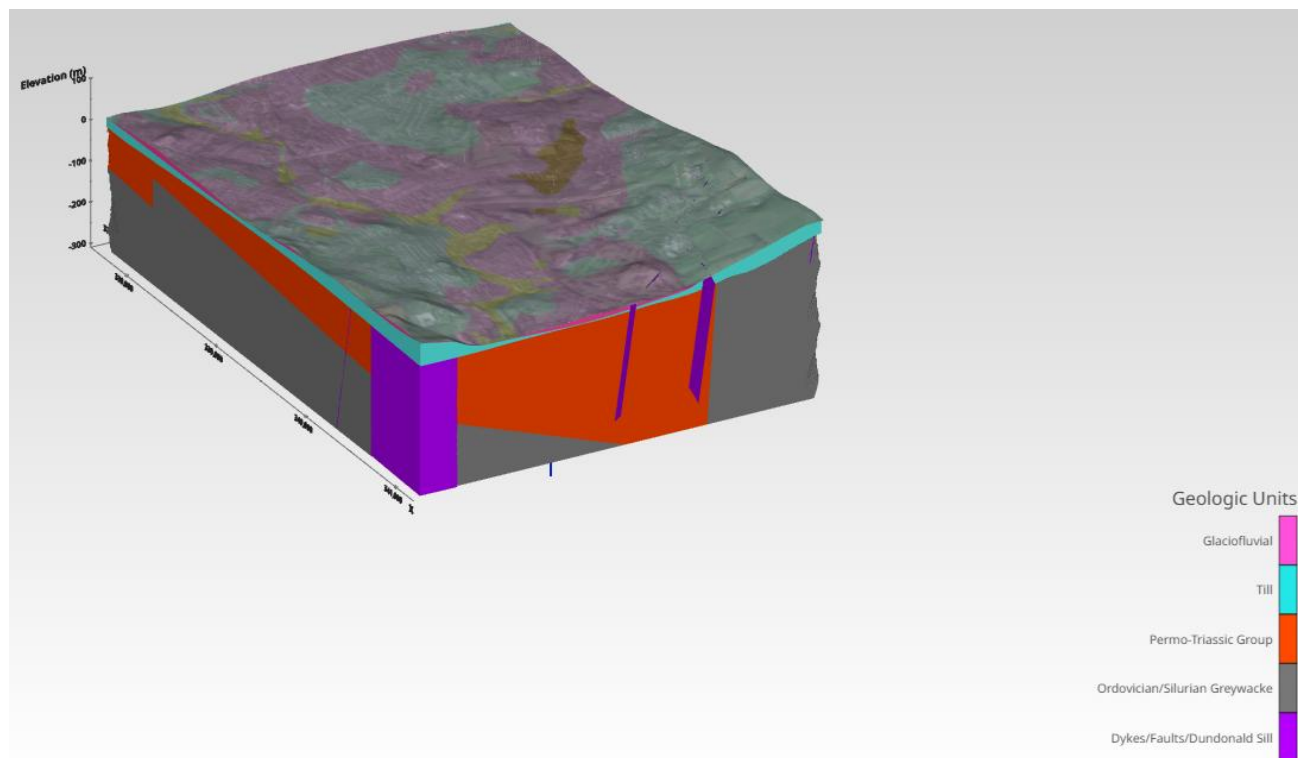
Figure 6.2 Pre-Investigation Geological Model



Following the investigation drilling, which indicated that the Sherwood Sandstone strata was relatively thin and weathered below the glacial deposits and with Permian mudstones, sandstones and breccias below this for several hundred metres (230.7m proven at STRAT borehole) the model was revised to reflect this.

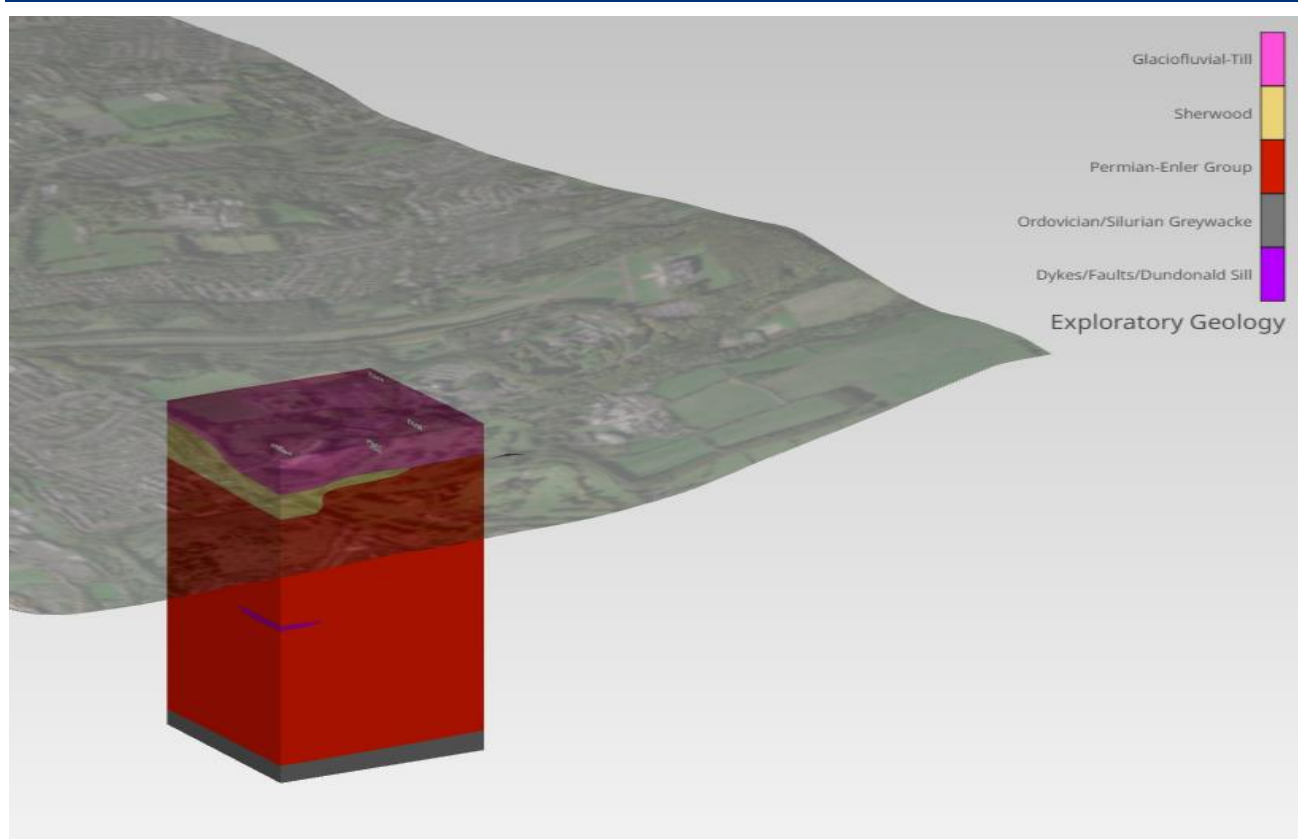
The geologic logs for these investigation boreholes were converted into an EVS file format to display the borehole data. Based on the logs, no Sherwood Sandstone was present at EB5. The thickness of the Sherwood Sandstone differs significantly between both the cross-section maps/ regional geology maps and the borehole logs.

Figure 6.3 Post-Investigation Geological Model



Additionally, a sub-area model was developed just around the investigation borehole locations area to depict in more detail the geological conditions as encountered in this area.

Figure 6.4 Post-Investigation Sub-Area Geological Model



A web scene viewer file, or CTWS file, was generated in EVS that allows the end user to view the three data sets described above. For viewing [C Tech 3D Scene Viewer](#) was used.

The developed models are based on limited confirmed data available for the subsurface in the model areas. Whilst the geological interpretations have been extrapolated to the full model area for illustrative purposes the information obtained from the investigation at Stormont has confirmed that the geological setting is more complex in this part of Belfast even compared with the areas to the east towards Newtownards and west to central Belfast/Lagan Valley. The models are considered useful for understanding how geological settings can be more variable than available datasets may indicate (especially where there is limited confirmatory bedrock outcrop and validated borehole records) and the importance of investigation programmes to improve interpretation of the subsurface.

6.6 GEOTHERMAL FEASIBILITY STORMONT

As part of the assessments completed for the Stormont Estate, a feasibility assessment was completed which considered heating loads at various government buildings on the site and how heating energy needs could be met from shallow geothermal energy sources. These were informed by the information gained from the intrusive investigation and testing works completed including the updated understanding of

ground conditions at the site and from site specific measurement of ground thermal properties from TRT testing at EB5 borehole.

The assessment is reported in:

Tetra Tech, 2025. Stormont Geothermal Feasibility Report

6.7 LESSONS LEARNED

The drilling investigation phase revealed that ground conditions were different to that anticipated, based upon the interpretation of data prior to the investigation. This in particular related to the thickness of Sherwood Sandstone across the site, which was limited in thickness and weathered.

As a result, drilling progressed through a much more varied geological sequence, mainly mudstones, sandstones and breccia of Permian-age. At some boreholes a significant thickness of Paleogene intrusions was also encountered. Drilling rates, using mudflush (main drilling method used for the purpose of limiting the requirement for management of encountered groundwater) were variable and at times slow, which influenced timescales associated with the drilling programme.

The variable lithology including unstable marls and thickness of superficial deposits is considered to have increased the difficulty in maintaining hole condition to allow ground loops to be installed, with this not achieved in an attempt at one of the boreholes.

The experience of grouting in a U-loop at another borehole confirmed the importance of ensuring grout selection and a detailed methodology for grout mixing and application is in place for such works and that roles of responsibility for this are clearly defined as part of project specification.

The investigation was essential to confirming the geological setting across the site to allow the options for implementing a geothermal scheme at the site to be properly considered. This confirms the value of allowing for an initial investigation stage for larger projects, where there is insufficient existing quality datasets available for the proposed development area.

7.0 GEOTHERMAL VISUALISATION SERVICE

As part of the overall promotion of geothermal it was recognised that use of visualisation technology that could be adopted across a range of platforms would be beneficial to achieving the overall aims of the project, including to showcase geothermal energy, demystify geothermal energy and familiarise people with the subsurface.

Tetra Tech engaged a specialist, multi award winning and globally renowned creative production studio (Studio Liddell) to develop this aspect of the service provision.

Initial workshops with DfE, GSNI, Tetra Tech and the communications team (Morrow Communication) to confirm objectives and development content style and ideas were undertaken, with regular follow-on meetings held to review developed draft content and development concepts, including scripts for voiceovers and scene graphics.

An XR (Extended Reality) application (app) which includes AR (Augmented Reality) capability designed and developed for use was developed. This focused on the two investigation areas at Stormont Estate and Greenmount.

The applications were designed and built for simultaneous class exploration, presentation, teaching and solo learning. Group remote learning is also possible with a wi-fi connection to the internet.

The VR application was designed to be inclusive and also easily portable. This was achieved using Meta Quest 2 hardware which is a very easy to use, high quality immersive headset. 15 No headsets were provided for use in public engagement events.

Application features include a solo mode (for personal viewing of the content), a presentation mode (for ‘casting’ the content to a tv screen or projector for a larger group to view) and a classroom mode which is ‘teacher’ led. In Classroom mode, classes of up to 15 VR users can be accommodated simultaneously and viewers can even join in from multiple remote locations, Wi-Fi / internet allowing.

8.0 COMMUNICATIONS AND STAKEHOLDER ENGAGEMENT SUMMARY

Overview and Objectives

An important part of the scope of services was the development and implementation of an effective communications strategy to promote geothermal as a renewable energy option with a wide range of applications.

While well-established elsewhere in the world, geothermal energy is still relatively unknown in Northern Ireland and yet is seen a key part of our efforts to meet net zero targets as set out in the Northern Ireland Energy Strategy. It is also hoped that it can enhance our security of energy supply as a local, renewable and low carbon energy source.

With an expected low level of awareness and understanding about geothermal energy and its potential to play a key part in the future energy mix, the strategy was an important element to bridge this information gap. This was also intended to include a significant educational element to explain the concept of geothermal to a wide range of stakeholders and the general public while preparing the ground for a continued effort to build the geothermal sector in Northern Ireland.

Tetra Tech engaged Morrow Communications a leading integrated communications consultancy to lead on and deliver this key element of the project.

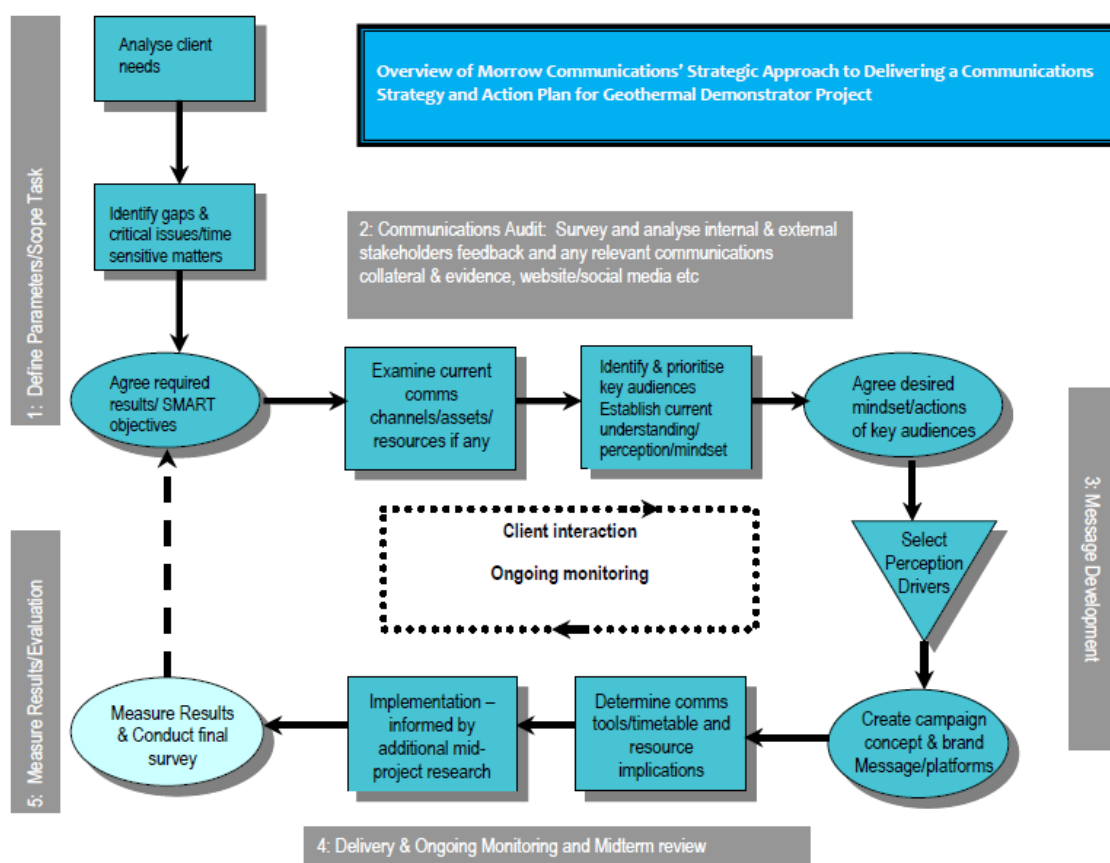
Some of the key objectives set out in the scope of works were:

- To showcase and ensure social acceptance of geothermal energy and demystify it while also familiarising people with the subsurface
- To better understand public knowledge, attitudes and perceptions to geothermal before, during and after the project and associated communications
- Enable an educational benefit from the project to inform the public, help build the sector and demystify geothermal technology as a source of heating and cooling.
- Help visualise the earth's subsurface and its potential as a valuable resource, proving that there is usable heat at accessible depths in key locations that can be used to decarbonise heating and cooling.
- De-risk future investment in geothermal sector and technologies by giving confidence to the sector that NI is committed and serious about using geothermal energy
- Support market sector development in NI.

Communications Strategy and Results

Morrow Communications developed a comprehensive and fully integrated communications programme designed to inform and educate the public and key stakeholders about geothermal energy and deliver positive engagement and awareness of the GeoEnergy NI demonstrator projects based at Stormont and the College of Agriculture, Farming and Rural Enterprise (CAFRE) Greenmount site near Antrim.

The strategy was developed and delivered using the following process:



Based upon what was achieved over the duration of the project it is considered that a very purposeful communications campaign was delivered, and it's reach, impact and results has been significant. Some of the result highlights to date include:

- On social media the project typically gets around 12000 social media impressions a month and an average engagement rate of between 10-15%. A good industry standard is 1-3% which demonstrates just how engaged people are with the project and the desire to find out more about geothermal energy.

- Through attending festivals and events like the Balmoral Show, and the NI International Air Show we've been able to reach over 250,000 people through our mobile GeoEnergy Discovery Centre (GDC).
- Through our school's engagement programme, we've visited 9 council areas and welcomed over 40 schools and a number of council leaders to the GDC.
- We've had thousands of visitors to the GeoEnergy Discovery Centre at Stormont alongside the drilling programme including Ministers, Assembly Committee members. MLAs and VIPs.
- The project website has had 11,000 unique visitors and over 26,000 visits since it launched in June 2023.
- Great media coverage about the project and Northern Ireland's geothermal potential was achieved across TV, radio, print and online – including UTV, BBC TV and Radio, Q Radio, Cool FM/Downtown, U105, Irish News, Belfast Telegraph, Newsletter Belfast Live and widespread regional paper coverage in each school / council area.
- Delivered impactful advertising campaign (print, radio and digital) to coincide with key milestones including GDC Roadshow and Documentary Launch.
- Circulation reach
 - Radio campaigns: 844,000 (average Opportunity to Hear 3.6)
 - Press / digital ad impressions: 457,000
 - Estimated media coverage: 850,000
- Delivered 7 quarterly project newsletters to a broad stakeholder database – also accessible online following distribution.
- The documentary published in late February 2015 was shown to 200+ people across NI Science Week events and has been viewed a further 150 times online already. It was also broadcast on Belfast TV channel NTV in March 2025.
- Early indications from research shows an increased awareness and understanding of geothermal energy across Northern Ireland since the project began.
- Geothermal is now regularly referenced as a key part of the future NI energy mix in key policy and stakeholder forums.

The project has left a lasting legacy through the creation of a number of valuable communication assets and tools which can continue to support the ongoing development of a geothermal sector in Northern Ireland. These resources will continue to help communicate the potential and help inform and educate key audiences about the role of geothermal in Northern Ireland's future energy mix.

Key Project Deliverables

Some of the key elements of the communications strategy successfully delivered to meet the client's requirements included:

Branding and Communications Assets - We developed the GeoEnergy NI project brand and associated brand usage guidelines and ensured its consistent application across all communication initiatives. We also produced a range of other design assets including information stands/backdrops. Information leaflets and branded presentation materials and merchandise.

Website Development - We designed and delivered a comprehensive project website including all copy and content. Alongside this we produced an introductory project animation video to provide a project overview and simplify complex messaging around the technology solution.

Research - We delivered market research to establish a baseline awareness and understanding of geothermal technologies and to highlight any concerns people might have. This informed subsequent communications activities and messaging and will also be used to gauge the success of the communications efforts in a secondary post campaign phase of research.

Media & Stakeholder Relations & Events - We managed all media and stakeholder engagement relations activity for the project since the beginning, writing and issuing all press releases, managing photography and fielding media requests. Key to our messaging approach has been to outline the potential project benefits and the key role it can play in the decarbonisation challenge, organising stakeholder events and engagement/ speaking opportunities.

We led on all stakeholder engagement and briefings, and this has included organising a stakeholder launch event and supporting public consultation events ahead of a future planning application process. We also facilitated visits from a number of Ministers, Assembly committees, VIP visitors and MLAs to the drill sites and the GeoEnergy Discovery Centre.

Stakeholder Newsletter - As part of the stakeholder outreach, we designed and delivered a quarterly project newsletter which was issued via email to our database of stakeholders. This ensured a steady flow of information about the project and the role of geothermal in Northern Ireland's future energy mix.

Community Consultation & Schools Outreach - One of the key objectives of the project was to inform and educate the local market and key stakeholders about the potential for geothermal energy. While commonly used across other parts of the world it is currently underutilised in Northern Ireland and therefore not very well understood. We developed a public engagement programme to help inform the wider public and stakeholders about the benefits and potential of geothermal energy in NI. This included a school's outreach programme and attendance a number of high-profile public events including Balmoral Show and the Portrush Air Show.

Geo-Energy Discovery Centre (GDC) - A key part of our outreach programme was the design and development of a bespoke interactive and immersive Mobile Visitor Centre which was used alongside the drilling phase at Stormont. We also took it on the road throughout Northern Ireland where it showcased the project and geothermal energy potential at different public events and school visits.

Social Media - We established and managed the various social media channels for the GeoEnergy NI project across X, Facebook, LinkedIn and Instagram. We also delivered planned content calendars to keep stakeholders and key audiences updated on the projects' progress. This included delivering promoted content to agreed budgets.

Video Content/Documentary - Alongside the project animation mentioned previously, we captured and edited a range of video content to support the project across all digital channels and in-person events/meetings. This included a number of project update videos and a series of case studies showcasing locations in NI which were already benefiting from geothermal energy.

We also delivered a documentary short film to capture the story of the project and premiered this at a series of events in the Ulster Museum as part of NI Science Week 2025. This formed a key part of the public awareness programme to ensure people better understand the geothermal potential and benefits in NI and leaves a valuable learning resource for future audiences.

Educational Resources - Alongside the website and video content/documentary we also worked with GSNI to design and deliver some additional schools' resources for KS2, and KS4 age groups. This included teaching resources and learning packs which can be used alongside the other video assets and website.

Advertising - we delivered targeted advertising campaigns across print, radio and digital channels to promote the project and the Geo-Energy Discovery Centre experience as it made its way across Northern Ireland.

Sample of Key Communication Assets/Results







by Richard Buckley, Editor, Business Eye

An interactive mobile discovery centre designed to help visitors 'unearth the heat beneath their feet' is set to visit a town near you this year as it embarks on a geothermal energy information roadshow across Northern Ireland. The GeoEnergy Discovery Centre is a key part of the GeoEnergy NI project being delivered by the Department for the Economy (DfE), with scientific support from the Geological Survey of Northern Ireland (GSNI).

Designed to help schools, families, businesses, and community groups discover the power and potential of geothermal energy as a renewable energy source, the centre is packed full of educational resources, including interactive experiences such as virtual reality (VR) technology.

The discovery trailer is setting off on its first road trip shortly with stops planned at the Giant's Causeway Visitor Centre, which is already heated by geothermal energy, Coleraine and Derry-Londonderry in February. The centre will be open to the public and group bookings during this time, as well as visiting Northern Ireland Science Festival and local schools. This is the first phase of the information roadshow, with further locations around Northern Ireland to be visited.

Launched last October, the GeoEnergy Discovery Centre in Belfast and it is now the public with over 1,500 visitors so far. GeoEnergy NI project is testing the public geothermal potential is being tested at an Enterprise GreenHub Campus near...

Ryan White, Director of Heat, Buildings and Energy, said: "This geothermal energy is UK and showcases the Department for the Economy's commitment to supporting the island's geothermal potential. Geothermal decarbonise our energy sector in pursuit of net-zero."

"The GeoEnergy Discovery Centre provides an educational and fun experience. As well as this, the projects knowledgebase Geo Ambassadors handle rocks from below the Earth's surface."

Free to visit, the GeoEnergy Discovery Centre will be available to visit on Saturday 17th February, 22nd February and the Holy Well, Derry on Saturday 23rd February.

Eye

Ryan White, Director of Heat, Buildings and Energy, Department for the Economy is pictured launching the GeoEnergy NI project.



Geothermal drilling at Stormont to explore green energy

Exploratory drilling and testing has commenced at Stormont as part of a \$3 million geothermal energy project. The study will examine shallow geothermal potential and its possible future application to provide low carbon, renewable heating and cooling systems for a number of buildings on the estate.

A second study at the CAPRE GreenSmart campus near Antrim will explore the potential for a future deep geothermal borehole project. A total of five boreholes will be drilled at Stormont over the next six months, four of which will be hydro-geology boreholes around 250 metres deep, and one borehole will be around 500 metres deep.

A series of tests and analyses including down-hole geophysics will then be carried out on the boreholes to identify the optimum numbers and depths of boreholes required to deliver low carbon and renewable heat to the estate.

Economy Minister Conor Murphy, Finance Minister Dr. Columba Connolly and the US Special Representative to Northern Ireland for Economic Affairs, Joe Kennedy II, were among the first to visit the first borehole site last week.

"Despite being in its infancy, the geothermal sector is well positioned to thrive and with the right investment and support it can deliver real productivity, outdoor jobs, and promote regional balance across the region," said Mr. Murphy.

"While the north is fortunate to have very suitable geology for geothermal energy it remains a relatively unexplored resource here compared to other countries."

"Geothermal offers several distinct advantages and unlike other renewables is available 24/7, whatever the weather which makes it more reliable and reliable."

"This is a feature that can serve to offset energy costs and increase security of energy supply."

Unearthing the heat beneath our feet

An interactive mobile GeoEnergy Discovery Centre will open to the public at Belfast's Stormont Estate on October 17.



The GeoEnergy Discovery Centre provides an educational and fun experience. As well as this, the projects knowledgebase Geo Ambassadors handle rocks from below the Earth's surface.

Free to visit, the GeoEnergy Discovery Centre will be available to visit on Saturday 17th February, 22nd February and the Holy Well, Derry on Saturday 23rd February.

It's called geothermal energy and it's low carbon and cool. It's a renewable energy source that can heat and cool our homes and buildings, 24 hours a day - whatever the weather.

Want to find out more about Northern Ireland's geothermal potential?

Visit the Department for the Economy's mobile GeoEnergy Discovery Centre based on the Stormont Estate, Belfast. It's open to the public on World Geothermal Energy Day on Tuesday 17th October 2023. School and group bookings welcome.

Packed full of educational resources including interactive technologies, it's free to visit and will help you discover the geothermal heat beneath your feet.



GeoEnergy NI welcomes visitors



Pictured at the GeoEnergy Discovery Centre with Councillor Sarah Duffy.

The Department for the Economy's GeoEnergy NI project is designed to help visitors unearth the heat beneath their feet. The project is a joint venture between the Department for the Economy and the Geological Survey of Northern Ireland (GSNI). It highlights the potential of geothermal energy as a renewable source and mentions that the project will be supported by the Department for the Economy. The article also notes that the project is a key part of the Department's strategy to promote green energy and create jobs in the region.



9.0 LESSONS LEARNED

9.1 OVERVIEW

An important objective of the project, by implementing a range of surveys, investigations, planning applications and stakeholder engagement, was to understand the opportunities, challenges and barriers to developing geothermal in Northern Ireland. Similar issues are likely to be being experienced in other countries/jurisdictions and efforts are being made to address existing limitations. With this practical understanding now gained for Northern Ireland, recommendations can be made to inform and guide the industry and regulators on how some of the challenges can be addressed and/or what further debate/investment/guidance is necessary to allow geothermal to become an enhanced practical, viable renewable energy option for homes, businesses, industry throughout Northern Ireland.

It is recognised that geothermal is not new technology and that shallow and deep geothermal systems have and continue to be proven technology for heating, cooling and power in the UK and Ireland as well as elsewhere worldwide. The project communications strategy included examples of successful implementation in a range of building types in Northern Ireland. There are a range of feasibility studies and investigations underway or being proposed across the island of Ireland and the UK, looking at different end-user types. There are schemes which have been implemented in private dwellings, terrace housing, tower blocks, factories, schools, hospitals and use in agricultural and other industries. All available information indicates that the technology can be implemented nearly everywhere, through selection of the most appropriate geothermal option and with good design. Restrictions to implementation include financing, the regulatory framework, industry knowledge and capacity, development and application of industry standards and knowledge sharing within the industry and with the wide range of potential end-users. Many of these factors are being addressed or at least progressed by a wide range of technology experts and promoters.

This project did not have the objective of resolving all the relevant issues in Northern Ireland but was intended to identify some of the issues both in practical implementation of geothermal and with regard to more strategic policy associated with planning and financing. Through this, recommendations are offered with regard to how market sector development can be supported in Northern Ireland.

9.2 LAND GEOPHYSICAL SURVEYING

For deep geothermal schemes, improving knowledge on the geological setting at depth is an important element of de-risking future investigatory/production drilling, with its associated high costs.

New information for an area is typically gained through geophysical surveying, as was undertaken around Greenmount as part of this project.

Given the intensity of land-use in typical UK and Ireland settings implementing surveys is always a compromise between desired survey layout (i.e. relatively straight seismic lines and regular patterns of other survey points (MT, Gravity) and available road/track routes and ability to obtain landowners co-operation to undertake survey works.

For the Greenmount survey there was a high overall percentage of landowner co-operation. This was obtained through provision of non-technical information leaflets and face-to-face meetings to explain the overall objectives of the work. Data collection was not possible in some parts of the survey area due to no agreement being reached with landowners but with no specific reasons typically being given as to reason for refusal.

For all such future surveys early engagement with landowners, local community organisations and public representatives is regarded as a crucial element to maximising access to land areas for surveying.

Working on public roads requires planning and early engagement with relevant authorities. A specialist traffic management company should be engaged for activities which require traffic management, for traffic flow and for health and safety of field staff. Such companies have the necessary experience in obtaining relevant permits and can advise on the different levels of traffic control that needs to be applied to different types of roads/verges. Where expensive and specialist equipment (such as vibroseis) are being used over a short available period of time, understanding what other potential road works (e.g. utility works) are planned for the survey period can be important, with permits being limited for work on any one road, to avoid too much traffic disruption.

For busier roads, for survey techniques such as seismic, evening and night time surveying is likely to be required most suitable with respect to minimising influences on recorded data from other noise/vibration sources.

9.3 GEOLOGICAL SETTING CONCEPTUAL MODEL

As encountered in the Stormont demonstrator site, geological conditions can be more variable than might be expected, based upon review of existing available datasets. For shallow geothermal schemes where drilling to several hundred metres will be typical, the number of existing good quality (with respect to recorded details) deep borehole records which confirm exact ground conditions at a specific location or area is limited.

This is not a new phenomenon and has been encountered on a wide range of developments where interaction with the sub-surface is required.

As such this confirms the importance for larger schemes to allow for an investigatory stage of works which secures accurate site specific data on geological conditions and strata thermal properties, allowing scheme design to be refined and optimised.

9.4 PLANNING REGULATIONS AND ENVIRONMENTAL LEGISLATION

Development of new policies and a regulatory framework that supports and promotes opportunities to unlock Northern Ireland's geothermal energy potential are vital if we are to meet our low carbon heat sector ambitions.

NORTHERN IRELAND SPECIFIC BARRIERS TO SUCCESS

This section outlines some of the other planning related considerations that face geothermal exploration projects in Northern Ireland. Shallow geothermal schemes completed to date in Northern Ireland have typically been advanced as part of wider development proposals and therefore planning permission has not been required specifically for this constituent part of the wider development.

Potential Barrier/Constraint #1: Permitted development rights for geothermal exploratory drilling and associated operations (surveys and testing etc.) remain unclear. In the absence of clear legislation drilling operations have, in some instances, been viewed as 'engineering operations' and in that context would be classed as 'development' under the terms of Section 23 of the Planning Act (Northern Ireland) 2011; thus, requiring planning permission.

The Planning (General Permitted Development) Order (Northern Ireland) 2015 (GPDO) does not provide specific regulations for exploratory drilling for geothermal purposes and therefore presents a potential barrier to those who wish to investigate and or assess the underground heat potential at their site. Whilst the 2015 GPDO gives permitted development rights in respect of borehole drilling for mineral exploration projects, Planning Officers unfamiliar with geothermal investigation techniques are likely to air on the side of caution and determine that the works require planning permission.

Potential Barrier/Constraint #2: Geothermal Drilling does not fall neatly into any development classifications (Schedule 1 or Schedule 2) of The Planning Environmental Impact Assessment (EIA) Regulations (NI) 2017. Schedule 2, Category 2(d) of the regulations references 'deep drillings' including geothermal drilling. Although the Directive does not define "deep drillings", in other jurisdictions the legal

definition of deep geothermal uses a threshold of >500 meters². The threshold and criteria in respect of this category of development triggers an EIA determination when "...drilling is to be undertaken within 100 metres of any waterway or water in underground strata". The threshold appears onerous, as most hydrogeologists investigating shallow geothermal potential (<500m depth) in Ireland will almost certainly be drilling within 100 meters of water in underground strata. It is possible that the regulations were written with deep geothermal drilling or enhanced geothermal systems in mind, but the current wording has potential significant cost implications which could act as a significant barrier to investment.

The Department for Infrastructure (DfI) in Northern Ireland launched a consultation on 06 April 2023 on Review of Regional Strategic Planning Policy on Renewable and Low Carbon Energy³. Within this, geothermal energy is referenced under 'emerging technologies' with a recommended option to revise existing Strategic Planning Policy to better support, guide and facilitate new and emerging technologies. This represents a further opportunity for geothermal stakeholders to input and shape future policy.

Potential Barrier/Constraint #3: With the absence of grant funding in Northern Ireland to support domestic scale geothermal exploration, it is likely that most of the near-term investment and development will have to come from the non-domestic market. Currently boreholes drilled for the purpose of investigating the geothermal potential at non-domestic sites could constitute a 'Major' Planning Application in Northern Ireland if the total development area exceeds 1 hectare.

Major planning applications are a special category of development under The Planning (Development Management) Regulations (Northern Ireland) 2015. There are several triggers for major development, including "sites of 1 hectare or greater". Major planning applications require the submission of a Proposal of Application Notice (PAN), indicating how you will carry out consultation, twelve weeks before submission of the formal planning application. Application fees are higher and Major applications typically take longer to determine.

Non-domestic scale heating and cooling schemes can comprise multiple abstraction and re-injection wells. Consider a four borehole well field, two abstraction and two re-injection boreholes, each 100m apart. Maximising the separation distance between points of groundwater abstraction and re-injection increases the efficiency of ground source heat pump operation. This four-borehole system would theoretically trigger a major planning application as the drill sites and the area between would likely exceed 1 hectare when you

² [Geothermal energy - British Geological Survey](#)

³ [Review of Regional Strategic Planning Policy on Renewable and Low Carbon Energy - Public Consultation | Department for Infrastructure](#)

consider the space required for the drilling compound, temporary material storage areas and access arrangements.

9.5 SCHEME IMPLEMENTATION AND INDUSTRY CAPACITY

For larger shallow geothermal schemes involving multiple boreholes and for deep borehole schemes there is limited available specialist capacity within Northern Ireland.

For local drilling contractors the predominance of work to date has been for site investigation and/or water wells. Most companies are small and operate only a few drilling rigs capable of drilling boreholes to the 100-200m depths required for shallow geothermal borehole schemes. As such equipment and skills are adapted/concentrated for those purposes. Whilst many of the skills are transferable for geothermal drilling works and equipment can be used/adapted, for larger schemes, to make drilling/installation works as efficient and cost effective as possible, there is benefit to be achieved in enhancing skills and in use of equipment tailored for efficient use (such as loop installation).

Whilst it is likely that the industry would invest in training and equipment where geothermal schemes become a larger part of future business, another factor at play is the difficulty some of the drilling companies report in being able to recruit the next generation of drilling crews to be trained up, from the relatively limited pool of existing experienced drillers.

For other related services such as TRT testing and borehole logging there is a similar limited number of operators available.

For deep drilling projects this requires larger rigs with very experienced crew. In the UK and Europe there is a limited supply of such expertise and equipment and a relatively high demand for its use.

In addition to supporting the drilling industry to develop capacity, investment is likely to be required to develop the skills and knowledge of other technical supporting services such as geologists, hydrogeologists, scheme designers, project managers, M&E engineers and building services operators.

APPENDIX A - SPECIFICATION DETAILS

Gravity:

- The requirement for the survey was to provide infill data over an area of ~20 km². The area is of low relief, ranging from ~15 m to ~140m AMSL. A minimum of 20 and a maximum of 60 new data points were to be acquired. Taken with the existing data this should provide an average station density of 2 to 4 stations per km². The station layout pattern was to be agreed with GSNI and was to be designed to produce a fairly even spacing distribution.
- The survey was to be carried out to a high degree of accuracy and repeatability, tied to existing gravity base stations.
- A modern gravity meter with a high gravity measurement accuracy is required.
- The gravity meter(s) should be calibrated at the start of the survey, and the calibration checked at the end of the survey.
- At least two gravity readings (these may be consecutive values from continuous sampling if an automatic meter is used) should be taken at each station. A measurement can be taken if the two readings differ by not more than 5 microgals. If the readings differ by more than 5 microgals they should be repeated until this level of consistency has been achieved.
- A visual estimation (and written record) of terrain corrections for Zones B and C is required.
- Differential GPS to provide X, Y to better than 20 cm and Z to an accuracy of between 2 and 5 cm. At least one temporary GPS base station should be established in the survey area and tied to a known Ordnance Survey of Northern Ireland control point at the beginning and end of the survey.
- Terrain corrections should be calculated out at least to zone K and to zone M, if possible. OSNI DTM data can be supplied by GSNI. Hydrographic charts should be used where appropriate.
- All station data including, time, gravity readings and XYZ measurements should be recorded manually (as a back-up in case of system failure or data corruption)
- At least one local gravity base station (at/near the GPS base station) should be established which should be occupied at the start and end of each day to measure meter drift. Meter drift, after corrections, should not exceed 5 – 10 microgals.
- The survey gravity base station(s) should be tied to an established GSNI gravity
- base station near Aldergrove (GSNI to supply details).

Seismic:

- A seismic survey was to be complete, comprising a high-density nodal grid and line-based survey to connect with existing 2D seismic reflection lines, with increased density across the CAFRE site.
- Reprocessing of 3 x 2D seismic lines totalling 110 m, provided by GSNI.
- High density nodal seismic acquisition to be deployed across the area (estimated 6000 nodes).
- The survey design was to be produced in collaboration with GSNI and approved by GSNI and the project Steering Group. The survey design was to be commenced in discussion with GSNI as soon as possible following the award of the contract. This would enable it to be approved and any permitting and consents processes to be initiated with necessary landowners and government organisations.
- Nodes should be fitted with either a piezometric accelerometer or a geophone.

- The CAFRE site footprint is approx. 3.5 sq km and most of the land comprises open ground, with some minor roads and tracks available. Whether the spacing of the nodes was reduced and areas outside of the CAFRE site included (also mostly open ground) was to be agreed during the survey design stage.
- 2 x Seismic lines either produced using geophones or nodes and laid out along roads to connect the site with an existing 2D line path to the south. Estimated length of lines is 3.5 km and 3.7 km. The new acquisition is to tie in with existing lines from a 2011 survey an acquisition along two roads that run between the paths of two 2011 lines should be included within the scope (3.5 km and 3.7 km respectively).
- Mobilisation and transport of a seismic source of sufficient energy to image strata at depths of 2 km (with up to 1 km of basalt cover), within the range of 1-125 Hz.
- Processing of all new seismic acquisition data.
- Seismic interpretation including depth conversion and velocity model of the data from the new vibroseis line and high-density nodal survey and the 110 km of existing seismic.

Magnetotelluric Survey:

- To make MT soundings at both reconnaissance spacing detailed spacings (one site per km²). The estimated number of stations is 20, although the exact distribution may vary according to the site selection process.
- At each MT sounding location broadband, full tensor magnetotelluric measurements, using 24-bit data acquisition systems according to specifications below was required.
- A Time Domain EM (TDEM) sounding at each MT site was also required to provide MT static shift correction. Other methods could also be proposed as an alternative MT static shift solution, with illustrated reasoning.

The technical specifications for each MT and co-located TDEM sounding included the following:

- Five-component MT sounding, (Ex, Ey, Hx, Hy and Hz) at each and every site.
- Recording frequency range for all components, including 5-channel (minimum) receiver and magnetic sensors – 10,000 Hz to 0.001 Hz.
- Specify exact recording schedule proposed to measure the bandwidth.
- A fixed remote-reference 4-component MT sounding (Ex, Ey, Hx, Hy) was to be installed for the duration of each survey. The remote-reference sounding is used to reduce or eliminate the effects of local noise and must be located in a suitably quiet and secure site.
- Overnight soundings of minimum 14 hours duration were required to deliver quality measurements over the required frequency range.
- Magnetic coils were to be buried to at least 15cm depth at each site to avoid wind and thermal noise.
- Electrodes: Pb-PbCl or equivalent, non-polarizing electrodes, new for the job.
- Dipole wire: new, PVC-coated wire. E-line dipole lengths minimum 2 x 100m orthogonal dipoles.
- If chosen as method to correct MT static shift, Time domain electromagnetic (TDEM) sounding at each MT sounding site for correcting static shift. The TDEM loop had to be of a size such that there is sufficient depth overlap between the deepest modelled TDEM resistivity and the shallowest modelled MT resistivity. Other proposed methods had to include similar details of acquisition processing parameters.