APPENDIX A PRELIMINARY LANDSLIDE HAZARD AND RISK ASSESSMENT (ESP, 2019)

Earth Science Partnership

Consulting Engineers | Geologists | Environmental Scientists

Godre'r Graig Primary School, Godre'r Graig
Preliminary Landslide Hazard and Risk Assessment

Report Reference: ESP.7234e.3221

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Godre'r Graig Primary School
Preliminary Landslide Hazard and Risk Assessment

Prepared for:
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Report Reference: ESP.7234e.3221

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1 Introduction

1.1 Background

Neath Port Talbot County Borough Council (hereafter known as the Client) have instructed Earth Science Partnership Ltd (ESP) to undertake a Preliminary Landslide Hazard and Risk Assessment on an area of land in Godre'r Graig, near to Godre'r Graig Primary School (the school), located in the Tawe Valley.

The geological map for the area (SN 70 NE) labelled an area of 'shallow slips' some 250m northeast of the school and our assessment examines the surrounding area for evidence of such shallow slips and any other landslides hazards that may impact upon the school.

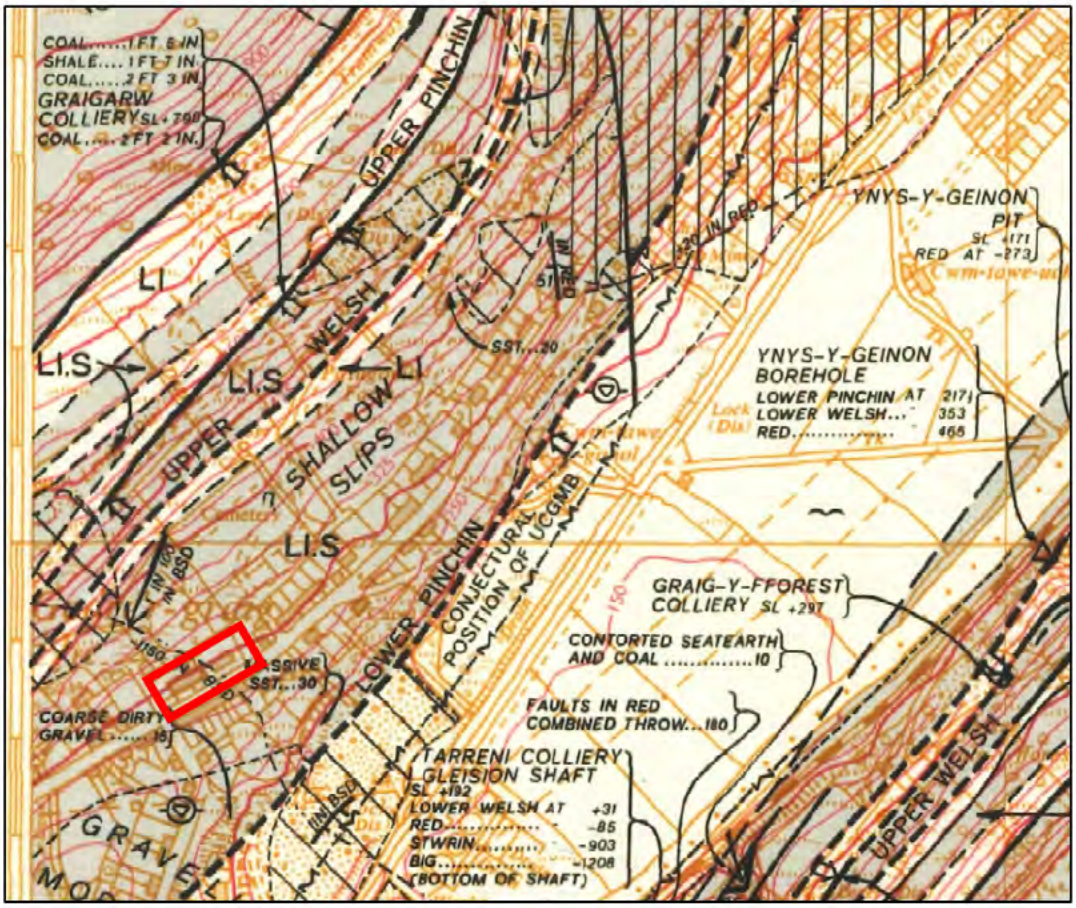
The general location of the study area is shown on Insert 1.

Insert 1: General Study Area 1:10,000 (Ordnance Survey License No.: AL100015788).

The location of the shallow slips in relation to the school is shown in Insert 2, which is an extract of the geological map for the area. The area of the shallow slips is not defined, there is a '?' prefix to the shallow slips, suggesting some uncertainty to the location, or perhaps the presence of such features.

There is no record of these shallow slips in the South Wales Landslip Survey by Conway et al in 1980.

Thus, the study area for the assessment was chosen as the slopes generally above the school to the summit of Mynydd Allt-y-grug and nearby terrain for similar features in a similar geological and geomorphological setting.



Insert 2: Geological Map extract. Red rectangle shows school location. (BGS licence number: C15/05 CSL) Not to scale

1.2 Objective and Scope of Works

As discussed in Section 1.1, the aim of this report is to provide an assessment of the terrain above the school (study area defined in Section 1.1) and assess any hazards and outline the risks they pose to the school.

The scope of works for the investigation was mutually developed with the Client and ESP within an agreed budget, and comprised:

- A geological and historical desk study;
- Obtaining aerial photograph and subsequent interpretation, including stereographical analysis;
- A site visit for orientation and initial morphological assessment;
- Generation of a preliminary morphological map with the assistance of low-level LiDAR information;
- Liaison with the Coal Authority to undertake an inspection of historical mining related features in the area;
- A preliminary site investigation in easily accessible areas and groundwater monitoring;
- Generation of a conceptual engineering geological model; and

- Development of a preliminary qualitative assessment of the hazards/risks and definition of next steps.

Some elements of this assessment, such as the data presentation, hazard identification and qualitative risk assessment are taken from the guidelines set out within a journal from the Australian Geomechanics Society (AGS, 2007) and subsequent papers to standardise its use worldwide (Fell et al 2008)[1]. There are no British Standards or Eurocodes for the assessment of natural landslide hazard and risk. It should be noted that this assessment is not in full accordance with the AGS guidance due to the availability of landslide data in the area local to the Godre'r Graig School.

The contract was awarded based on a competitive tender quotation. The terms of reference for the assessment are as laid down in the Earth Science Partnership proposal of 14th May 2019 (via email). The assessment was undertaken in May to July 2019.

1.3 Report Format

This report includes a geological and historical desk study, an aerial photograph interpretation including the findings of a site reconnaissance visit to undertake a preliminary morphological assessment of the site. The information gained is used to undertake a Hazard Identification Assessment following general principals of the AGS (2007) guidance and a qualitative assessment with recommendations provided. This report is issued in a digital format only.

1.4 Limitations of Report

This report represents the findings of the brief as detailed in Section 1.1. It should be appreciated that only a limited intrusive investigation has been undertaken to date. Should an alternative current land use or structure be considered, the findings of the assessment should be re-examined relating to the new proposals or land uses. Where preventative, ameliorative or remediation works are required, professional judgement will be used to make recommendations that satisfy the site-specific requirements in accordance with good practice guidance.

Consultation with regulatory authorities will be required with respect to proposed works as there may be overriding regional or policy requirements which demand additional work to be undertaken. It should be noted that both regulations and their interpretation by statutory authorities are continually changing.

This report represents the findings and opinions of experienced geo-environmental and geotechnical specialists. Earth Science Partnership does not provide legal advice and the advice of lawyers may also be required.

Access on foot for the walk over assessment was hampered by thick vegetation which may have potentially obscured/masked/hidden views of large or small scale landslide features.

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[1] Fell et al (2008) reporting on behalf of JTC-1 (Joint Technical Committee on Landslides and Engineered Slopes, an International Association of Engineering Geology and the Environment (IAEG), International Society for Rock Mechanics and Rock Engineering (ISRM) and International Society for Soil Mechanics & Geotechnical Engineering (ISSMGE) collaboration exercise, i.e. all relevant international professional geotechnical societies) provides guidelines for landslide hazard and risk assessments. JTC-1 is largely based on AGS (2007) with minor modification for international implementation. The Engineering Group of the Geological Society is the UK National Group of the International Association of Engineering Geology (IAEG).

2 Desk Study

The information presented in this section was obtained from desk-based research of sources as detailed in the text. The study area was visited on the 6th and 7th June 2019 during changeable weather conditions.

2.1 General Description of Study Area

The study area is located in the Tawe Valley, on the eastern flank of Mynydd Allt-y-grug, between Pontardawe and Ystalyfera.

The School is located part way up the valley side, west of Graig Road, which runs generally parallel with the valley contours. What appear to be predominantly residential dwellings line Graig Road to the north and south.

Land to the west of Graig Road, behind the houses for a general distance of 30m is used for animal grazing, as it is separated into several fields by post and wire fences. The land beyond the rough grazing ground is typically covered in trees and bracken and although not officially Common Land, it appears unused and overgrown. Further grazing is noted near to the base of a scree, or talus slope on the upper parts of Mynydd Allt-y-grug, and this is separated by a dry stone wall.

A cemetery, with an associated small car park is located some 50m north of the school. The cemetery has a stone wall boundary and a concrete track providing access to the higher portions of the cemetery.

There are two distinct quarries upslope of the school and numerous concave features which are also likely to be associated with previous mining activities.

From the River Tawe at the bottom of the valley, initially the slopes are relatively gentle and become steeper as you pass Graig Road going uphill.

The approximate National Grid Reference for the school is (SN) 275155 206870 and the postcode is SA9 2NY.

2.1.1 General Topographic Setting

The topography of the area slopes downward toward the southeast from the relatively steeply sloping, eastern flank of Mynydd Allt-y-grug to the west. The Tawe Valley forms a typical U-shape valley, however, there appear to a gently stepped nature to the valley side and this is likely to represent the harder and softer layers of bedrock (sandstone and mudstone) weathering at different rates.

The topography has been altered by man with two large quarries noticeable in the study area, and numerous other mining features which has generated steeper slopes and spoil mounds.

2.1.2 Shallow Slips

The area of the shallow slips was visually inspected on the 6th June and they were identified by relatively shallow depressions with springs and hydrophilic vegetation helping to delimitate their extent and width. A cutting for a track, circa 0.5m high, crosses the toe of two features and the exposure showed the slipped mass to be Colluvium, no evidence of movement could be seen in the cut slope.

2.2 History

The site history has been assessed from a review of available historical Ordnance Survey County Series and National Grid maps. The historical maps are presented in Appendix A and the salient features since the First Edition of the County Series maps are summarised below.

The first historical map studied, dated 1877, shows Graig road in its current day position with houses either side. The school has not been constructed and the site is currently shown in an agricultural layout as two fields.

The cemetery is shown some 50m north of the school site, an old quarry is shown some 200m northwest of the school area and another quarry, labelled as Cwar Pentwyn is sown some 220m west of the school site, which is labelled as disused on the 1964 map, so became disused between 1948 and 1964.

A spring originating near spoil mounds of the quarry to the northwest flows toward the southeast and intersects with the northern boundary of the school. A second spring and stream is located near the western quarry, which flows toward the east and also intersects the northern boundary of the site.

By 1897, coal levels to the north, northwest and west were common and the school was constructed between maps dated 1899 and 1913.

The 1960, 1:2,500 historical map provides good detail on the mining entries from the north to the west of the school, some seven mine adits are shown approximately 190m west of the school boundary and there is several mounds or spoil heaps shown in relation to the former quarry to the west and Cwar Pentwyn quarry to the southwest.

2.3 Hydrology

A review of the historical maps have showed a series of springs that emanate in the hillside above the school. They all flow downhill, toward the east or southeast. Two springs intersect the northern boundary of the school, and evidence of these features were noted on the site walkover.

These two springs are noted to emerge lower in the slope through the historical maps, and it is possible that debris/spoil from the quarries has been placed on top of the springs and their streams masking them. An alternative reason for their change in emergence is mining, and mine drainage may have altered their pathway.

Consideration to the position of the springs and the underlying geology, it is considered likely that they emerge at locations where more permeable strata, such as a sandstone, overlies less permeable strata, such as mudstone or siltstone units.

Water has also been noted to be flowing out of old mine adits, which are likely to be draining old workings.

2.4 Geology

The published 1:10,560 scale geological map for the area (Insert 2, Sheet SN 70 NE) indicates that the hillside is predominantly made up of the Upper Coal Measures (now formally known as the South Wales Upper Coal Measures Formation) which underlie a sandstone outcrop at the top of Mynydd Allt-y-grug of the Rhondda Member, which is part of the Pennant Sandstone Formation.

The No. 2 Rhondda coal seam outcrops at the base of the Pennant Sandstone Formation and forms the boundary between the (older) Upper Coal Measures which underlie the school, and the overlying (younger) Rhondda Beds which comprise sandstone.

The Upper Coal Measures comprises a series of units formally known as the Llynfi Beds, these are now referred to as the Llynfi Member and according to the Geological Memoir for the area, the Llynfi Member is essentially argillaceous, and contains sandstones bands within it that are generally thin and in-persistent.

The strata above the No. 2 Rhondda or roof rock in the overlying Rhondda Member is understood to be a Conglomerate.

The published 1:50,000 scale geological map for the study area (Sheet 230, available on the website of the British Geological Survey, 2019) generally confirms that above stratigraphy and shows the beds to be dipping toward the south at angles of between 3° and 5°.

As mentioned above the No. 2 Rhondda coal seam is situated high above the school, however there are other coal seams that outcrop in the hill side, which include the Upper Pinchin and the Upper Welsh. Another seam, the Lower Pinchin coal seam is likely to underlie the school at depth with in the Llynfi Member. All these seas are widely worked in the area, noticeable in the location of the Upper Pinchin above the school. Study of the geological map and adjacent sheets has shown the potential for several other seams, between the No. 2 Rhondda and Lower Pinchin, which include the Paynes and the Pant Rhyd Y Dwr, however these are not mapped in the study area, they occur in the same sequence in nearby areas and they may or may not be present.

Both the 1:10,560 and 1:50,000 scaled maps of the area show no glacial or superficial deposits on the hill side above the school, however, Diamicton and Fluvioglacial deposits are shown in the Tawe valley. Recent workings by ESP in the Tawe valley has shown Glacial Diamicton further upslope than mapped and some covering of glacial deposits is likely.

2.5 Hydrogeology

The combination of the geological setting and topography of the study area will dictate the hydrogeology. Generally, as discussed in Section 2.1, the wider study area is situated on the eastern flank on Mynydd Allt-y-grug in the Tawe Valley and water will most likely drain to the river which lies at the base of the valley.

Simplistically, Mynydd Allt-y-Grug is formed by sandstone (Rhondda Member) that overlies a series of mudstones, siltstones and sandstones of the South Wales Upper Coal Measures.

The sandstone units will be relatively more permeable (secondary porosity) than the underlying relatively argillaceous rocks and to a certain extent, the argillaceous rocks will limit downward migration of groundwater. The bedding planes of these strata all dip gently about 3° to 5° toward the south.

Whilst groundwater will percolate downward, due to gravity and primarily via fracture flow; some groundwater could also flow along bedding planes and near horizontal fractures and thus there may be a small component of groundwater flowing out of the eastern side of Mynydd Allt-y-Grug, into the study area. Spring lines will likely form where more permeable strata overlies less permeable strata and several springs within the study area are noted to mirror the outcrop pattern.

Any worked coal seams will likely provide a preferential pathway for groundwater to drain, given the dip this will be primarily toward the south.

2.6 Past Coal Mining

As discussed in Section 2.5, the site is underlain by bedrock of the South Wales Upper Coal Measures, which contains several seams of coal (and bands of ironstone).

From the geological map, coal seams that were expected to out crop in the hillside above the school included the No.2 Rhondda, Upper Pinchin and Upper Welsh. Although not shown on the geological map for the study area, in the same sequence of rocks nearby, other coal seams are encountered, which include the Pant Y Dwr and Payne's.

Evidence from the geological maps, online Coal Authority viewer and geological memoirs suggests that the No.2 Rhondda and Upper Pinchin were worked extensively in the area. There appears to be little evidence of other adits that would have worked the other seams, however, such information may be missing, or not recorded on plans/records.

The workings in the No.2 Rhondda and Upper Pinchin coal seams have results in colliery spoil being discarded, normally down slope of the adits or quarries where they were worked, and the historical maps show the location of the adits and associated spoil mounds.

It should be appreciated that the Coal Authority records are incomplete, partly because there was no statutory and mandatory requirement on colliery owners to survey and record the extent of mine workings until the Coal Mines Regulation Act of 1872. Therefore, given the potential age of the potential workings, no surveys may ever have been undertaken on them and therefore, the lack of records does not discount the possibility of workings. In addition, where records were kept, due to copying of plans through time is it not uncommon for the plans to contain plotting errors or replots of the same features, such as mine shafts and adits. Thus, where a high number of mine entries are located in a small area, it is possible that the seam feature is replicated, and this should be borne in mind when assessing their information.

2.6.1 Summary of Mining information

The information obtained to date indicates a large amount of coal mining in the study area, it is likely that most of the mining concentrated upon the No. 2 Rhondda and Upper Pinchin, but other seams exist above and below the school which would also have likely been worked. The workings in the No.2 Rhondda and Upper Pinchin are most noticeable when considering he historical maps and mining date, spoil from quarries and adits accessing these coal seams have been placed on the landscape above the school.

3 Coal Authority Inspections

3.1 Introduction

The Coal Authority were instructed to undertake an inspection of the quarries and tips in the study area. The purpose of their inspection was to provide an assessment of stability and relevant safety issues. The report is provided in full in Appendix C and the below provides a summary of pertinent points of the report.

3.2 Comments upon their Inspection

The Coal Authority assessment covers three broad areas, Site 1, Site 2 and Site 3; these reference to Cwar Pentwyn (1), the old unnamed quarry and spoil north west of the school (2) and the adits and associated spoil north-northwest of the school (3) respectively. The relative location of these area are provided on Figure 1 within the Coal Authority report.

It should be noted that the Coal Authority have used descriptive words, such as low probability to assess risk from potential failures. Their report does not provide any risk assessment basis for these descriptors and should be considered as a general statement or estimate.

3.2.1 Site 1 or Cwar Pentwyn

This area comprises Cwar Pentwyn and associated spoil tip. Recent evidence of working, of suspected stone for road building has occurred and new tips were identified over old spoil mounds and one adit.

Water was issuing out of adits into local unnamed water courses.

The tip was noted to be heavily vegetated with steep sides, a location of a small failure was identified and there were signs of soil creep, but generally little evidence of recent instability was observed.

The Coal Authority suggested that if a significant failure of the spoil heaps occurred, it would impact the access road to Pentwyn Farm and the properties along the access road. Blockage of the water emanating from the mine entries could lead to increased pore water pressures within the spoil and result in failure.

Legal and permissible consideration will also need to be given to the recent activities in the quarry and the tipping of spoil.

3.2.2 Site 2 or Unnamed Quarry and Tip

Vegetation over the general area was well developed and limited visual observations and made access difficult. This made delineating the extent of spoil with accuracy not possible. Occasional exposures of small boulders were noted, and a number of dry short gully type features were observed, covered in dense vegetation and generally orientated downslope. These were reported to likely be attributed to localised movement from surface water erosion.

No evidence of recent movement was identified, and they suggested that the tip material was likely to be coarse and free draining.

A moderate seepage was noted from a former adit near to the quarry which was observed to pass into what was described as coarse quarry spoil and re-emerge down slope where it eventually flowed into a drain at the rear of Godre'r Graig School.

Although they suggest it unlikely, they speculated that a major failure of the spoil tip would be able to reach Godre'r Graig School and recommended slope stability analysis and investigation.

3.2.3 Site 3 – Line of Adits and Associated Spoil

Site 3 comprises a series of adits and a series of liner spoil tips at the base of the ridgeline. The adit mouths were assessed as collapsed and had a narrow linear form, rather than a 'horseshoe' shape. The tip flanks were well vegetated and colliery spoil was noted where possible.

There were no obvious drainage features in this area.

Evidence of slow soil creep and probably historic rock falls were noted, however, they stated that these were likely to present a low risk to public safety.

They speculated that if a significant failure was to occur, it could 'flow' downslope to the east with the potential to reach Godre'r Graig Cemetery, although they considered that this had a low probability.

3.3 Coal Authority Recommendations

The Coal Authority provided recommendations, considerations and actions which, for ease of reference, are replicated below:

- Investigate ownership of Site 1 and establish wat measures, if any, have been taken with regard to placing recent materials over historic spoil materials;
- Investigate activity within Cwar Pentwyn to establish if planning or quarry regulations have been breached;
- Ensure drainage system from adit positions at Cwar Pentwyn is maintained;
- Consider clearing vegetation to allow inspection of drainage routs at Site 2;
- Ensure drainage infrastructure to the rear of Godre'r Graig Primary School is regularly inspected and maintained;
- Consider undertaking a slope stability analysis for Site 2 based on available information supplemented by ground investigation;
- Consider spraying of Japanese Knotweed to rear of school; and
- Undertake an inspection during winter, when vegetation has died back to allow a more detailed viewing of the site with less vegetation constraints. The requirement for further inspection should be determined following the winter inspection.

4 Preliminary Exploratory Investigation

4.1 Investigation Points

4.1.1 Introduction

A preliminary intrusive investigation was undertaken between 21st and 25th June 2019 in accordance with BS5930:2015 (method only) and was designed to provide an initial indication of the shallow soils located to the north of the school where evidence of shallow soil creep was occurring. It comprised trial pitting and windowless sampler boreholes. A short period of groundwater monitoring has been undertaken.

Due to dense vegetation and steep slopes, it was not possible to undertake a wide ranging investigation at this time.

The exploratory holes were supervised and logged by an engineering geologist in general accordance with BS5930:2015. Descriptions and depths of the strata encountered are presented on the borehole and trial pit records in Appendix C and Appendix D respectively. The investigation point positions are shown on Figure 1.

The ground levels indicated on the investigation point records are approximate only. The number of investigation points was limited on site following discussion with the land owner, this was to limit disturbance to the site, whilst still providing initial information for the ground model.

4.1.2 Trial Pits

5no. trial pits (TP1 to TP5) were excavated across the site on 21st June 2019 using a wheeled, backacting hydraulic excavator. The trial pits were excavated to depths of between 1.8m and 2.9m. The trial pit records are presented as Appendix C, and their positions are shown on Figure 1.

Disturbed samples were collected from the trial pits for laboratory testing as shown on the trial pit records.

On completion, the trial pits were backfilled with arisings in layers compacted with the excavator bucket, and the Topsoil reinstated on the surface. The arisings were left slightly proud of the adjacent surface to allow for future settlement.

4.1.3 Windowless Sampling

6no. windowless sample boreholes (WS1A to WS6) were constructed on 24th and 25th June 2019 to depths between 2.7 and 5m. The borehole records are presented as Appendix D, and their positions are shown on Figure 1. Borehole position WS1 was terminated at shallow depth due to obstructions, and WS1A as excavated near to this position.

A hydraulically powered rig was used to drive plastic lined sampling tubes into the ground, with the soil recovered within the tubes, which are then split to allow sampling and logging. Disturbed samples were obtained throughout the boreholes for identification and laboratory testing purposes, as shown on the borehole records. The windowless sampling provided generally good recovery to the depth of refusal.

At the commencement of each borehole, a square of the grass landscaping was cut, and a service inspection pit excavated by hand to a depth of 1.2m.

Standard Penetration Tests (SPT) were carried out using a split spoon in the boreholes in accordance with BS EN ISO 22476-3 (2005) and BS5930 (2015) to assess the relative density of the coarse-grained soils encountered in the borehole and to provide a correlated assessment of the likely undrained shear strength of fine-grained soils using relationships published by Stroud (1975). As required in BS5930:2015, the SPT N-values shown on the borehole records are the direct, uncorrected results obtained in the field.

On completion, monitoring instrumentation was installed in the boreholes as detailed in Section 4.2.

4.2 Groundwater Installations and Monitoring

A 50mm diameter HDPE monitoring well was installed in selected boreholes to allow monitoring sampling of groundwater in general accordance with BS ISO 5667-22 (2010). The wells, comprising slotted plastic pipe with a gravel/sand surround (the response zone), bentonite seals above the response zone, and a lockable vandal proof cover, were installed in boreholes as detailed on the borehole records and summarised in Table 1 below.

Table 1: *Well Installations*

Well ID	Installation Type	Date of Installation	Response Zone depth	Response Zone Stratum	Rationale
WS1A	50mm well	24/5/2019	1.0 – 4.0m	Diamicton	2
WS2	50mm well	24/5/2019	1.0 – 5.0m	Diamicton	2
WS3	50mm well	24/5/2019	1.5 - 3.0m	Diamicton	2, 3
WS4	50mm well	25/5/2019	0.7 – 3.7m	Diamicton	2
WS5	50mm well	25/5/2019	0.7 – 2.7m	Diamicton	2
WS6	50mm well	25/5/2019	1.0 – 5.0m	Diamicton	2

Notes to Table 1

1. Details of each monitoring well are presented on the individual borehole records (Appendix C).
2. Well installed in Diamicton with large response zone to understand general water level.
3. Deep section of bentonite seal to prevent any inflow from suspected land drain.

The installations have been monitored on a spot basis on two occasions, the first on 19th July 2019 and the second visit on 8th August 2019.

4.3 Geotechnical Laboratory Testing

Geotechnical laboratory testing was undertaken on samples from the suitable quality classes recovered from the exploratory holes in order to obtain information on the geotechnical properties on the soils beneath the site.

The results of some particle size analysis tests are presented in Appendix E.

5 Development of the Conceptual Model

5.1 Conceptual Ground Model - Geology

The exploratory holes have shown that generally a thin veneer of topsoil overlies Diamicton, pockets of made ground are present, notably near existing structures. Weathered rock or bedrock was not encountered but is anticipated at depth.

Made Ground: encountered to a maximum depth of 1.7m as a dark grey to dark brown clayey sandy gravel with cobbles of brick, concrete and plastic fragments.

Topsoil: the typically comprises dark brown clayey gravelly organic sand with roots and typically extended to a depth of about 0.2m.

Glacial Diamicton: encountered beneath the Made Ground and Topsoil to a maximum depth of 5m, initially as an orange-brown sandy very gravelly clay whereupon a coarser unit was encountered which comprised a dark grey to brown clayey sandy gravel to sometimes a gravelly clay. Gravel and cobbles in both Diamicton units was rounded to subangular and fine to coarse, with notable more prevalent fine coal gravel in the orange brown Diamicton.

Field SPT N-values within the upper sandy gravelly clays suggested a firm to stiff and very stiff consistency. SPT N-values within the lower clayey gravels were typically medium dense to dense and very dense.

Within borehole WS6, the SPT N-values dropped, suggesting a loose horizon at a depth of around 4m to 5m; groundwater was struck at a depth of 4m in WS6. The Diamicton at this depth comprised more sand then at other points and it is considered the combination of sandier materials and the groundwater resulted in the lower SPT values.

South Wales Upper Coal Measures Bedrock: not encountered in the investigation but will be present at depth.

5.2 Conceptual Ground Model - Hydrogeology

5.2.1 Monitoring and Groundwater Bodies

The groundwater conditions identified in the investigation are summarised in Table 2 below:

Table 2: *Summary of Groundwater Ingress in the Investigation*

Hole ID	Stratum	Comment on groundwater encountered
TP2	Diamicton	Seepage of groundwater at 1.4m.
TP3	Diamicton	Seepage of groundwater at 1.6m.
WS2	Diamicton	Groundwater struck at a depth of 4.8m
WS4	Diamicton	Groundwater struck at a depth of 3.4m
WS6	Diamicton	Groundwater struck at a depth of 4.0m

Notes to Table 2:

1. Full details of groundwater ingress presented on exploratory hole records in Appendix C and D.

The results of the monitoring are presented in Table 3 below.

Table 3: Monitoring Data

Well ID	Response Zone depth	**Visit 1 (19/07/2019)**	**Visit 2 (08/08/2019)**
		Depth to water (m)	
WS1A	1.0 – 4.0m	Standpipe dry to 5m	Standpipe dry to 5m
WS2	1.0 – 5.0m	2.21	2.15
WS3	1.5 - 3.0m	1.82	1.65
WS4	0.7 – 3.7m	1.57	1.55
WS5	0.7 – 2.7m	Water at ground level	0.7
WS6	1.0 – 5.0m	Standpipe dry to 5m	Standpipe dry to 5m

Based on the above findings and the Conceptual Ground Model, we consider that the main groundwater body beneath the site is within the bedrock below the depth of the investigation, however, the site observations and monitoring suggest an in persistent, or variable groundwater body within the Diamicton. This has been noted to be near the surface in one of the visits carried out to date.

6 Hazard Identification and Risk Assessment

6.1 Introduction

A Landslide hazard and risk assessment for the terrain above Godre'r Graig School ("the School"), Godre'r Graig, South Wales (Inserts 1 and 3) has been undertaken. We have collaborated with Steve Parry[2] on the assessment of natural hazards/landslides. The hazard and risk assessments for man-made hazards/landslides in the study area are detailed in the individual sections below.

The Study Area extends upslope (NW) for a horizontal approximately 400m from Graig Road. ESP have provided copies of historical maps, aerial photographs, and a technical note (5859e – 00 GYG School Technical Note). In addition, an orthorectified aerial photograph (2013) and DEM were obtained.

Insert 3: Location Plan. School outlined in red.

The landslide hazard and risk assessment comprises three phases:

1. Phase one, an initial appraisal comprising an evaluation of historical data, aerial photography interpretation and engineering geomorphological mapping from the desk study data;
2. Phase two, site specific engineering geomorphological mapping; and

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[2] Co-editor of: Developments in Engineering Geology. Geological Society Special Publication. 2016.
Author of: Landslide hazard assessments: problems and limitations. Examples from Hong Kong. 2016.
Chair of the IAEG commission C25 'Use of Engineering Geological Models'.
Member of the European Federation of Geologists' 'Group of Experts' on Natural Hazards and Engineering Geology.
Member of the International Association of Geomorphologists' Working Group on Applied Geomorphological Mapping.

3. Phase three, a final appraisal of the landslide hazard and risk for the school.

This report comprises the final assessment of landslide hazard and risk for the school.

6.2 Landslide Hazard and Risk

There are no UK standards for the assessment of landslide hazard and risk. However, Fell et al. (2008), reporting on behalf of JTC-1 (Joint Technical Committee on Landslides and Engineered Slopes, an IAEG, ISRM, ISSMGE collaboration exercise, i.e. all relevant international geotechnical societies) provides guidelines for landslide hazard and risk assessments. JTC-1 is broadly in line with AGS (2007) with minor modification for international practice.

The guidelines provide:

- Definitions and terminology for use internationally;
- Description of the types and levels of landslide zoning;
- Guidance on where landslide zoning and land use planning are necessary to account for landslides;
- Definitions of levels of zoning and suggested scales for zoning maps taking into account the needs and objectives of land use planners and regulators and the purpose of the zoning;
- Guidance on the information required for different levels of zoning taking account the various types of landslides;
- Guidance on the reliability, validity and limitations of the methods; and
- Advice on the required qualifications of the persons carrying out landslide zoning and advice on the preparation of a brief for consultants to conduct landslide zoning for land use planning.

The guidelines also provide the following definitions:

Hazard — *A condition with the potential for causing an undesirable consequence. The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the probability of their occurrence within a given period of time*.

Elements at risk —*The population, buildings and engineering works, economic activities, public services utilities, other infrastructures and environmental values in the area potentially affected by the landslide hazard.*

Vulnerability — *The degree of loss to a given element or set of elements within the area affected by the landslide. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is (are) affected by the landslide.*

Risk — *A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability of a phenomenon of a given*

> *magnitude times the consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form. For these guidelines risk is further defined as: (a) For life loss, the annual probability that the persons at risk will lose their life taking into account of the landslide hazard, and the temporal–spatial probability and vulnerability of the person (b) For property loss, the annual probability of a given level of loss or the annualised loss taking into account the elements at risk, their temporal–spatial probability and vulnerability.*
>
> Zoning — *The division of land into homogeneous areas or domains and their ranking according to degrees of actual or potential landslide susceptibility, hazard or risk or applicability of certain hazard-related regulations.*

The guidelines note that "*Qualitative methods are often used for susceptibility zoning, and sometimes for hazard zoning. When feasible it is better to use quantitative methods for both susceptibility and hazard zoning. Risk zoning should be quantified. More effort is required to quantify the hazard and risk but there is not necessarily a great increase in cost compared to qualitative zoning*".

Lee and Jones (2014) note that there are three broad types of risk estimation:

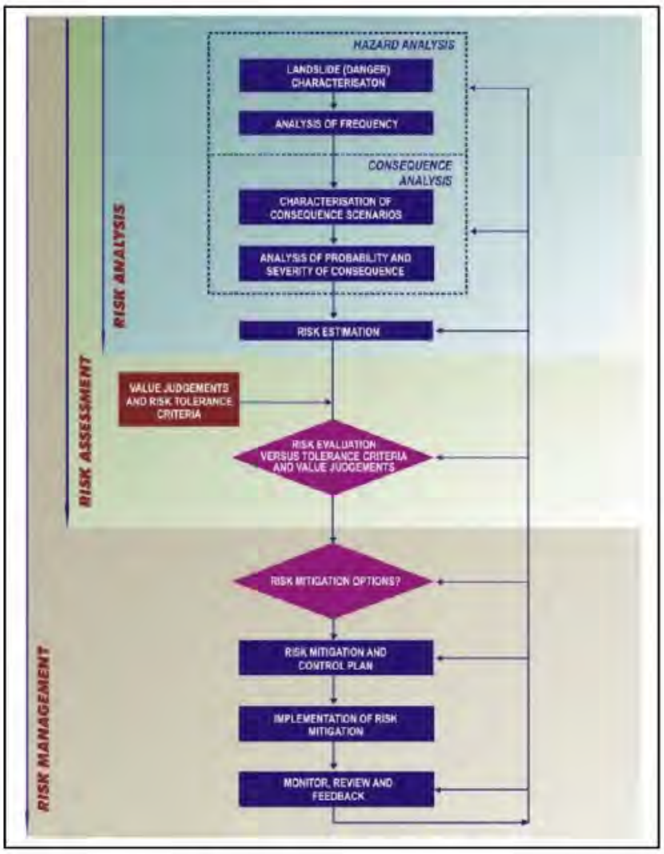
- Qualitative risk estimations are "*those where both likelihood and adverse consequences are expressed in qualitative terms. They are therefore highly subjective estimations*"
- Semi-quantitative risk estimations which are "*combinations of qualitative and quantitative measurements of likelihood and consequence*"
- Qualitative risk estimations (or quantitative risk assessments, QRA) which "*combine values of detriment with probabilities of occurrence. It must be noted that such an approach frequently does not produce a single answer*"

Whilst the AGS/JTC-1 guidelines were developed for hazard and risk zoning, i.e. assessing landslide hazard and risk for new developments, they are equally applicable for evaluating landslide hazard and risk to existing developments. Where appropriate, the AGS guidelines were used as the basis of this assessment.

JTC-1/AGS (2007) suggest the following stages for a landslide hazard and risk assessment:

- Hazard identification which comprises classification of landslides, extent of landslides (area and volume), travel distance of landslides and rates of movement;
- Frequency analysis comprising estimation of frequency, historic performance, relate to initiating events;
- Consequence analysis comprising elements at risk, temporal probability and vulnerability; and
- Risk calculation.

Once these steps have been undertaken an evaluation of risk and risk mitigation can be considered.



Insert 4: Framework for landslide risk management (Fell et al, 2008)

6.2.1 Landslide Classification

Landslides are typically classified in terms of material type (rock, debris, earth) and movement type (fall, topple, slide, flow) following the definitions of Cruden & Varnes (1996). However, landslides can be complex processes. For example, a landslide may initiate as a slide, disaggregate and become a debris avalanche, enter a drainage line and become a debris flow, enter a flatter area, deposit the coarse material but continue downstream as a debris flood. Hungr et al., 2001 noted problems with the use of the flow terminology as proposed by Cruden & Varnes (1996) and proposed amended terminology (Table 4).

Table 4: *Classification of Landslide Types (after Hungr, et al., 2001).*

Movement Type	Rock	Debris	Earth
Fall	1. Rock fall	2. Debris fall	3. Earth fall
Topple	4. Rock topple	5. Debris topple	6. Earth topple
Rotational sliding	7. Rock slump	8. Debris slump	9. Earth slump
Translational sliding	10. Block slide	11. Debris slide	12. Earth slide
Lateral spreading	13. Rock spread	-	14. Earth Spread
Flow	15. Rock creep	16. Talus flow	21. Dry sand flow
	-	17. Debris flow	22. Wet sand flow
	-	18. Debris avalanche	23. Quick clay flow
	-	19. Solifluction	24. Earth flow
	-	20. Soil creep	25. Rapid earth flow
	-	-	26. Loess flow
Complex	27. Rock slide-debris avalanche	28. Cambering, valley bulging	29. Earth slump-earth flow

Consequently, where a landslide is interpreted as involving *"a rapid to extremely rapid flow of saturated non-plastic debris in a steep channel" (Hungr et al., 2001*), it is classified as a debris flow, where it is interpreted as involving *"very rapid to extremely rapid shallow flow of partially or fully saturated debris on a steep slope without confinement in a channel." (Hungr et al., 2001*), it is classified as a debris avalanche. As noted by Hungr et al., 2014 *"the practical consequences of the distinction between debris flow and debris avalanches are obvious. A debris flow hazard study begins with the definition of the path and at least the lateral limits of the deposition area (fan). The path and the debris fan can be expected to contain evidence of past occurrences which can be used to derive information on magnitude and frequency. Debris avalanche studies, on the other hand, must examine tracts of steep slopes, many segments of which may not have experienced debris avalanches during the observable past*".

6.3 Hazard Identification

6.3.1 Elements at Risk

The elements at risk are the school building (temporally and spatially fixed) and the population of the school (temporally and spatially variable). The school was built between 1899 and 1918 (Section 4.3) and is of masonry construction. The school playground is located at the rear of the school below a masonry retaining wall (Plate 1).

***Plate 1**: Retaining wall between the school playground and the natural slope.*

6.3.2 Previous Landslide Assessments

The most significant landslide in the area is the large complex landslide (Godre'r Graig Landslide), the right flank of which is located approximately 580m northwest of the school. This became significantly active in the late 1950's and early 1960's, which eventually led to the closure of Graig Road (A4068) and the abandonment of the village of Pantyffynnon (Halcrow 1987). This area was studied by Halcrow (1987) however this study does not extend beyond the boundary of the landslide itself.

The British Geological Survey (BGS) geological map sheet SN 70 NE records an area of "shallow slips" 250m NE of the school.

A search of NPTC records by ESP has not located any additional landslide information in the study area.

6.3.3 Historical Maps

The earliest historical map (1877) shows the school has not been constructed but the cemetery is present as well as two quarries, one to the NW and one to the NNW. Both are shown with spoil extending down slope from the quarries. Both quarries were extended by 1899. The school was constructed between 1899 and 1918. In 1960 a series former adits trending NE from the disused quarry located to the NW of the school, aligning with the position of the Upper Pinchin as shown on the geological map.

6.3.4 Aerial Photograph Interpretation

An Aerial Photograph Interpretation (API) of historical aerial photographs supplied by ESP has been undertaken. The photographs evaluated are documented in Appendix 1.

The API was carried out using a Sokkisha stereoscope with x3 binocular attachments. The API was made on a basis of shape, pattern, size, tone/colour and texture together with morphographical position.

The API has two key aims:

- to generate an initial engineering geological and engineering geomorphological maps of the study area, and
- to evaluate for any evidence of previous landslides in the study are and, if present, generate a site-specific landslide inventory.

The engineering geological and engineering geomorphological mapping was undertaken predominantly using the 1945 and 1952 aerial photographs given their higher quality. However, all the aerial photographs were reviewed to evaluate for the presence of landslides as well as anthropogenic modification that could induce instability.

The aerial photographs were imported into a Geographical Information System (GIS) using the software ArcGIS and the images orthorectified to assist with the locations of features observed in the API.

6.3.5 Engineering Geology and Geomorphology

An initial engineering geomorphological map was generated from API (PEGS, 2019). This formed the basis of the field mapping which was undertaken on 6 June 2019 with ESP and the final engineering geomorphological map of the site is shown in Figure 2.

The Study Area shows a distinctive "stepped" topographical profile, largely reflecting the underlying geology.

The highest terrain is formed by Mynydd Allt-y-grug which rises to a height of 338mOD. The summit is relatively gently sloping. A sharp convex break in slope is present at approximately 292mOD associated with a linear rock outcrop below which the terrain is steep (25-30°) and associated with limited vegetation and a talus drape. A dry-stone wall is present at the toe of the talus slope and there was no evidence of damage to the wall from rock fall nor any evidence of repairs resulting from rock fall.

***Plate 2**: Rock outcrop (Rhondda Sandstone) with the associated talus slope below.*

Larger individual blocks (rock falls) are present extending further downslope from the talus drape, the largest of which is 0.2m x 3.0m x 2.0m. A number of the features initially identified as rock blocks from the API actually comprise soil mounds (Plate 3). It is considered that the generation of large rock falls was probably associated with periglacial conditions at the end of the last ice age (approx. 11, 700 years BP) and consequently the main trigger for rock fall processes is no longer active. Smaller falls of cobble size blocks may still occur although again this process would have predominantly been active during periglacial conditions.

According to the published geological map Mynydd Allt-y-grug and the steep terrain is underlain by Rhondda Sandstone.

***Plate 3**: Soil mounds and rock blocks below the talus slope*

The base of this steeper terrain is marked by a district concave break in slope which corresponds to the outcrop of the No2 Rhondda coal seam at the base of the Rhondda Sandstone. Coal workings are evident in the form of adits and associated spoil in the NE of the study area, with the working of the seam apparently evident in the 1973 and 1975 aerial photographs. Below the No 2 Rhondda the Llynfi Beds are present, comprising alternating sandstone and mudstone resulting in stepped topography. The published geological map shows the Upper Pinchin Coal seam as outcropping at approximately 178mOD. This is associated with over steep, anthropogenically modified, terrain as well as a series of adits reflecting its historical working (Plate 4).

***Plate 4**: Anthropogenically modified over steep slope and location of a formed adit*

Two abandoned quarries are also present located above the outcrop of the Upper Pinchin. These are shown on the earliest historical maps (1877). Both quarries are associated with spoil heap with extend down slope. The Llynfi Beds are exposed at the Quarry to the NW of the School comprising weak to medium strong, thinly bedded, dark grey, partially weathered to unweathered, micaceous sandstone. Bedding dips at 20/185. Two additional discontinuity sets were observed 84/274 with an approximately 1m spacing and 74/018 with a spacing of approximately 5m. The latter set is dilated with an aperture of up to 10cm (Plate 5), reflecting either the effects of mining or cambering.

Plate 5: Bedding dipping from left to right (20/185) the rock face is formed by joint set 84/274 and the dilated joint set is formed by 74/018.

Plate 6: Recently deposited spoil from work in the quarry to the NW of the School.

Recent works have been undertaken in the NW quarry with an improved access road constructed. Spoil from this work has been end tipped below the quarry entrance (Plate 6).

Based on the exposure in the NW quarry, the spoil comprises interlocking, angular and tabular boulders and cobbles of weak to medium strong sandstone (Plate 7). The spoil associated with both quarries is associated with very dense vegetation, especially brambles limiting access.

Plate 7: Spoil exposed in the NW quarry

6.3.6 Landslide Inventory

There was very limited evidence for previous landslides from the API. These possible landslides were tentatively identified in the 1952 aerial photographs (Insert 5). Three arcuate depressions are located below these features that, based on the API, were considered to have been possible formed by landslide processes.

The "shallow slips" recorded on the geological map are not apparent on the historical aerial photographs. However, two areas interpreted as being associated with hydrophilic vegetation are evident in the 2013 orthophotograph (Insert 6).

Insert 5: Extract from 1952 photograph with possible landslides circled

Insert 6: Enlargement of 2013 Orthophotography showing possible landslides identified in the area of “shallow slips” recorded on the geological map

All these locations were inspected during the field mapping.

The features identified as possible landslides and depression in the API are associated with relatively deep (2-3m high) depressions which are probably the location of adits. The high reflectance evident in the 1952 aerial photographs is considered to reflect localised instability associated with the over steep adit sides. The longest run out is approximately 27m.

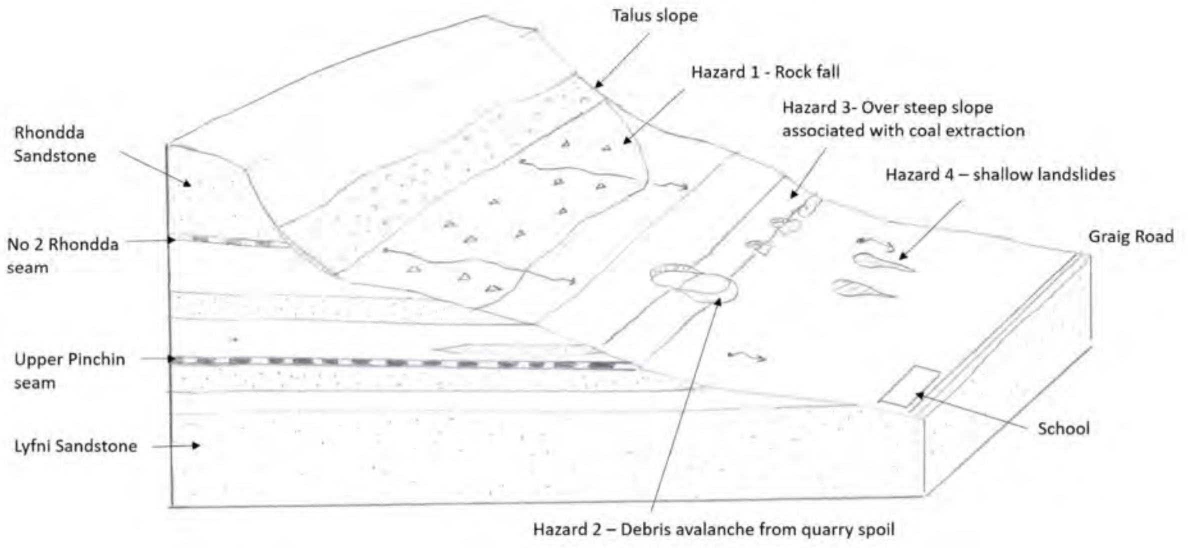
The area of “shallow slips” comprises a series of shallow depressions associated with springs and hydrophilic vegetation. A small cut slope 0.2m – 0.3m high, associated with a former tramway crosses the toe of these features. This exposes of clayey silt with occasional sub angular, medium to coarse gravel which has been interpreted as colluvium. There is no evidence of movement in this cut slope. Shallow (<0.2m) earthslides/earthflows may be associated with these depressions. This terrain extends across the study area to the SW and instability, in the form of a distressed road (Plate 8) and a shallow depression, was noted within the cemetery at approximately the same level. At the rear of the School there was no evidence of landslides or distress. However, terracettes suggesting very shallow soil movement and wet ground is present.

***Plate 8**: Distress evident in the upper part of the cemetery.*

6.4 Hazard Types

Based on the initial API, four possible hazard types were identified (Insert 7):

- Hazard type 1. Rock fall - possible structural damage, impact on people;
- Hazard Type 2. Debris avalanche initiating from quarry spoil – impact loading on structures, impact/burial of people outside building, burial of people inside buildings (ground floor) if sufficient volume;
- Hazard Type 3. Debris avalanches initiating from over steep slope – impact loading on structures, impact/burial of people outside building, burial of people inside buildings (ground floor) if sufficient volume; and
- Hazard Type 4. Shallow earth slides - slow ground displacement leading to vertical or lateral displacement, or undermining of structures and infrastructure.



Insert 7: Conceptual Engineering Geological Model of site from API

Evaluation of these potential hazard types was a focus of the site mapping.

6.4.1 Hazard Type 1: Rock fall initiating from outcrops of the Rhondda Sandstone typically at 260-270mOD.

Smaller, typically cobble size, more frequent, rock falls have led to the development of a talus slope. Larger blocks have travelled further with the nearest to the school located at 192mPD, approximately 180m horizontal distance from the outcrop. There was no evidence of damage due to rock fall or repairs resulting from rock fall to the wall at the toe of the talus slope. Movement velocities of rock fall tend to be rapid ($5x10^1$ mm/s to $5x10^{-1}$ mm/s i.e., 1.8m/hr to 3m/min). If rock falls reach the elements at risk these may result in a risk to life where individuals are in the school playground. The school buildings are likely to offer a high degree of protection and therefore they are unlikely to pose a risk to life. Any structural damage is likely to be limited.

6.4.2 Hazard Type 2: Impact from debris avalanche initiating from the spoil associated with the former quarry to the NW of the school.

Debris avalanches are likely to be rapid to very rapid ($5x10^1$ mm/s to $5x10^3$ mm/s i.e., 3m/min to 5m/sec). The boundary between rapid and very rapid is approximately the average human running speed. If the debris reaches the school, it may result in a risk to life where individuals are within the playground. If the volumes are relatively small, the debris may only result in limited structural damage. If larger volumes of debris are involved this may result in more significant damage and possible risk to life.

6.4.3 Hazard Type 3: Impacts from debris avalanches originating from the over steep slope associated with the working of the Upper Pinchin seam.

Associated movement velocities with debris avalanches are likely to be rapid to very rapid ($5x10^1$ mm/s to $5x10^3$ mm/s i.e., 3m/min to 5m/sec). The boundary between rapid and very rapid is approximately the average human running speed. If the debris reaches the school, it may result in a risk to life where individuals are within the playground. If the volumes are relatively small, the debris may only result in limited structural damage. If larger volumes of debris are involved this may result in more significant damage and possible risk to life.

6.4.4 Hazard Type 4: Shallow earth slides.

These were tentatively identified from API in the area of "shallow slips" noted on the geological map. Associated movement velocities are likely to be very slow to slow (5x10^{-7} mm/s to 5x10^{-5} mm/s i.e., 1.6m/year to 16mm/year). The limited depth and low movement velocities are unlikely to pose a risk to life and any structural damage is likely to be limited.

Figure 3 shows the location of each hazard type.

6.5 Frequency and Run Out

6.5.1 Hazard Type 1: Rock fall initiating from outcrops of the Rhondda Sandstone.

It is considered that the majority of the rock falls were associated with periglacial conditions occurring at the end of the last ice age (approximately 11,700 years BP). Whilst small scale detachments may still occur these are likely to be infrequent. The processes which triggered the large rock falls are no longer active in the current climate.

Rock fall associated with small-scale (cobble size) rock blocks is not considered to be a hazard to the School given their limited mobility.

Large rock falls potentially pose a hazard to the school. However, the field evidence suggests that these occurred during periglacial conditions and as such their likelihood of occurrence (i.e. new detachments) is likely to be extremely low. As a result, a return period of 10,000 to 100,000 years has been assumed for the probability of detachment of a large rock block.

The boundary of the school playground is approximately 410m horizontal distance from the outcrop, i.e. over twice the distance of the furthest observed boulder. Consequently, the probability of a detached rock block reaching the school is considered to be extremely low.

6.5.2 Hazard Type 2: Impact from debris avalanche initiating from quarry spoil.

There was no evidence of debris avalanches evident in the API or from the field mapping. The estimated distance between the toe of the quarry spoil heap and the school boundary is 50m.

Based on limited exposures the spoil probably comprises interlocking, angular and tabular boulders and cobbles of weak to medium strong sandstone. The relatively high permeability and interlocking nature of this material suggests the material is stable and there is a relatively low likelihood of occurrence of landslides. However, ground investigation and slope stability assessment is needed to confirm this.

The stability of the colliery spoil (Hazard Type 2) has been assessed separately.

6.5.3 Hazard Type 3: Impacts from debris avalanches originating from the over steep slope associated with the working of the Upper Pinchin seam.

There is no evidence of instability associated with the over steep slope from either API or field inspections. However, based on the API there is evidence for landslides (in the 1952 aerial photographs) associated with former adits, with a maximum interpreted run out of <30m. This suggests a minimum return period of 10's to 100's of years. There is only a single adit directly above the school and the distance between the adit and the school boundary is approximately 180m, i.e. almost seven times the furthest runout observed from API.

6.5.4 Hazard Type 4: Shallow earth slides.

Based on the site mapping these features appear to be relatively shallow (<0.2m) earthslides/earthflows. These are likely to reactivate during periods of intense rainfall, with return periods in the range of years to 10s of years. However, the likelihood of runout run out beyond the mapped extent is considered to be very low.

At the rear of the School there was no evidence of landslides or distress.

6.6 Risk Assessment

Based on the API and field mapping there is very limited evidence of recent landslide process occurring at the site. As a result, it is not possible to undertake a quantitative landslide assessment. Consequently, a qualitative assessment of both hazard and risk has been undertaken.

The AGS (2007) provide a methodology for the qualitative assessment of risk to property and this has been adopted for the identified hazard types (Tables 5 to 8). The risk levels are summarised in Table 4.

6.6.1 Hazard Type 1: Rock fall initiating from outcrops of the Rhondda Sandstone.

As discussed in Section 6, the majority of the rock falls are considered to have been associated with periglacial conditions occurring at the end of the last ice age (approximately 11, 700 years BP). Whilst small scale detachments may still occur these are likely to be infrequent. It is considered that the processes generating the large rock falls are no longer active in the current climate. As a result, a return period of 10,000 to 100,000 years has been assumed for the probability of detachment of a large rock block. Furthermore, the likelihood of a detached boulder reaching the school is considered low (assumed to be 10% probability). This suggests a likelihood of impact of >10-5 i.e. "rare".

The consequences of any impact is considered to be limited damage to part of the structure i.e. minor consequences. This suggests a very low level of risk to property from this hazard.

6.6.2 Hazard Type 2: Impact from debris avalanche initiating from quarry spoil.

The stability of the colliery spoil (Hazard Type 2) has been assessed separately, using the findings of the field mapping and an event tree approach (Section 7).

6.6.3 Hazard Type 3: Impacts from debris avalanches originating from the over steep slope associated with the working of the Upper Pinchin seam.

There is no evidence of instability associated with the over steep slope from either API or field inspections. However, based on the API there is evidence for landslides associated with former adits. The desk study and field mapping recorded 17 adits of which three have been interpreted as potentially having landslides associated with them i.e. 17% chance over a 74-year period. As a result, a return period of 100 years has been assumed for the probability of detachment

There is only a single adit directly above the school and the distance between the adit and the school boundary is approximately 180m, i.e. almost seven times the furthest runout observed from API and a <10% probability of runout reaching the School has been assumed. This suggests a likelihood of impact of $<10^{-3}$ i.e. "possible".

The limited spatial extent of the adits suggest that landslide volumes would be limited. The consequences of any impact is considered to be little damage, i.e. insignificant consequences. This suggests a very low level of risk to property from this hazard.

6.6.4 Hazard Type 4: Shallow earth slides.

There was no evidence of landslides or distress at the rear of the School as such it is considered this hazard does not pose a risk to the school.

Table 5: Summary Level of Risk to Property

Hazard Type	Likelihood Designation	Consequence Descriptor	Risk
Hazard Type 1 - Rock fall	Rare	Minor	Very low
Hazard Type 2 - Debris avalanche from quarry spoil	*	*	*
Hazard Type 3 - Debris avalanches associated with the **working of the Upper Pinchin seam**	Possible	Little damage	Very low
Hazard Type 4 - Shallow earth slides	N/A	-	-
Notes: *assessed separately			

6.7 Initial conclusions on landslide hazard and risk

There is insufficient data to undertake a quantitative risk assessment of the natural landslide hazard and risk.

Based on the assessment undertaken and described above, the natural landslide risk (including Hazard Types 1, 3 and 4) to the school building is considered to be very low. Hazard types 2 is considered further in Section 7.

7 Summary Risk Assessment and Implications

7.1 Introduction

The assessment has shown that there are four types of landslide hazard that have the potential to impact the school. Of these, two are natural process and two are man-made landslide/instability hazards and have been assessed separately below.

As discussed in previous sections, there is not considered to be a robust and widely used assessment criteria that can simply be adopted to undertake a preliminary qualitative assessment. Therefore, a modified assessment has been generated which is based upon terminology and qualitative descriptions used in the AGS 2007 guidance. It should be noted that the AGS 2007 qualitative assessment is for risk to property only.

In order to understand the potential risk posed from Hazard Type 2, an event tree has been considered to provide an indicative value of annual probability and the results are presented in Section 7.3.1. An event tree analysis uses a graphical construct to show the logical sequence of events or considerations that can be used to analyse the system leading to a particular outcome. It can be used for evaluation of probability of failure of a landslide, or consequence of failure, or risk. The logical sequence within the system is mapped as a branching network with conditional probabilities assigned to each branch of a node. The frequency of achieving a certain outcome is the product of the conditional probabilities leading to that outcome times the frequency of the initiating 'trigger' such as rainfall.

The modified descriptions and risk rankings used in this assessment are presented below. Table 6 provides a qualitative measure of likelihood and Table 7 presents a qualitative measure of consequences.

Table 6: Qualitative Measures of Likelihood

Approx. Annual Probability		**Implied Indicative** Landslide Recurrence **Interval (years)**		Description	Descriptor	Level
Indicative Value	**Notional Boundary**					
10^{-1}		10		The event is expected to occur ever the design life	Almost Certain	A
	$5x10^{-2}$		20			
10^{-2}		100		The event will probably occur under adverse conditions over the design life	Likely	B
	$5x10^{-3}$		200			
10^{-3}		1,000		The event could occur under adverse conditions over the design life	Possible	C
	$5x10^{-4}$		2,000			
10^{-4}		10,000		The event might occur under very adverse	Unlikely	D

				circumstances over the design life		
	5x10^{-5}		20,000			
10^{-5}		100,000		The event is conceivable but only under exceptional circumstances over the design life.	Rare	E
	5x10^{-6}		200,000			
10^{-6}		1,000,000		The event is inconceivable or fanciful over the design life.	Barely Credible	F

Notes:
1. The above table is adapted from the AGS 2007 Appendix C tables.

Table 7: Qualitative Measures of Consequence

Description	Descriptor	Level
Structure(s) completely destroyed and/or large-scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	Catastrophic	1
Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	Major	2
Moderate damage to some of structure, and/or significant part of the site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	Medium	3
Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	Minor	4
Little damage.	Insignificant	5

Notes:
1.The above table is adapted from the AGS 2007 Appendix C tables.
2.The table primarily considers risk to property.

The associated levels from Table 6 and 7 are then used in Table 8 to provide a qualitative risk ranking and Table 9 provides example implications for each risk ranking.

Table 8: Qualitative Risk Analysis Matrix

LIKELIHOOD	CONSEQUENCE (TO PROPERTY)				
	1 Catastrophic	**2** **Major**	**3** **Medium**	**4** **Minor**	**5** **Insignificant**
A – Almost Certain	Very High	Very High	Very High	High	Medium or Low^{2}
B – Likely	Very High	Very High	High	Medium	Low

C - Possible	Very High	High	Medium	Medium	Very Low
D - Unlikely	High	Medium	Low	Low	Very Low
E - Rare	Medium	Low	Low	Very Low	Very Low
F - Barely Credible	Low	Very Low	Very Low	Very Low	Very Low

Notes:
1.The above table is adapted from the AGS 2007 Appendix C tables.
2.Further consideration required, see AGS 2007 Appendix C tables for clarification.

Table 9: Risk Level Implications

Risk Level	Example Implications[1]
Very High	Unacceptable without treatment. Extensive detailed investigation, research, planning and implementation of treatment options essential to reduce risk to low. May be too expensive or impractical. Work likely to cost more than value of property.
High	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to low. Work would cost a substantial sum in relation to the value of the property.
Medium	May be tolerated in certain circumstances (subject to regulator approval) but requires investigation, planning and implementation of treatment options to reduce the risk to low. Treatment options to reduce the risk to low risk should be implemented as soon as practicable.
Low	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
Very Low	Acceptable. Manage by normal slope maintenance procedures.

Notes:
1.The above table is adapted from the AGS 2007 Appendix C tables.

A qualitative assessment has been undertaken using the information gained, which is to a large extent is governed by discrete points in time, i.e. when the aerial photographs were taken or when the area was resurveyed for the historical maps.

Whilst the historical maps have provided key information on the streams and mining features around the study area, they do not show any movement of the landslide, or show the form of the landslide which is likely to have been too small, or insignificant to show. Therefore, the assessment is largely based upon the period of time covered by the aerial photographs, from 1945 to the present day. The above assumption should thus provide a more conservative assessment.

7.2 Natural Landslide Hazards

7.2.1 Hazard Type 1

As discussed in Section 6.6, the majority of the rock falls observed are likely to have been associated with periglacial conditions occurring at the end of the last ice age.

If any small scale detachments occur, these are likely to be infrequent and the likelihood of a detached boulder reaching the school is considered low, assuming limited damage is occurred to the school, there is likely to be a very low risk to the property from this hazard.

7.2.2 Hazard Type 4

The 'shallow slips' suggested by the geological map were tentatively identified in the aerial photograph review and the site mapping showed these features to be relatively shallow (<0.2m) earthslides/earthflows.

No visual evidence of these features were noted at the rear of the school and the trial pits and boreholes showed no evidence of these features.

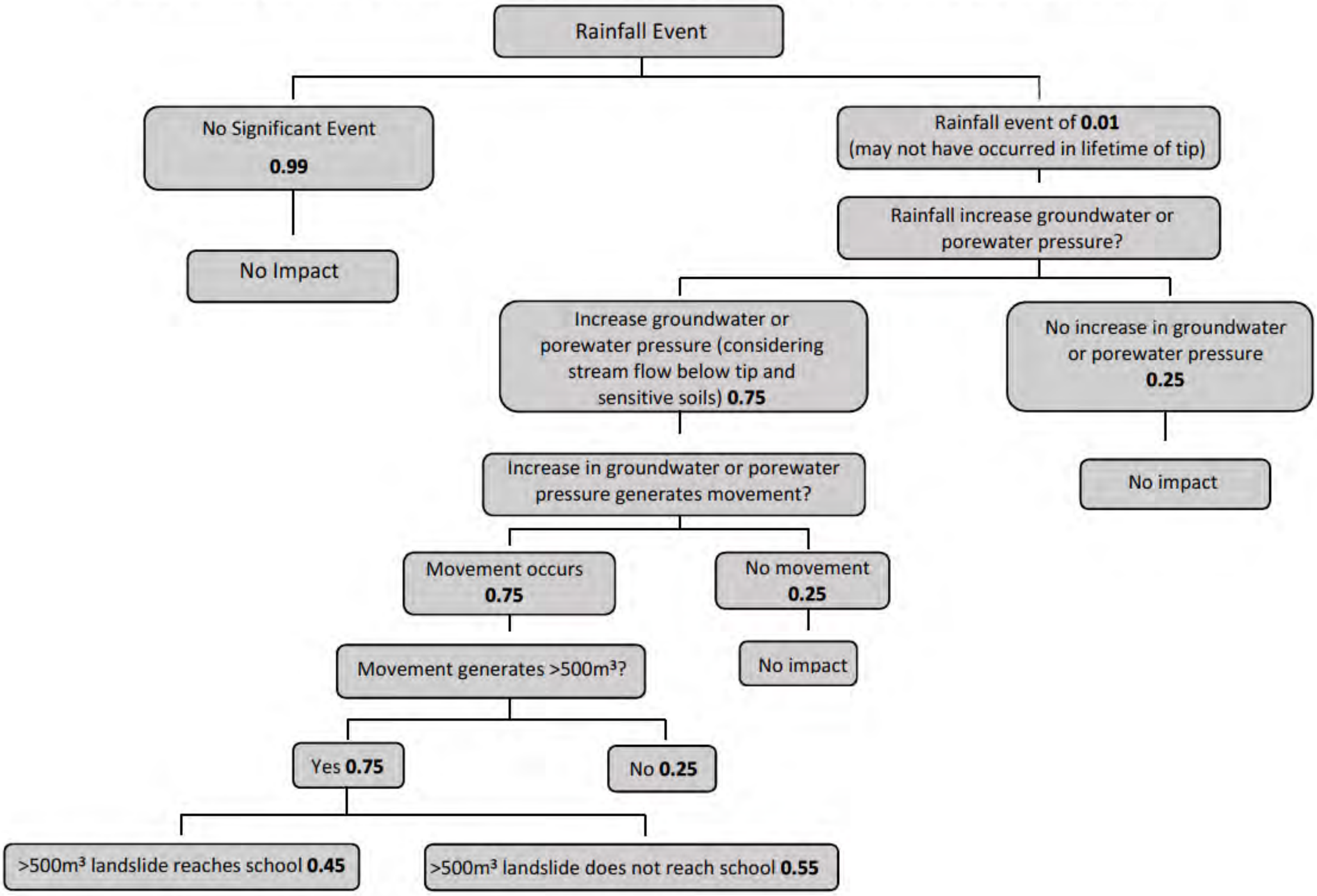
It is such considered that this hazard does not pose a risk to the school.

7.3 Man-made Landslide Hazards

7.3.1 Hazard Type 2

Impact from debris avalanche initiating from quarry spoil.

As discussed in Section 7.1, an event tree has been used to provide a qualitative, indicative value of approximate annual probability for such an event occurring. The event tree is presented below.



Using the probabilities assigned in the event tree, it suggests that the estimated annual probability of a landslide hitting the school is 0.0019, or $1.9x10^{-3}$. Using Table 6 above, this annual probability correlates to a 'possible' likelihood i.e. the event could occur under adverse conditions over the design life. Table C7 in the Commentary of the AGS guidelines provides some further information on a $x10^{-3}$ order of magnitude, which is that 'the occurrence of the condition or event is not observed in the available database. It is difficult to think about any plausible failure scenario; however, a single scenario could be identified after considerable effort'. We consider that this statement has similarities with our assessment for Hazard Type 2, as this observations made on site and some probable conditions (such as the coarse free draining nature of the tip) suggest that instability may not be possible, however, these conditions are unproven and cannot be assumed.

We consider that a $>500m^3$ debris avalanche reaching the school could cause moderate damage to some of the structure, and/or significant part of the site which would require large stabilisation works. Such a consequence is described as medium using Table 7 above.

Using table 8 above, the 'possible' likelihood and a consequence of 'moderate', the qualitative risk assessment is of medium risk.

The AGS guidelines state (Table 9) that a medium risk may be tolerated in certain circumstances (subject to regulator approval) but requires investigation, planning and implementation of treatment options to reduce the risk to low. Options to reduce or reclassify the risk to low risk should be implemented as soon as practicable and this requires information on the spoil tip.

For this site, such further measures/options should include:

- Visual assessment of the stream either after vegetation removal or during winter months;
- Investigation of the tip to allow monitoring and slope stability assessment (in line with Coal Authority recommendations); and
- Inspect drainage and clear as required to maintain function and performance.

7.3.2 Hazard Type 3

Impacts from debris avalanches originating from the over steep slope associated with working of the Upper Pinchin seam.

There is no evidence of instability associated with the over steep slope from either the API or field inspection. However, based on the API there is evidence for landslides associated with former adits. There is a single adit directly above the school, but it is at such a distance that the risk to property from this hazard is very low.

7.4 Other Stability Hazards

As discussed in Section 3.2.1, recent evidence that quarrying has taken place at Cwar Pentwyn (Plate 6). A review of the ownership, activities, permissions and conditions should be undertaken.

7.5 Uncertainties

There is very limited information on landslides within the study area and consequently the assessment of detachment and run out are largely based on judgement. The vegetation in the study area, in particular, in the areas of quarry spoil is extremely dense limiting both access and observations (Figure 4).

8 Recommendations

We consider that the further investigation and assessment would be required or prudent:

- A review of the ownership, activities, permissions and conditions should be undertaken for Cwar Pentwyn;
- Investigation of the upslope tip (Site 2) to allow monitoring and slope stability assessment;
- Complete the initial groundwater monitoring to help understand groundwater conditions;
- Carry out visual assessment of the stream (Site 2) either after vegetation removal or during winter months;
- Inspect drainage and clear as required to maintain function and performance.

9 References

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FIGURES

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Notes:

⊞ TP1 Trial Pit Position

⊕ WS1 Windowless Sampler Position

PROJECT:
GODRE'R GRAIG PRIMARY SCHOOL,
GODRE'R GRAIG

Scale: 1:500 (approx. at A3)

FIGURE 1:
INVESTIGATION POINT PLAN

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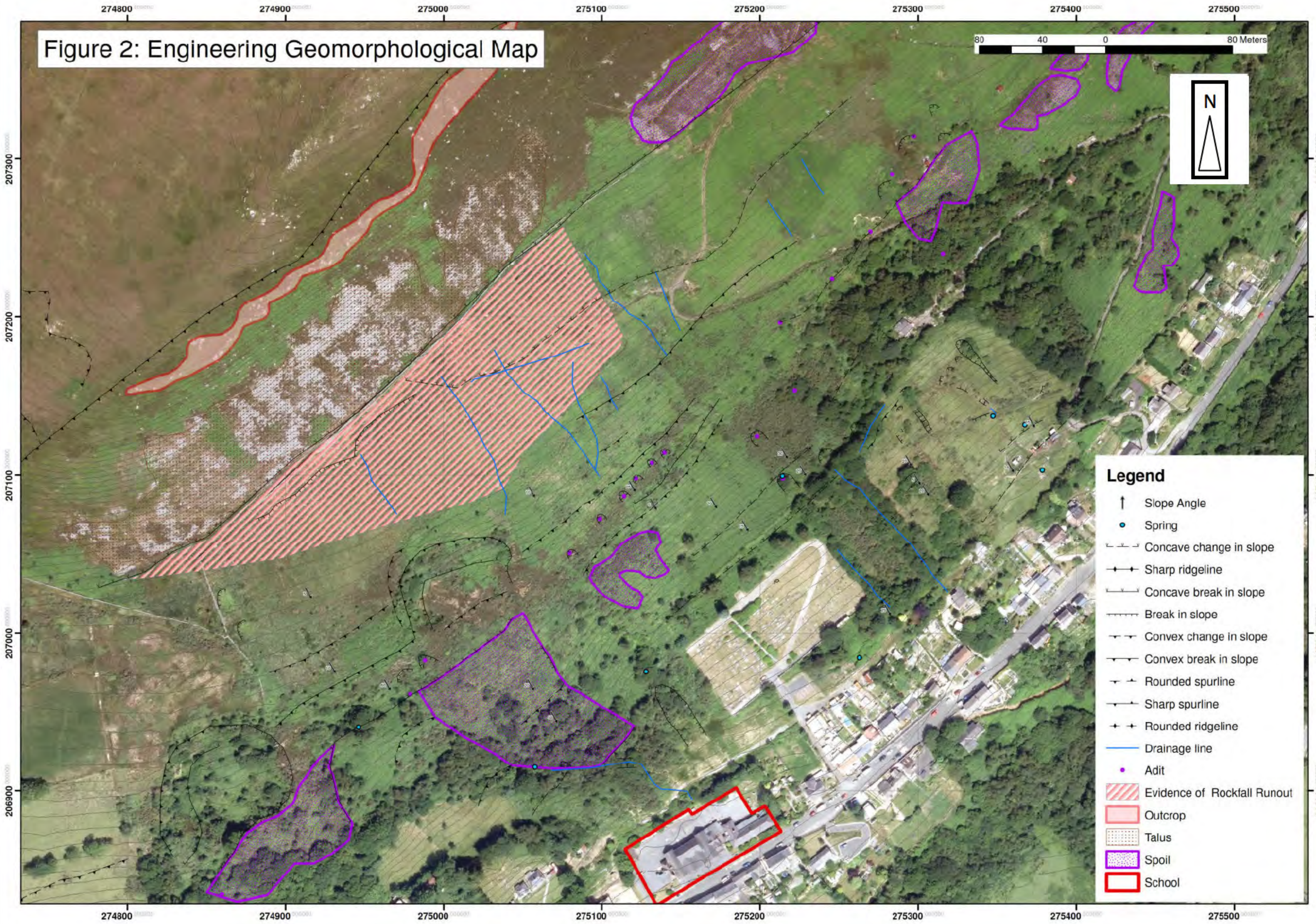

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Notes:

PROJECT:
GODRE'R GRAIG PRIMARY SCHOOL, GODRE'R GRAIG

Scale: AS SHOWN

FIGURE 2:
ENGINEERING GEOMORPHOLOGICAL MAP

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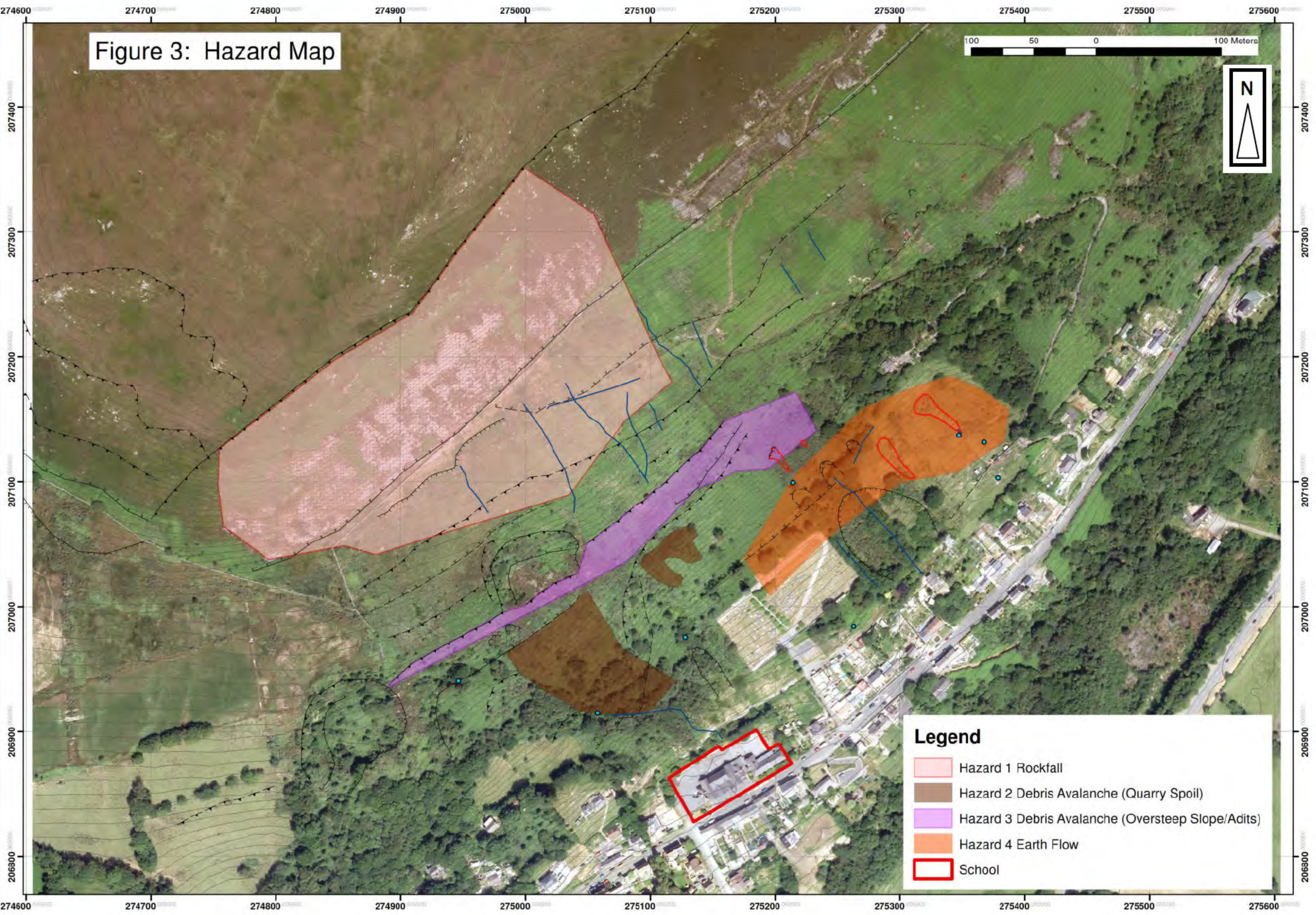
Figure 3: Hazard Map



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Notes:

PROJECT:
GODRE'R GRAIG PRIMARY SCHOOL, GODRE'R GRAIG

Scale: AS SHOWN

FIGURE 3:
HAZARD MAP

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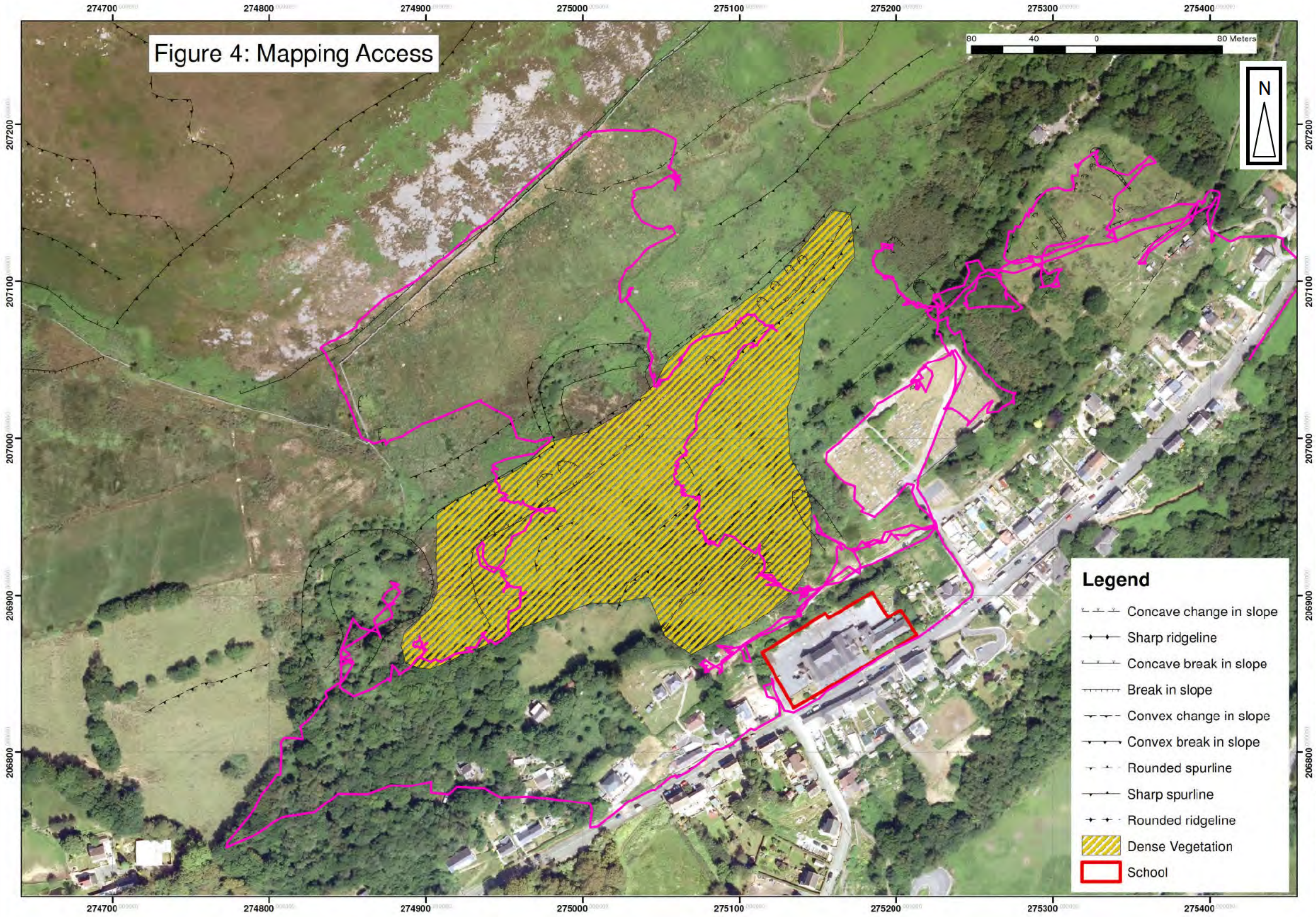
Cardiff CF15 7RB Tel: 029 2081 3385
enquiries@earthsciencepartnership.com

7234e.3221



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Notes:

Mapping route

PROJECT:
GODRE'R GRAIG PRIMARY SCHOOL,
GODRE'R GRAIG

Scale: AS SHOWN

FIGURE 4:
MAPPING ACCESS

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APPENDIX A

EXTRACTS OF HISTORICAL MAPS

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Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

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Map date:	**1877**
Scale:	1:2,500
Printed at:	1:2,500

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Surveyed 1877
Revised 1877
Edition N/A
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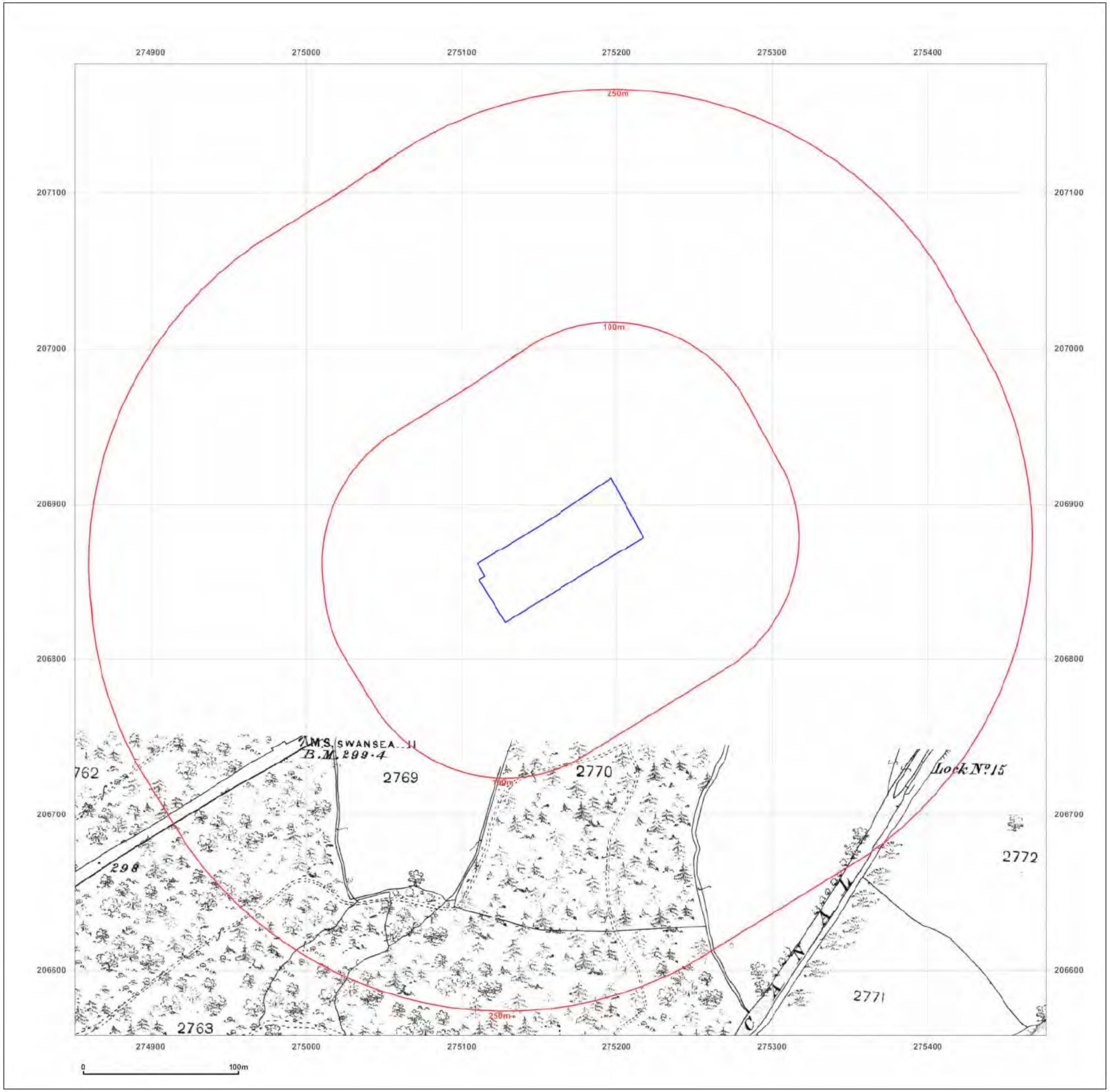

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PRIMARY SCHOOL, GRAIG
ROAD, GODRE'R GRAIG, SA9
2NY

Client Ref: 8060_7234e
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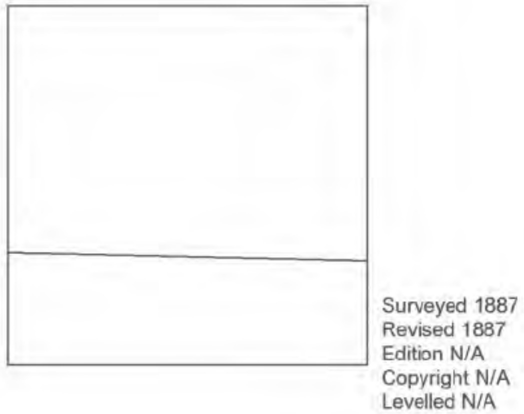

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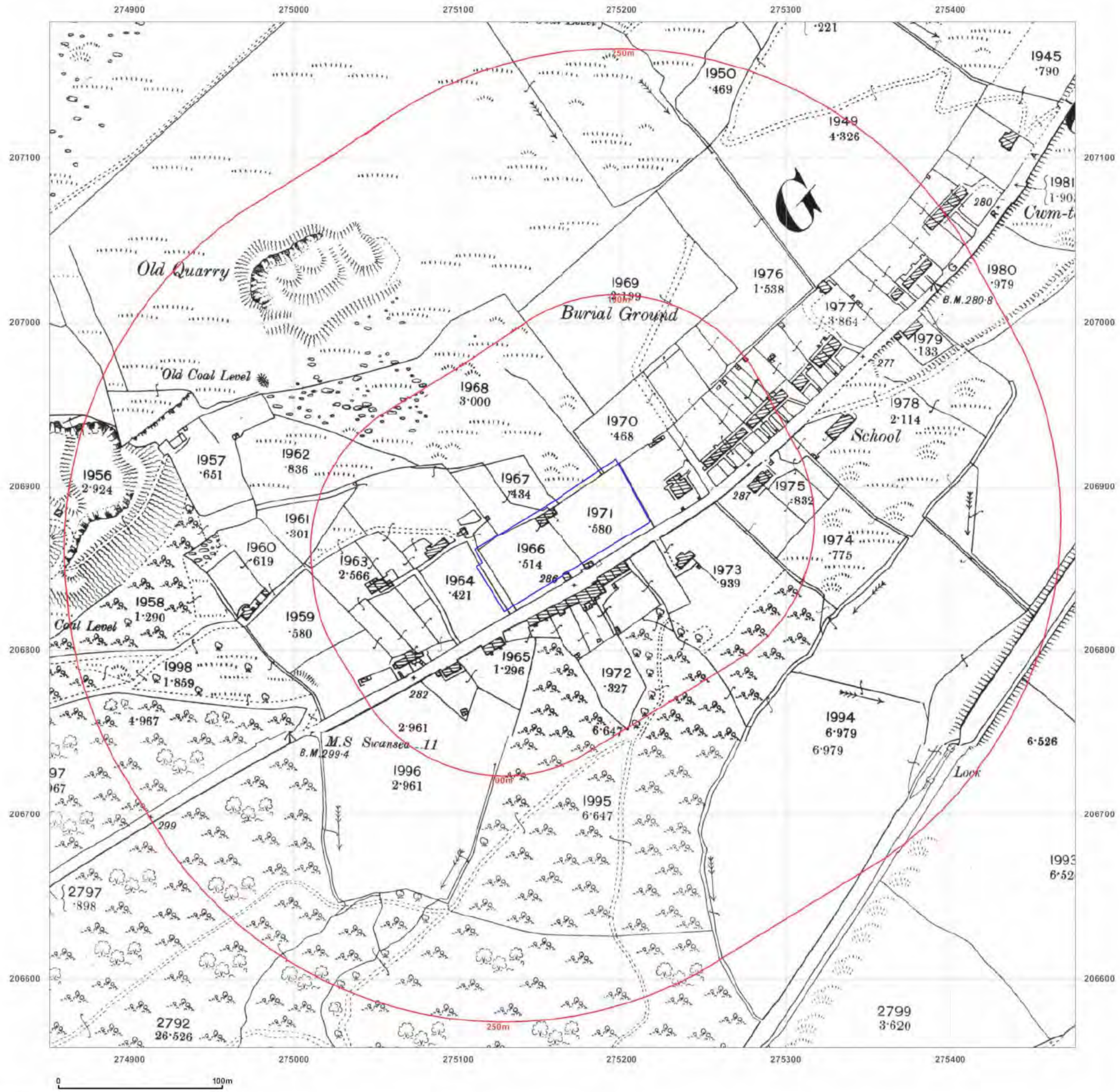

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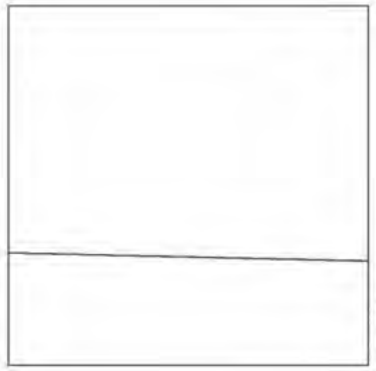

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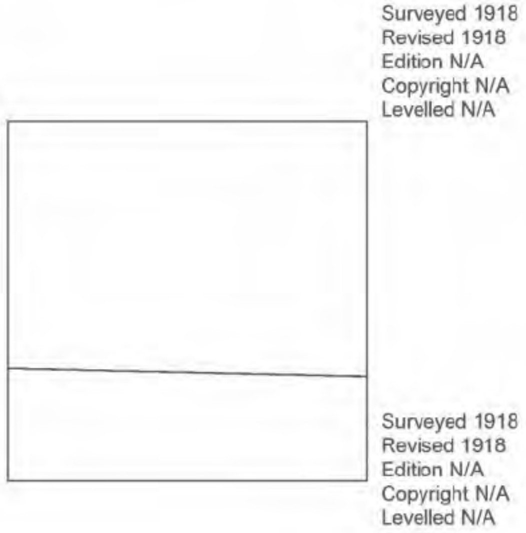

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Edition N/A
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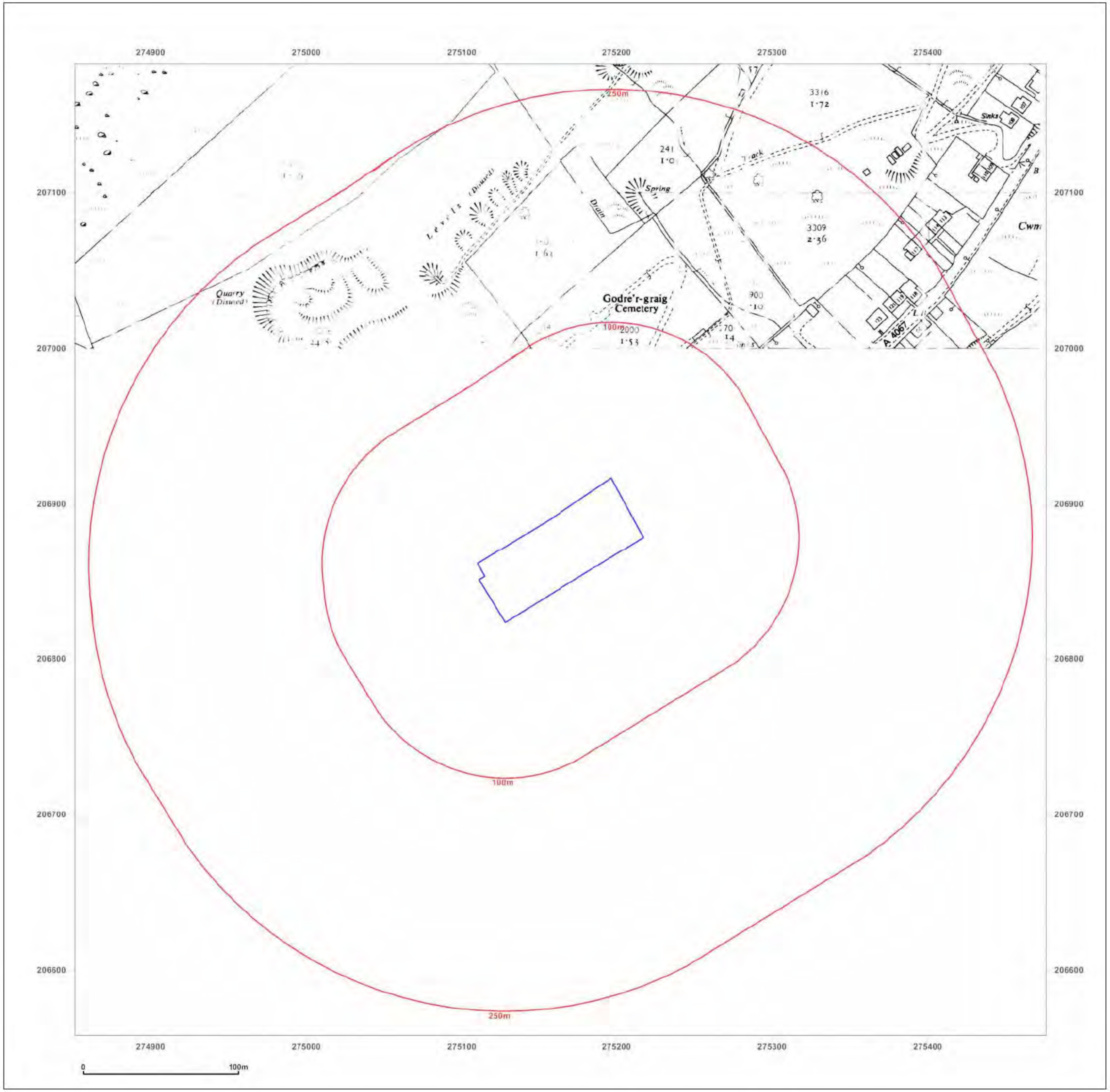

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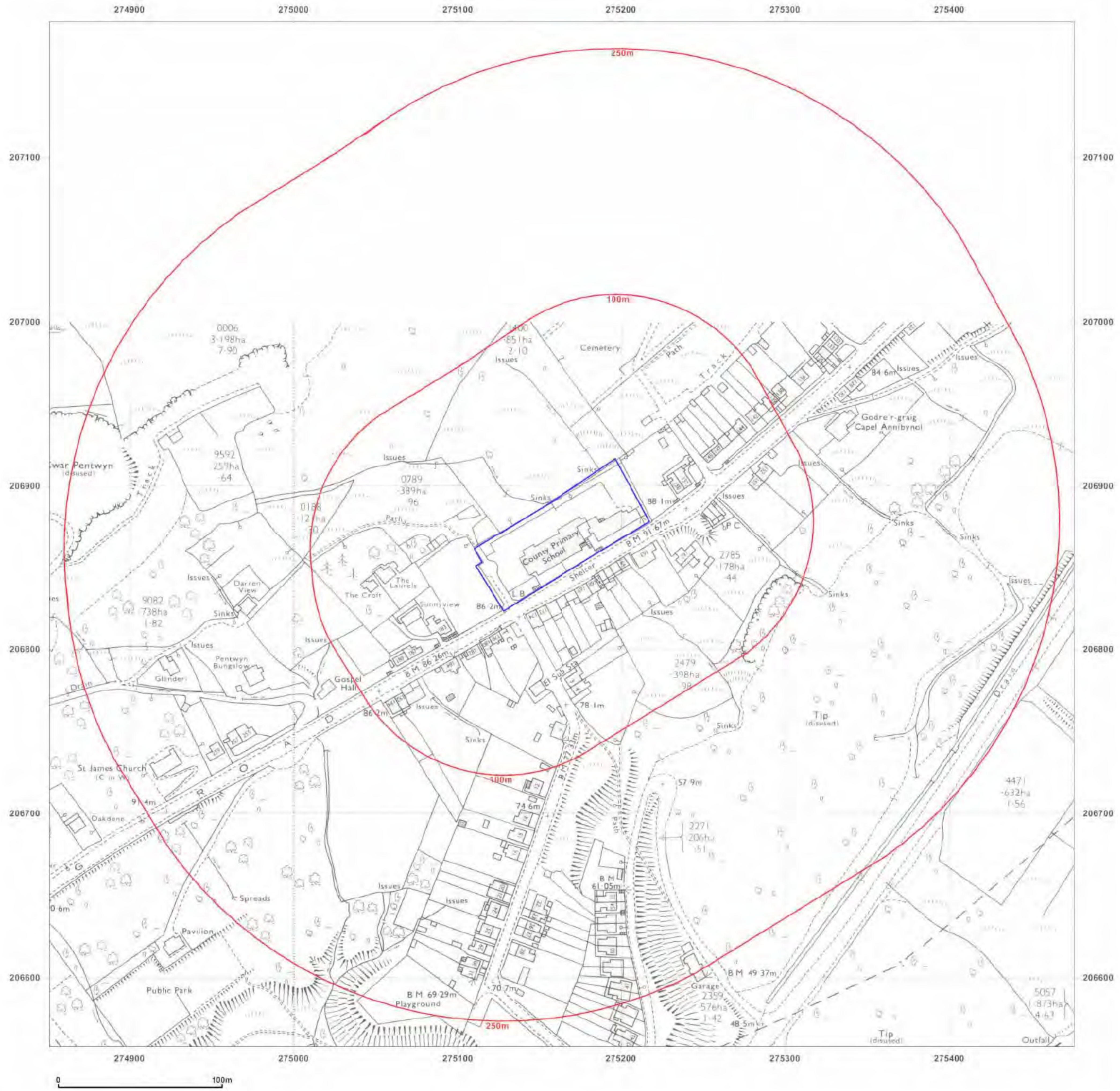

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PRIMARY SCHOOL, GRAIG
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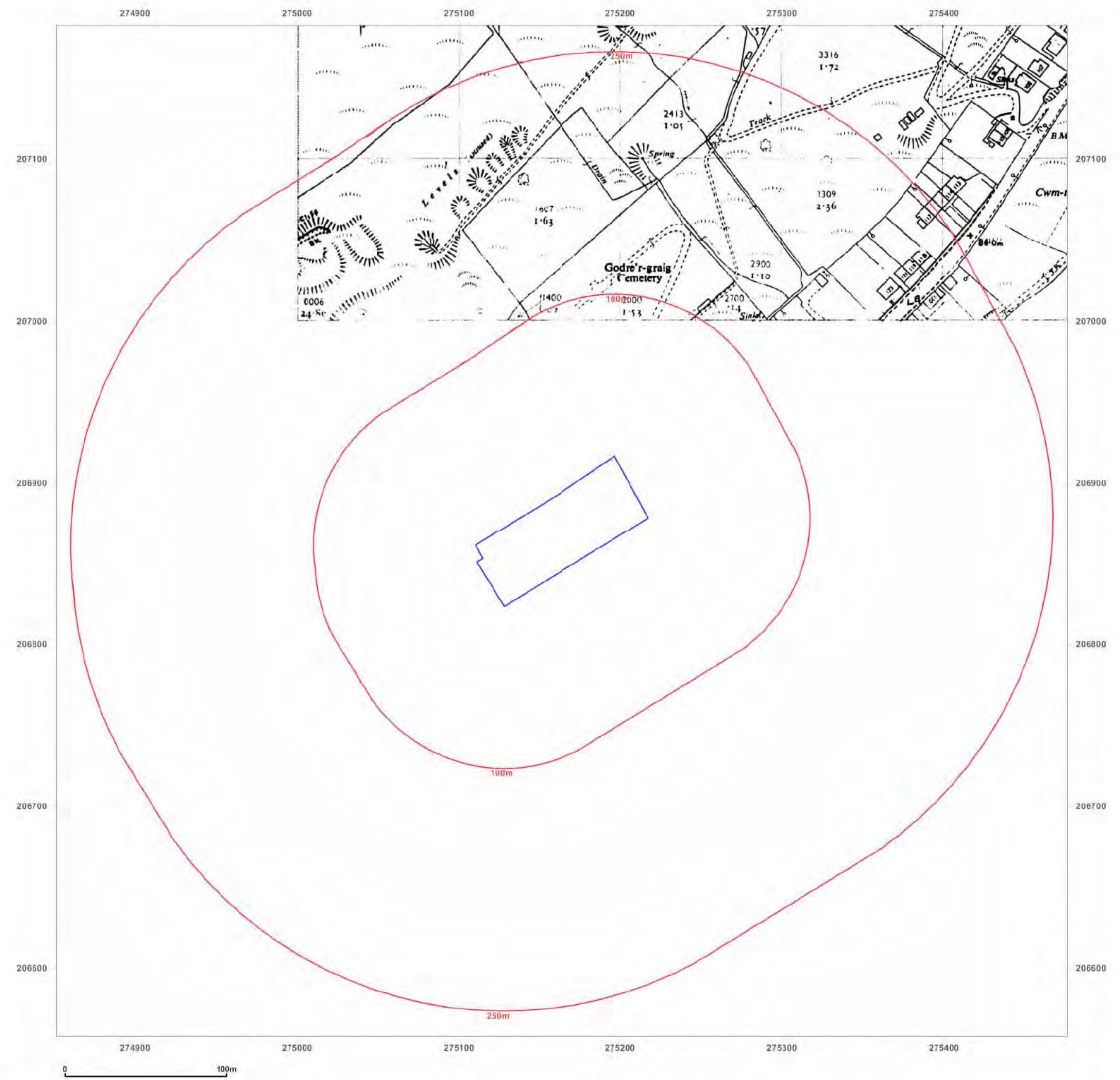

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Edition N/A
Copyright 1979
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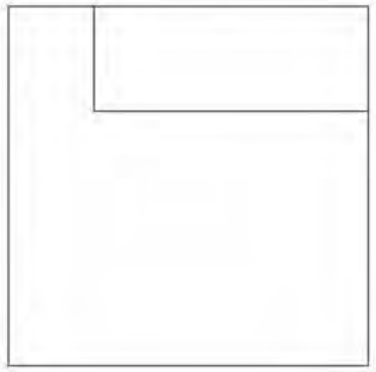

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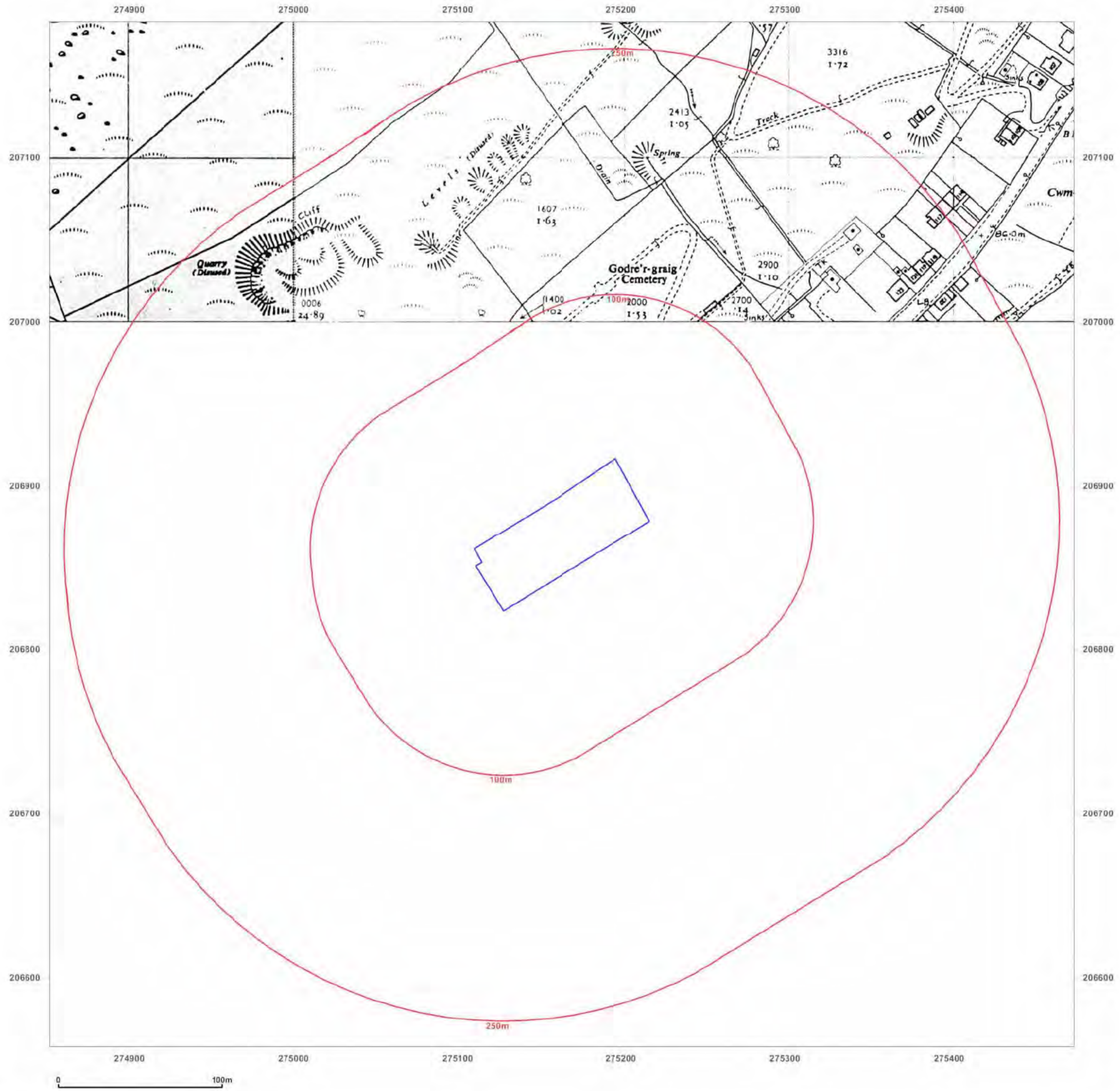

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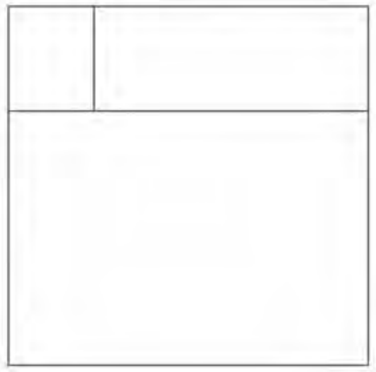

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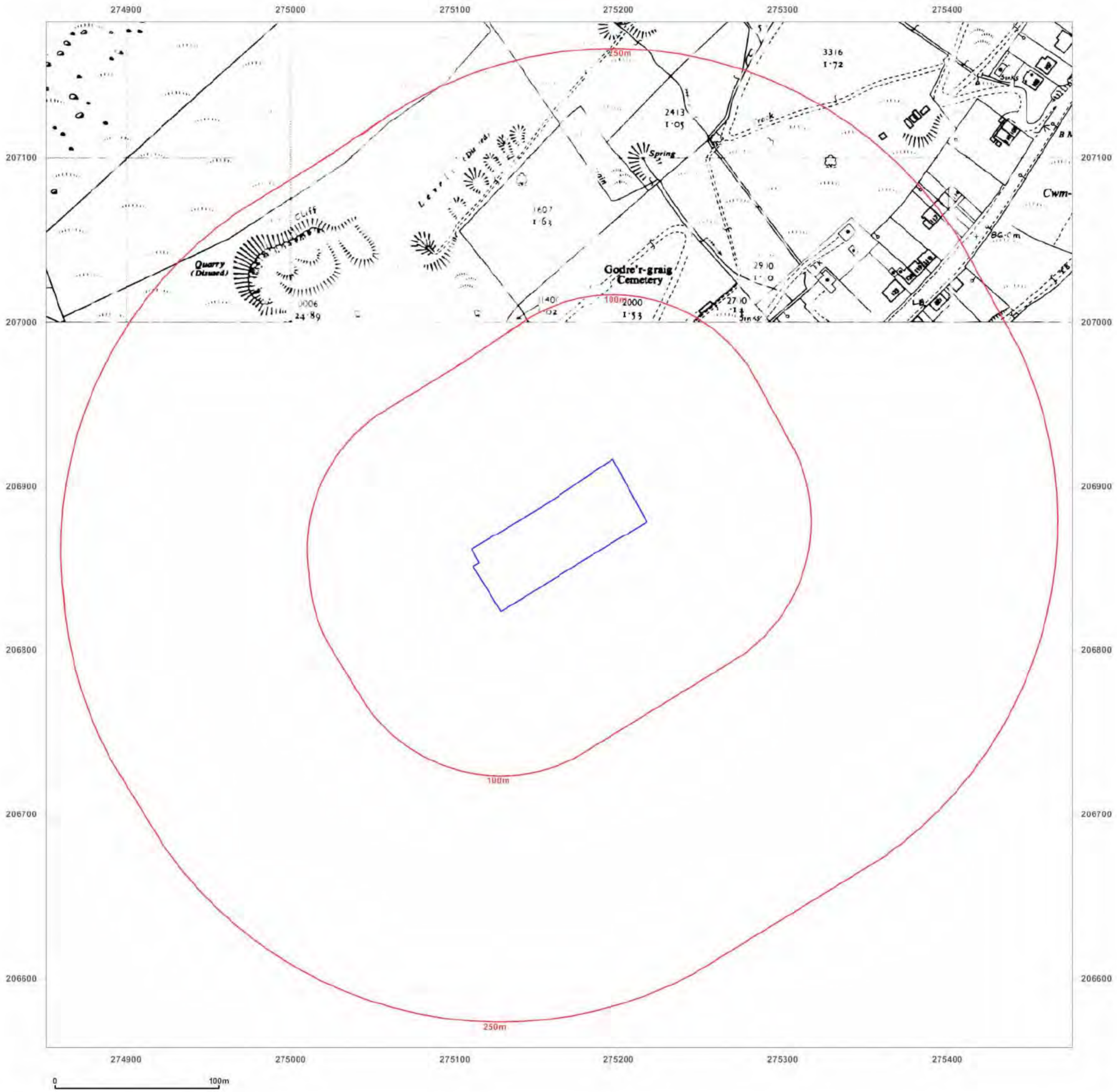

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Report Ref: ESP-6040430
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Report Ref: ESP-6040430
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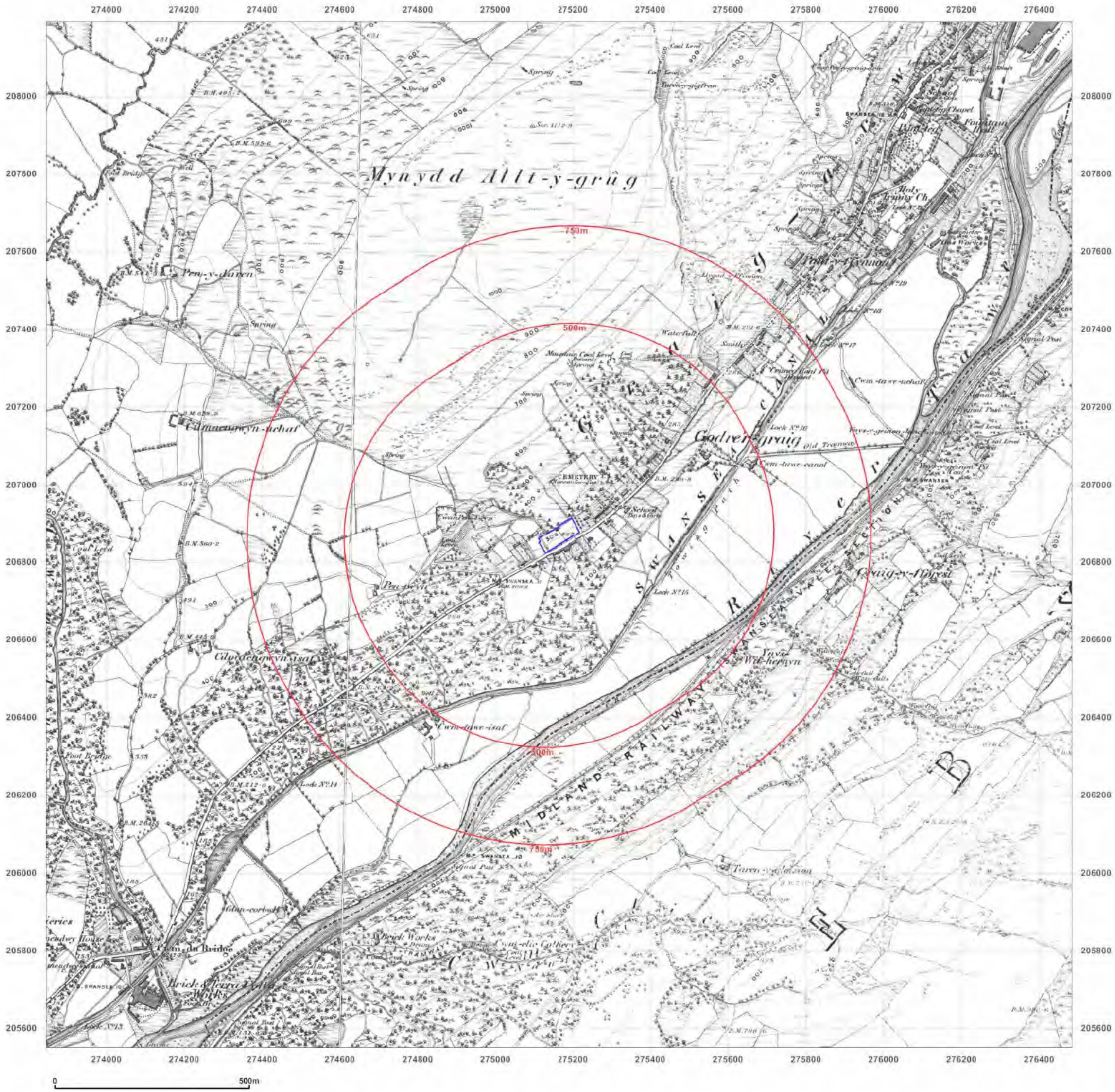

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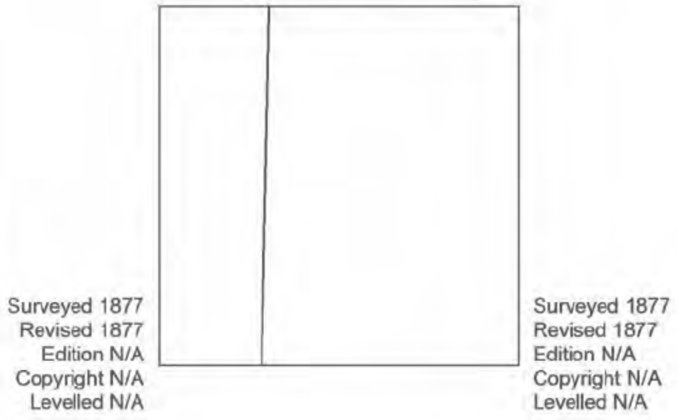

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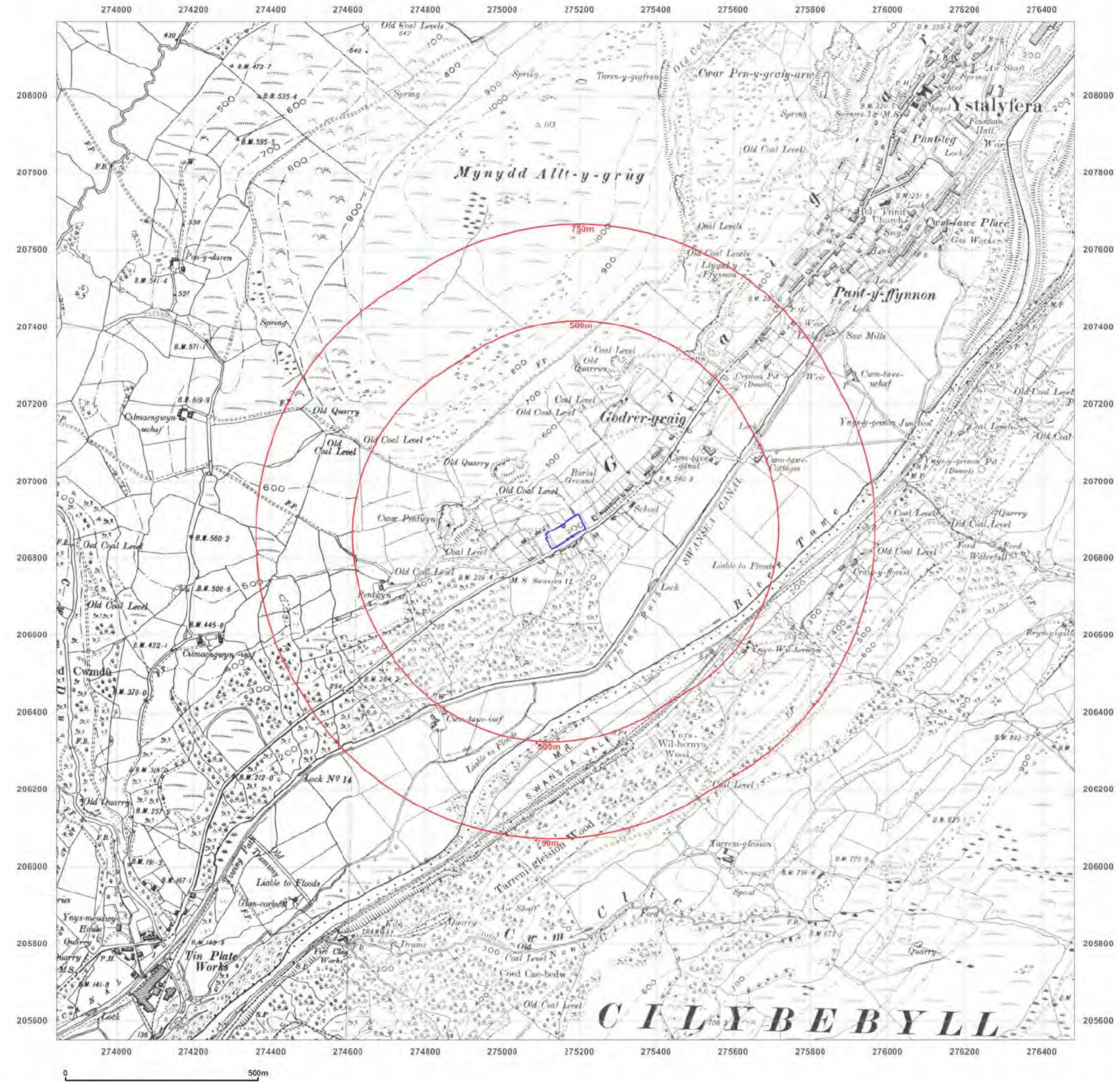

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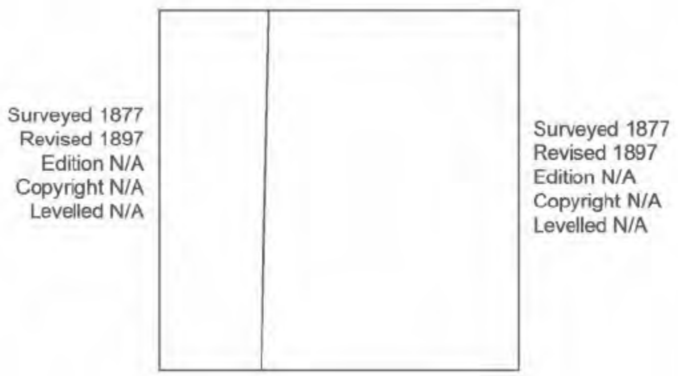

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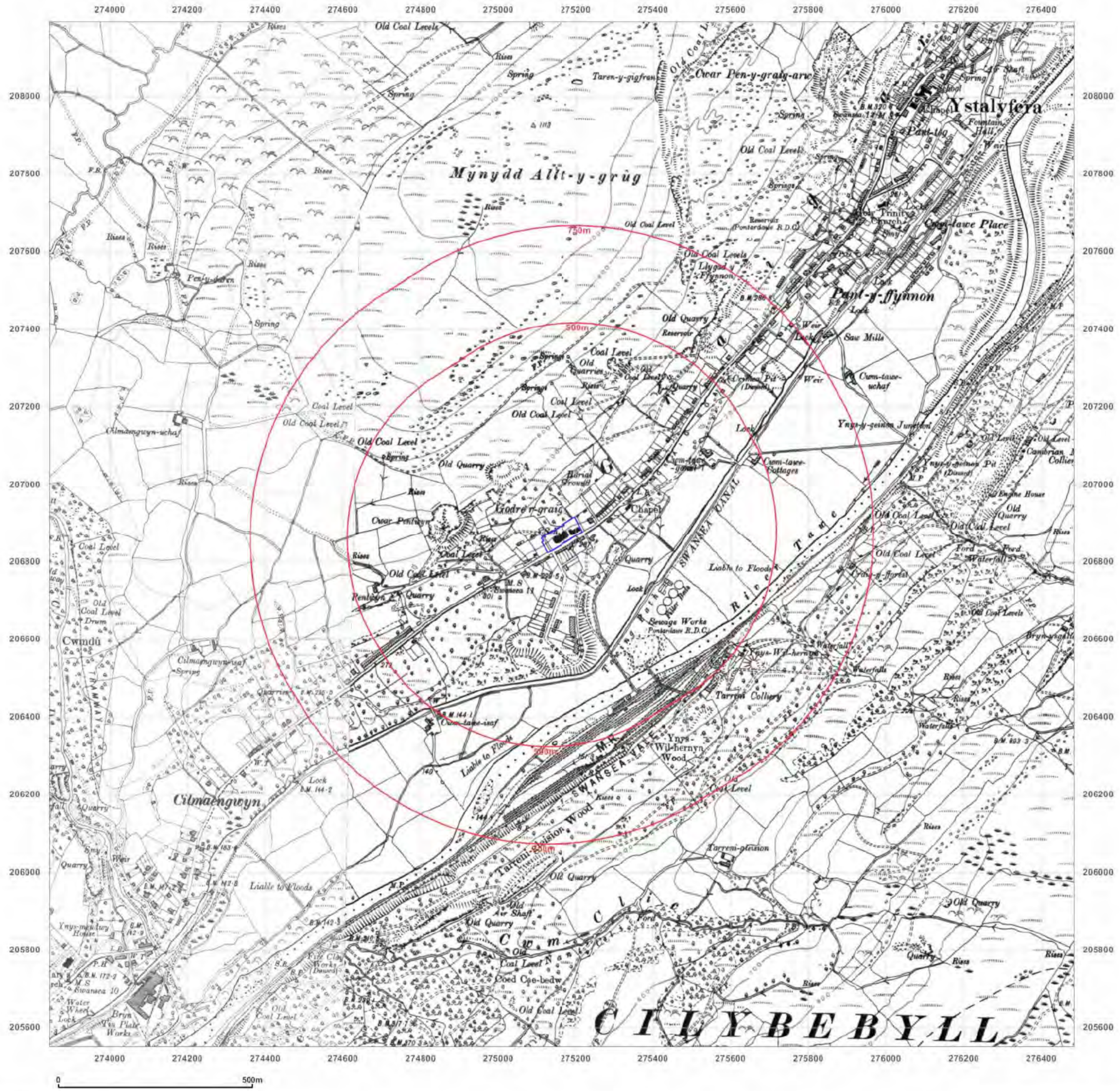

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ENGINEERS
GEOLOGISTS
SCIENTISTS

Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

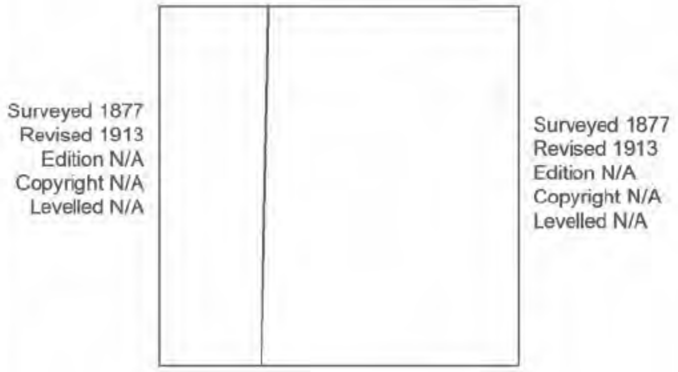
Client Ref: 8060_7234e
Report Ref: ESP-6040430
Grid Ref: 275163, 206870

Map Name: County Series

Map date: **1913**

Scale: 1:10,560

Printed at: 1:10,560



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Production date: 20 May 2019

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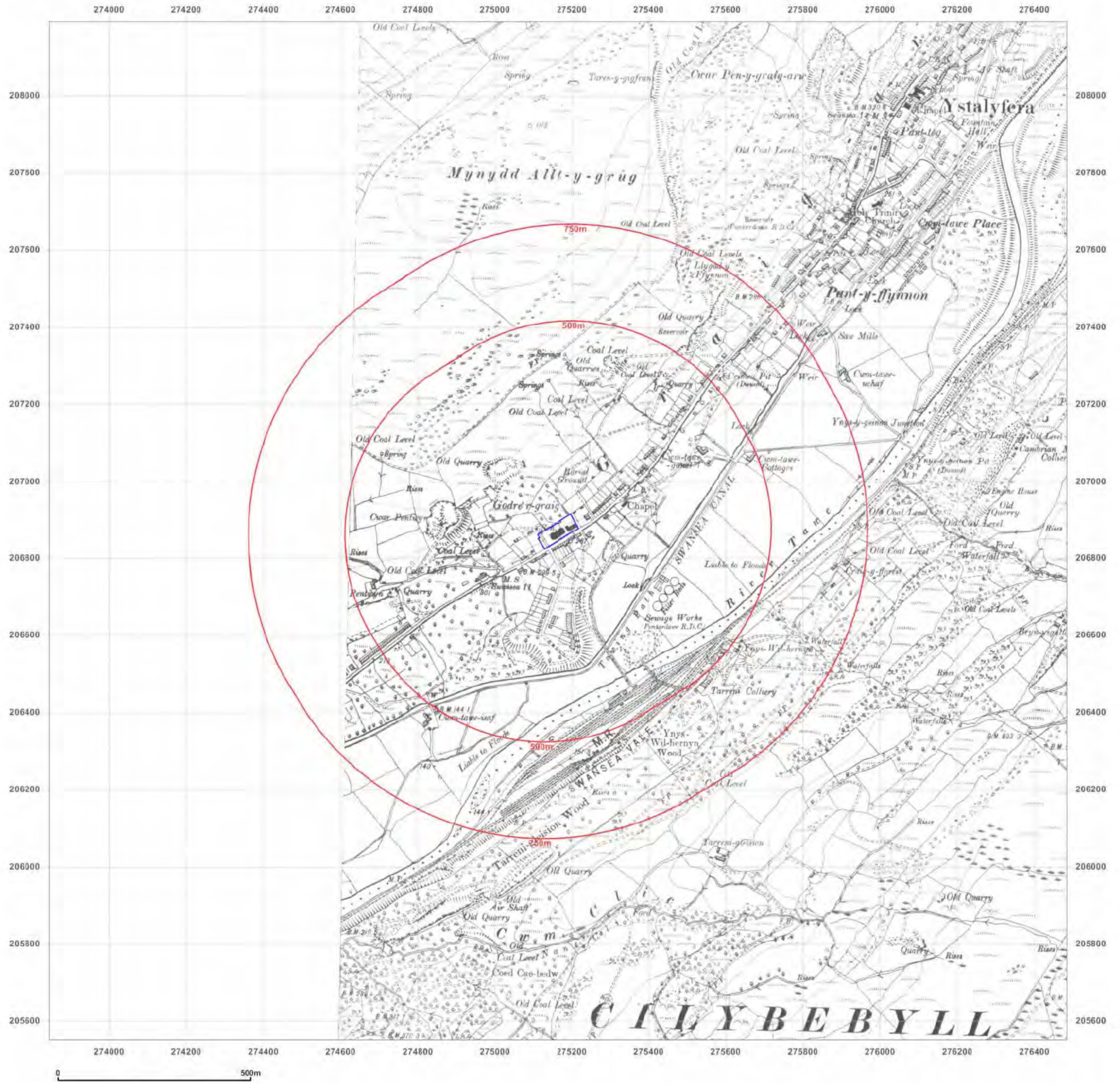

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Site Details:

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Client Ref:	8060_7234e
Report Ref:	ESP-6040430
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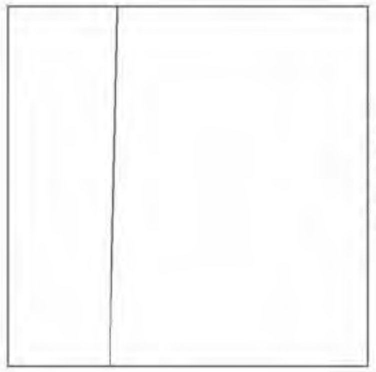

Surveyed 1877
Revised 1913
Edition N/A
Copyright N/A
Levelled N/A

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Production date: 20 May 2019

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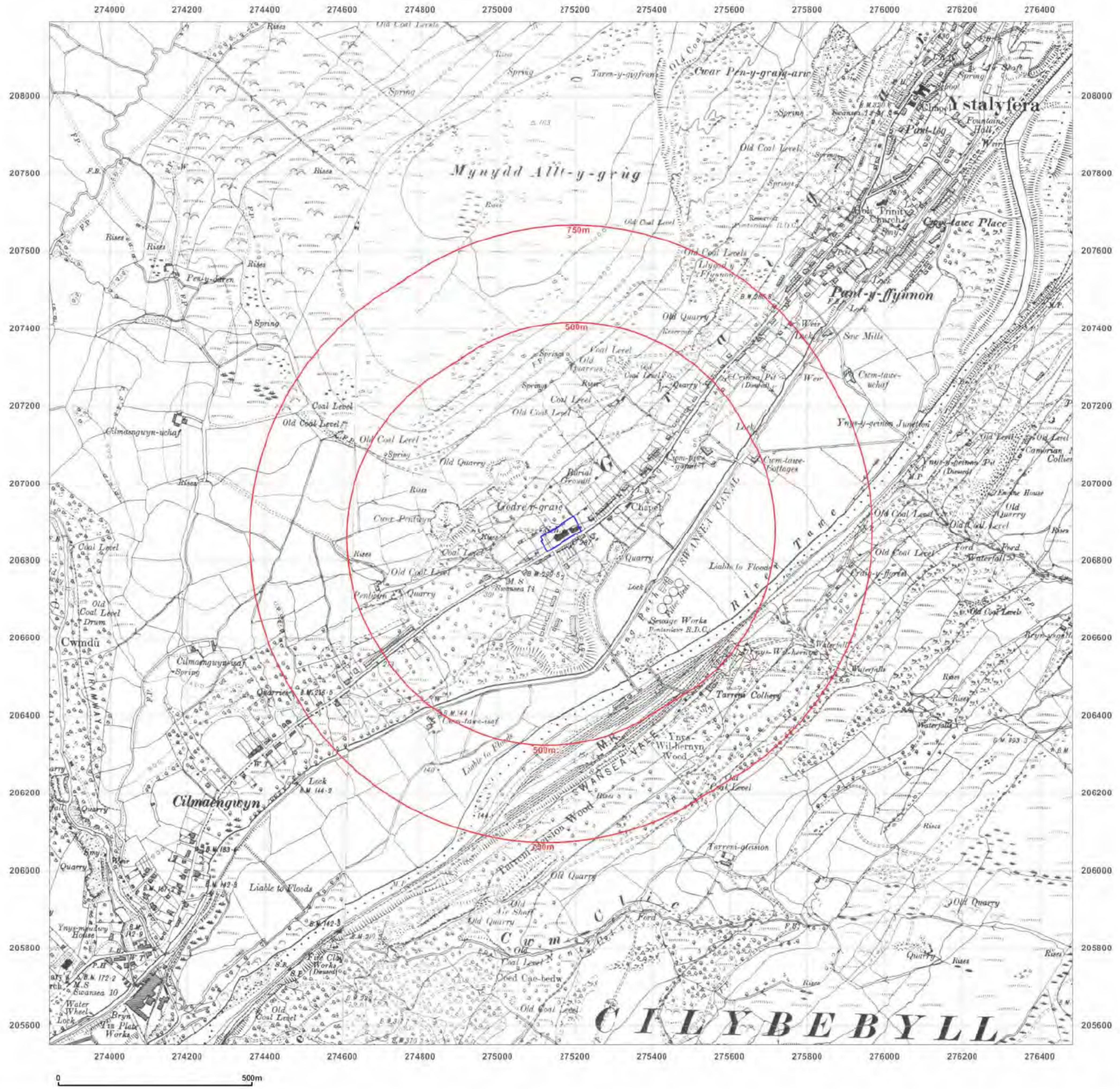

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Site Details:

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Grid Ref:	275163, 206870

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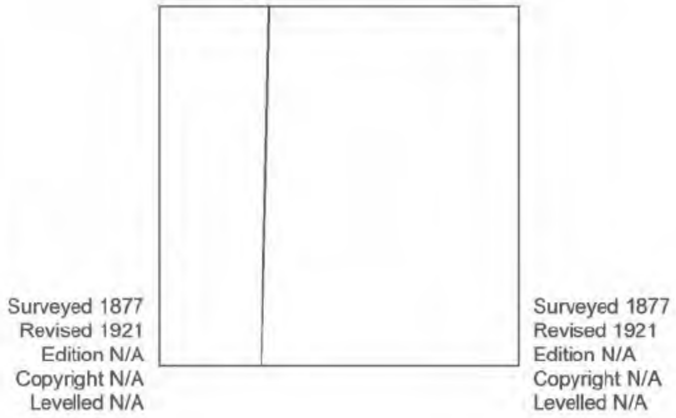

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Production date: 20 May 2019

Map legend available at:
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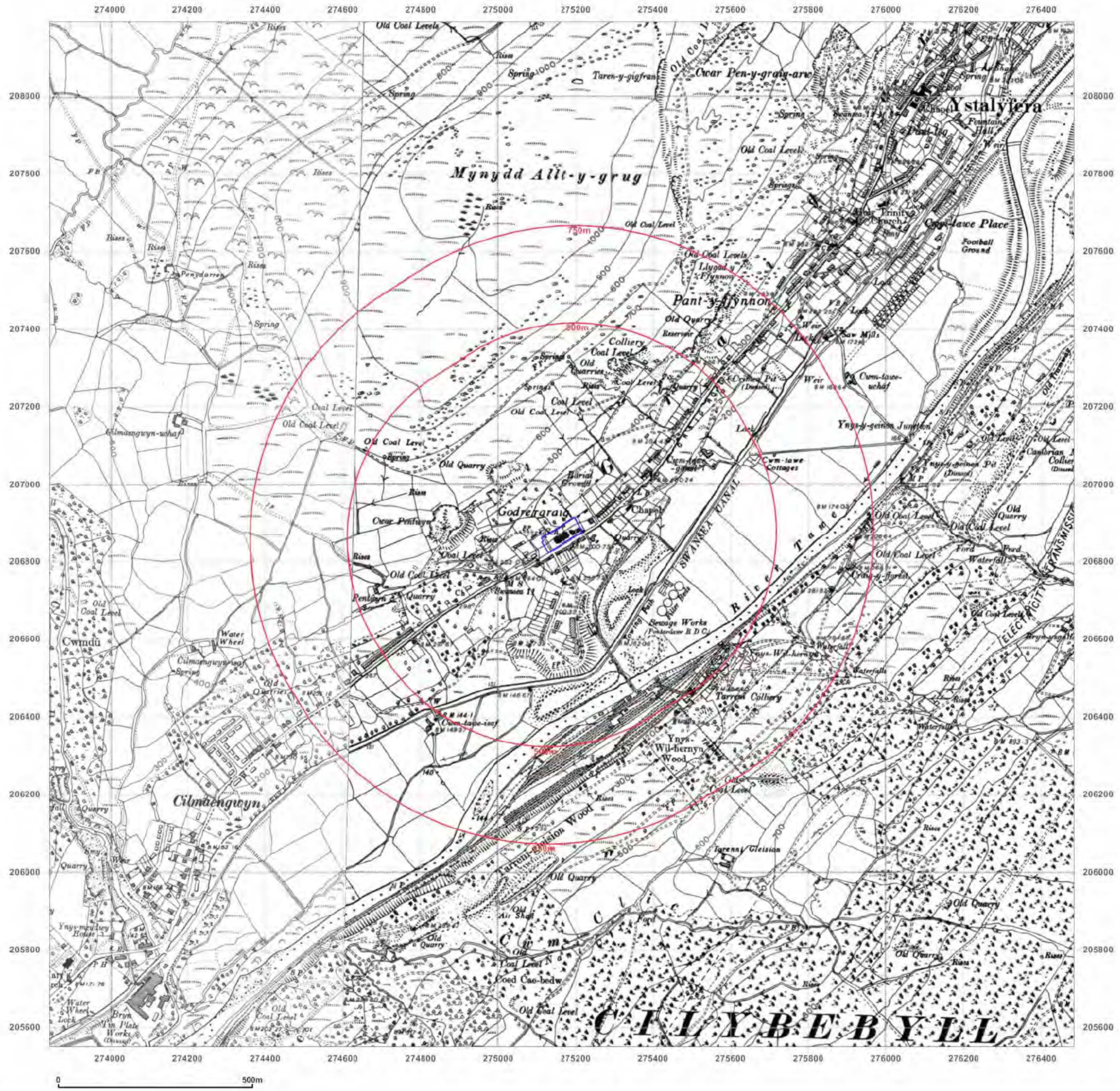

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

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Report Ref:	ESP-6040430
Grid Ref:	275163, 206870
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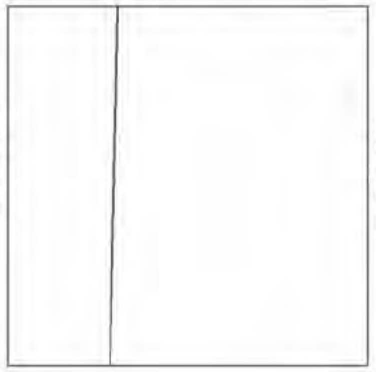

Surveyed 1877
Revised 1948
Edition N/A
Copyright N/A
Levelled N/A

Surveyed 1877
Revised 1948
Edition 1948
Copyright N/A
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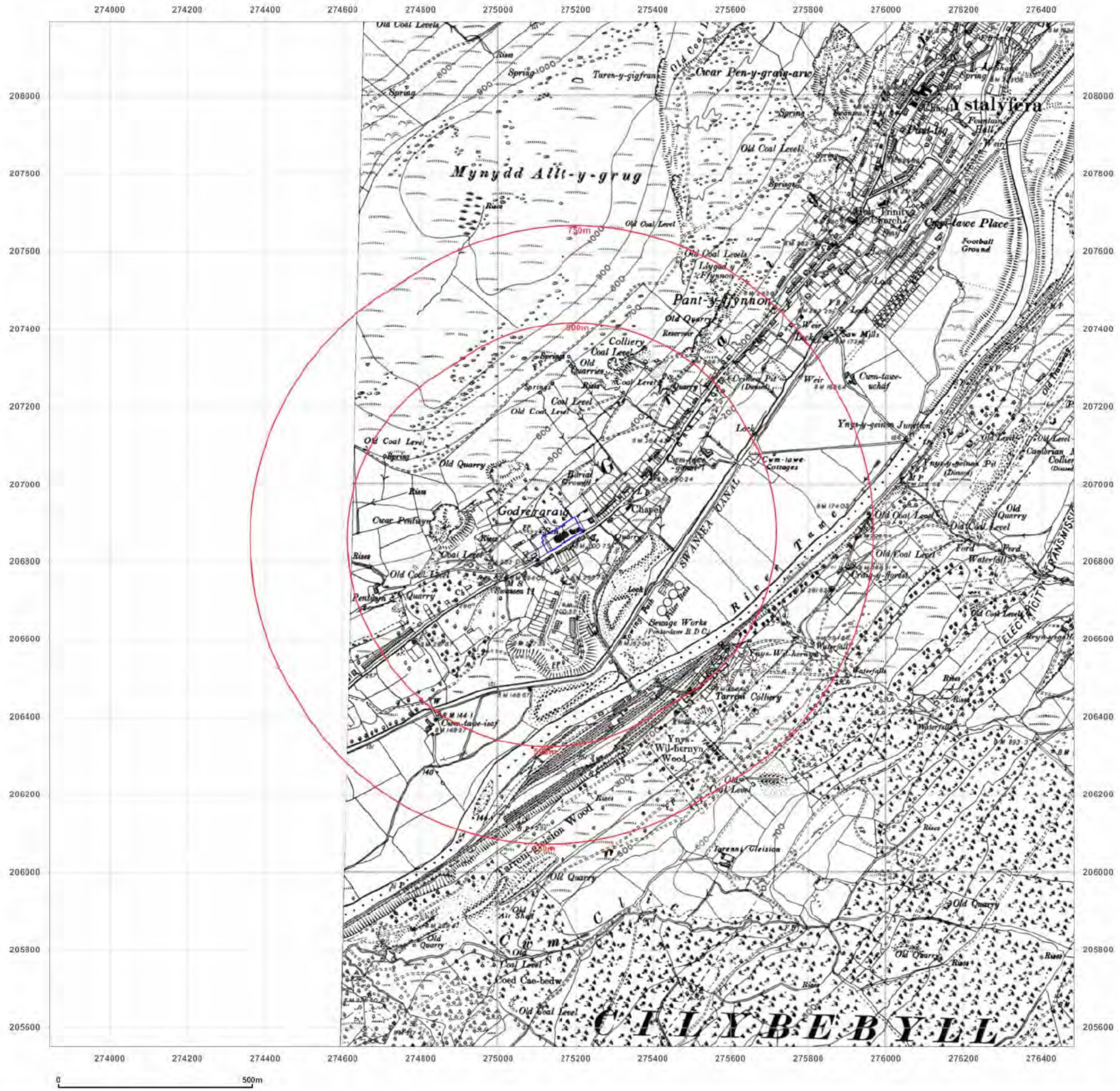

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

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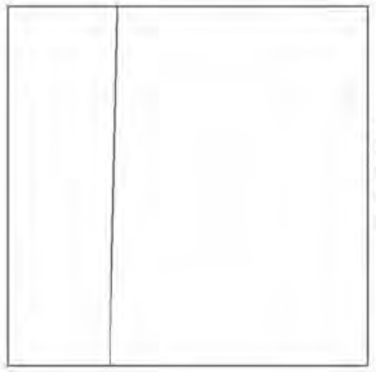

Surveyed 1877
Revised 1948
Edition N/A
Copyright N/A
Levelled N/A

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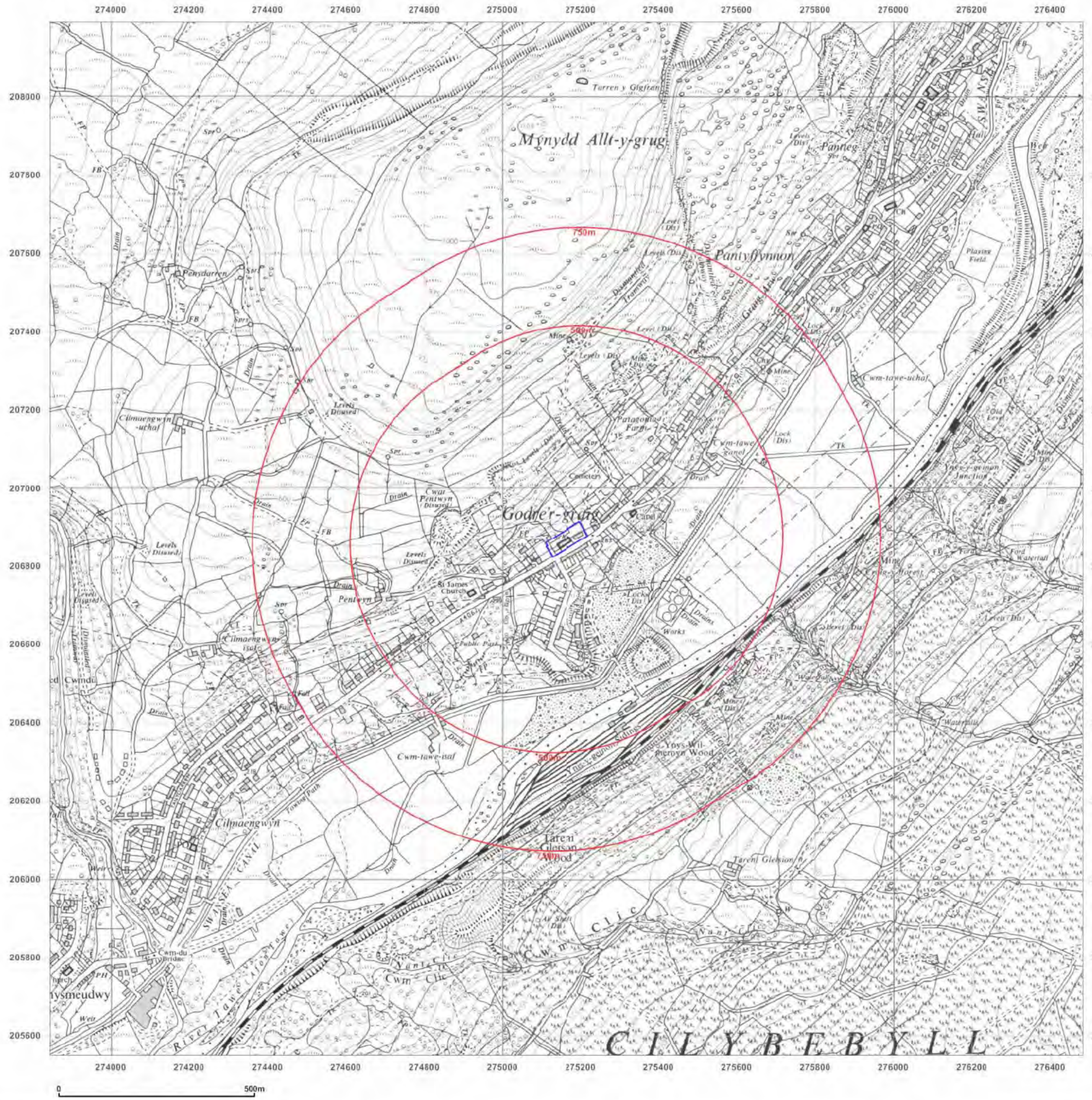

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

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Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

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Surveyed 1963
Revised 1964
Edition N/A
Copyright 1965
Levelled N/A

Surveyed 1965
Revised 1965
Edition N/A
Copyright N/A
Levelled N/A

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Production date: 20 May 2019

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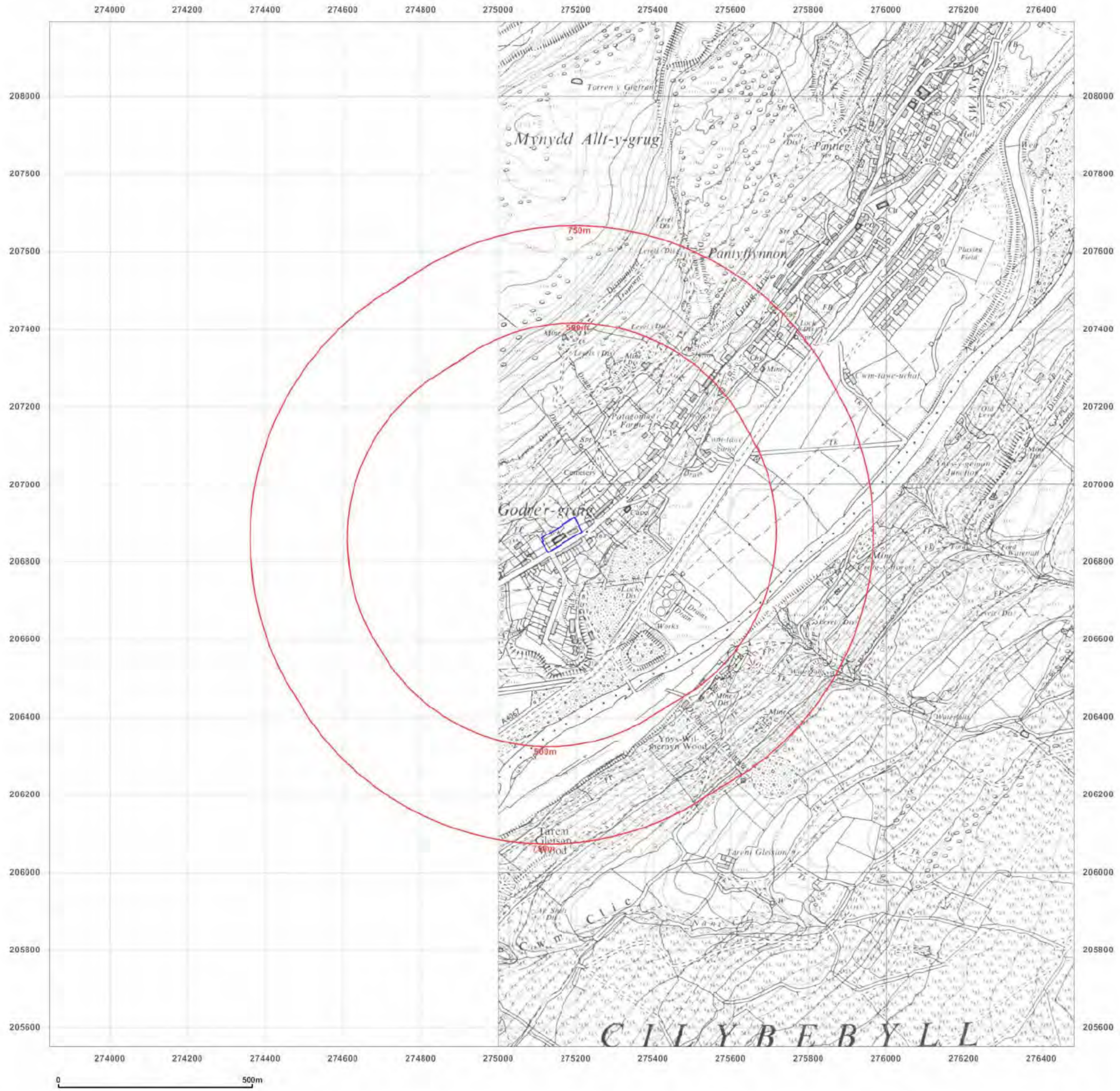

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref: 8060_7234e
Report Ref: ESP-6040430
Grid Ref: 275163, 206870

Map Name: Provisional

Map date: **1980**

Scale: 1:10,560

Printed at: 1:10,560

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Surveyed 1980
Revised 1980
Edition N/A
Copyright N/A
Levelled N/A

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Production date: 20 May 2019

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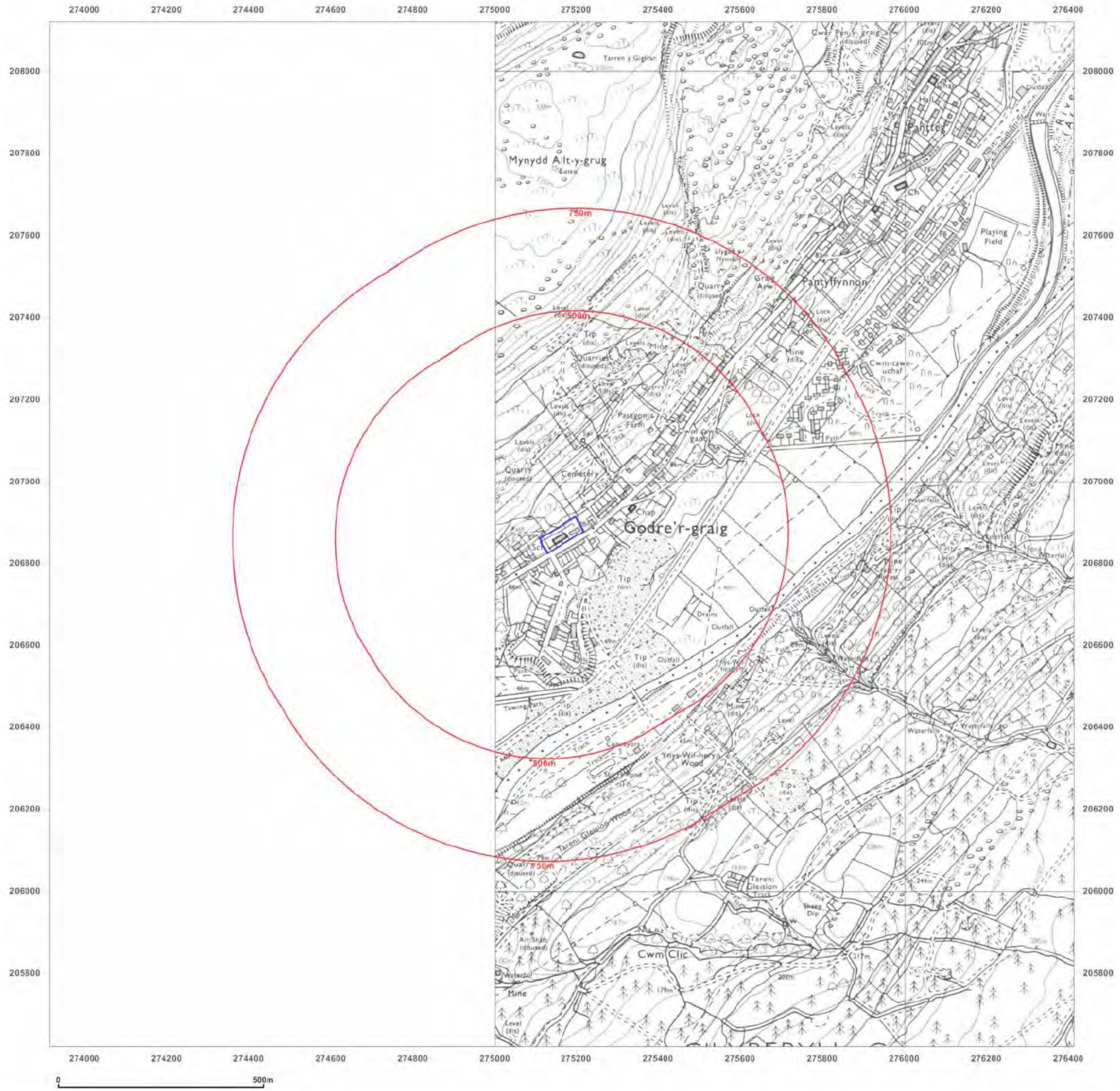

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
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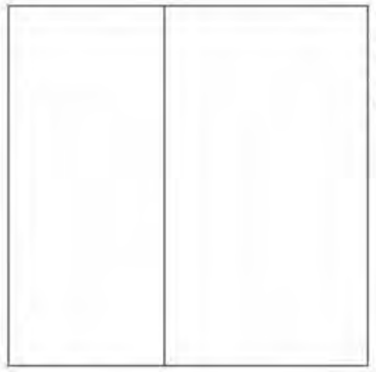

Surveyed 1975
Revised 1983
Edition N/A
Copyright N/A
Levelled N/A

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Production date: 20 May 2019

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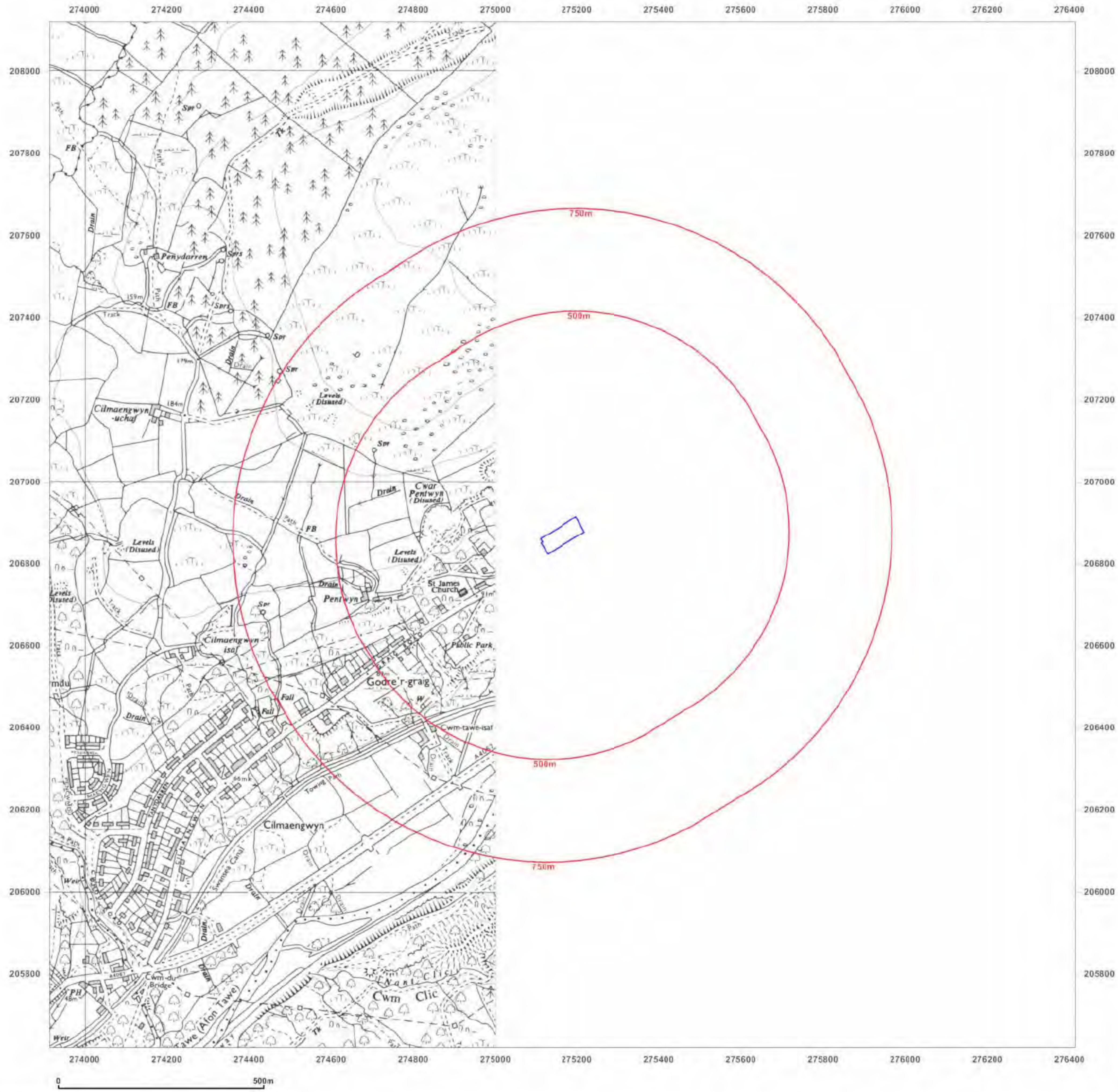

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	National Grid
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Scale:	1:10,000
Printed at:	1:10,000

Surveyed 1983
Revised 1990
Edition N/A
Copyright N/A
Levelled N/A

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Production date: 20 May 2019

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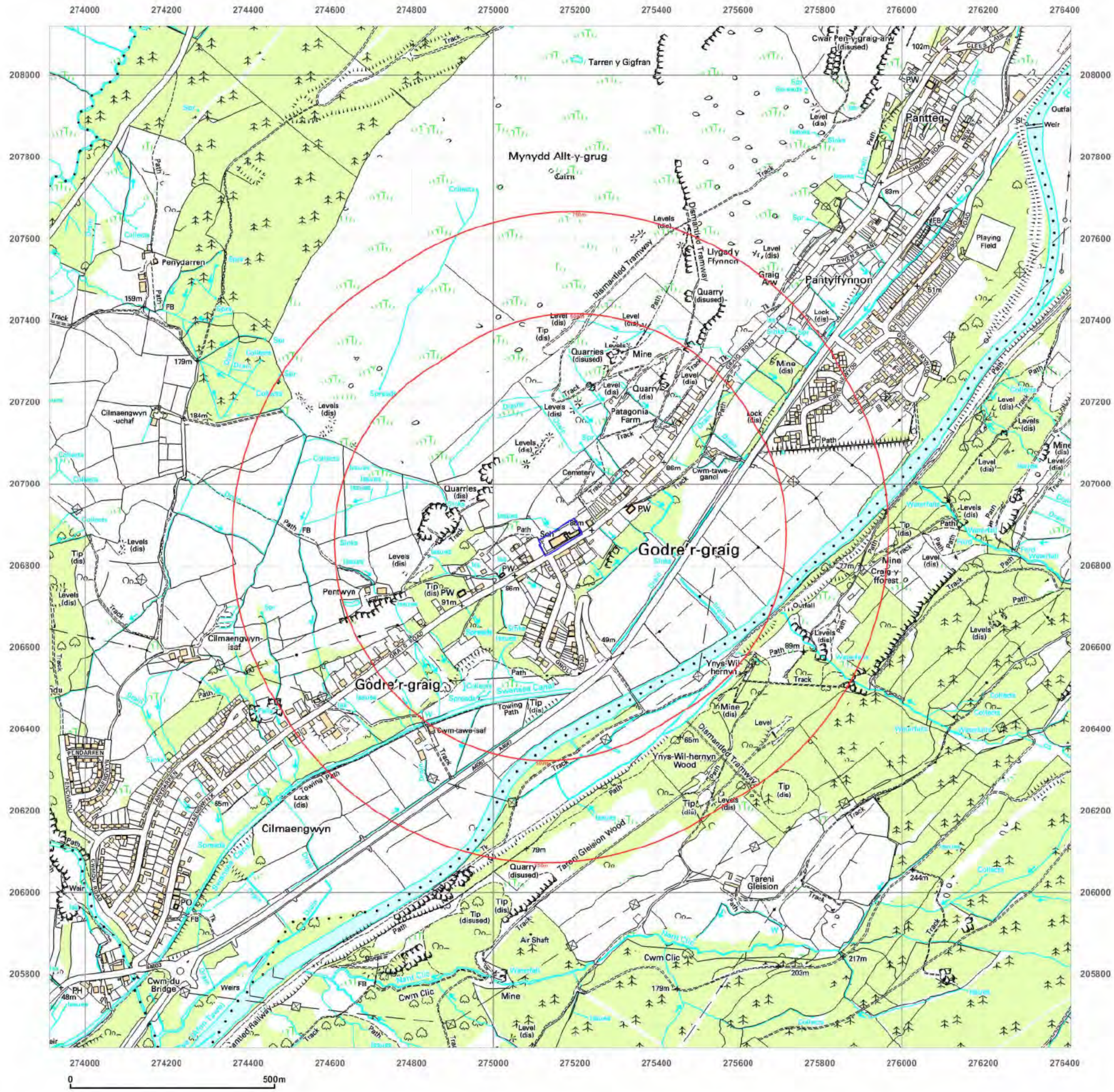

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

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Scale:	1:10,000
Printed at:	1:10,000

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Production date: 20 May 2019

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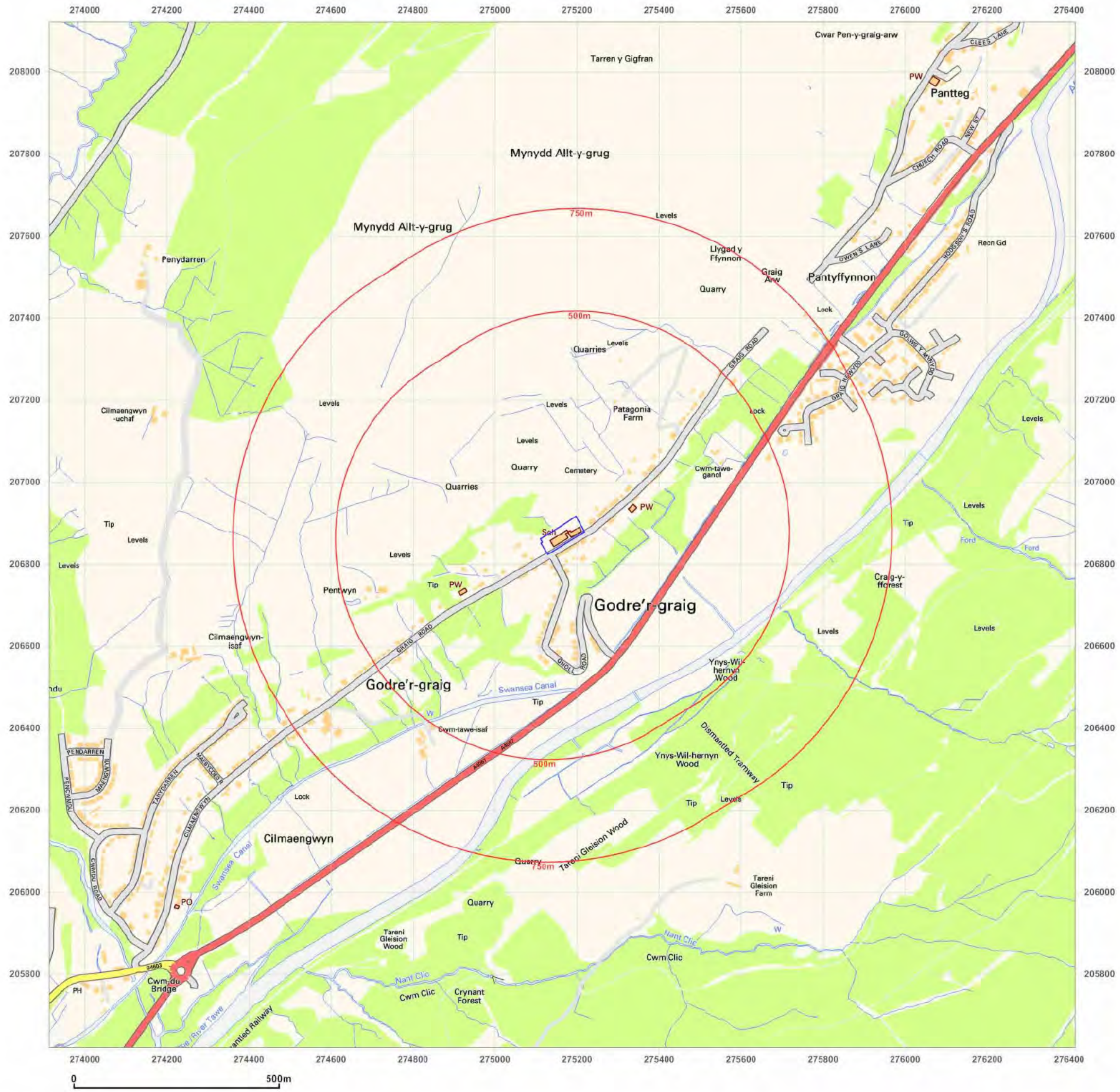

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870
Map Name:	National Grid
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Printed at:	1:10,000

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Production date: 20 May 2019

Map legend available at:
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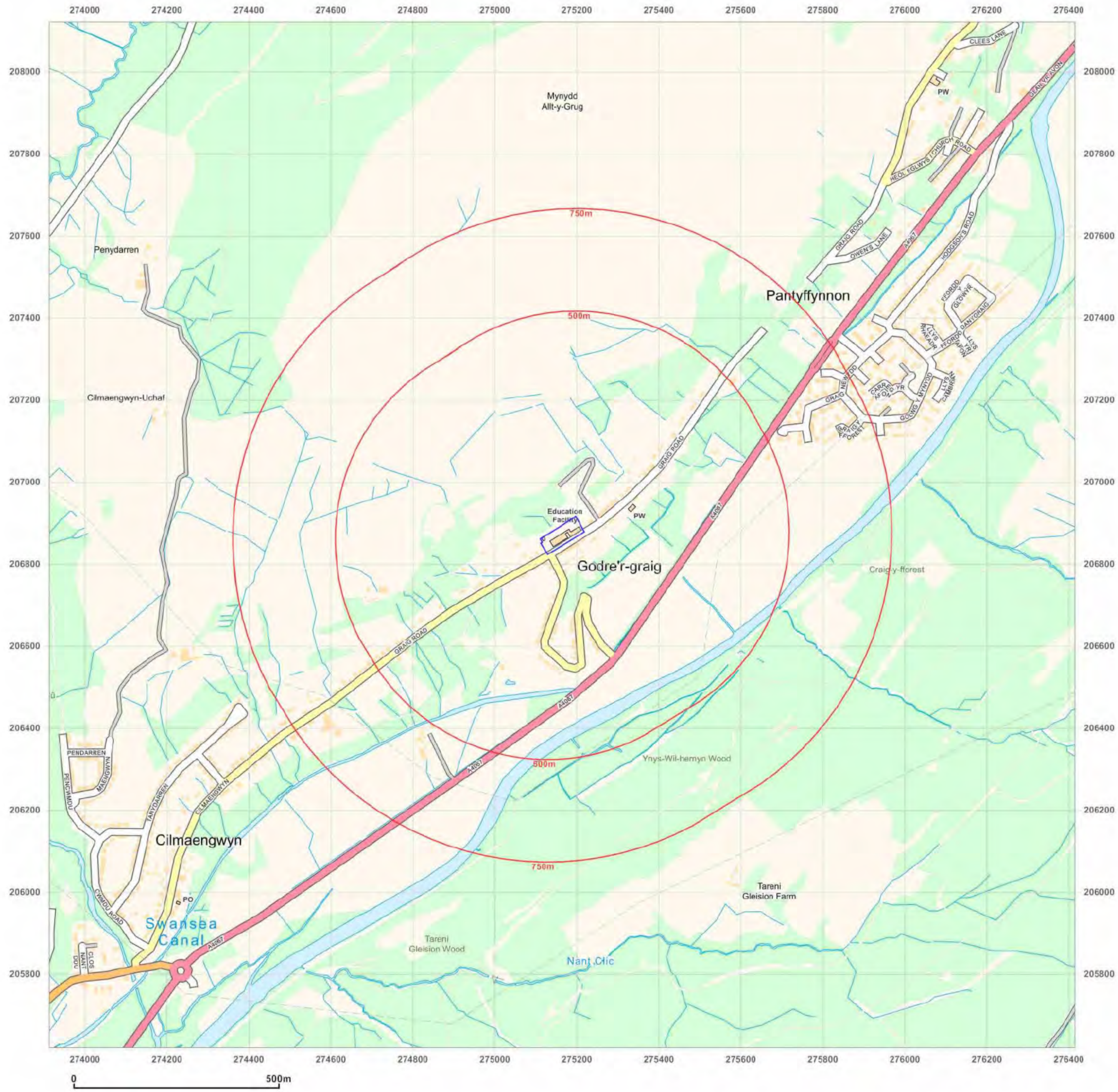

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	National Grid
Map date:	**2014**
Scale:	1:10,000
Printed at:	1:10,000

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Production date: 20 May 2019

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APPENDIX B

COAL AUTHORITY TIP REPORT

The Coal Authority

Site Inspection Report

L44 – Godre'r Graig Tips

Client: Earth Science Partnership

Report prepared by: Darren Bryant

Principal Project Manager – The Coal Authority

Date: July 2019

Contents

Appendices

1.0 Introduction

The Coal Authority was instructed by Earth Science Partnership (ESP) to undertake an inspection of three quarry spoil / colliery spoil tips at Godre'r Graig, near Ystalyfera in the Swansea valley.

The purpose of the inspection was to provide an assessment of stability and safety issues pertaining to the site in conjunction with a stability report being prepared for ESP on behalf of Neath Port Talbot County Borough Council.

The site was inspected by Darren Bryant and Robert Sullivan of the Coal Authority, on the 13th June 2019.

Weather conditions at the time of inspection were mild and damp, with occasional drizzle and heavy showers.

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The inspection has taken account of features observable at the time of inspection, and may not characterise all aspects of the site due to restrictions on access for safety reasons and extensive vegetation coverage. It is possible that evidence of ground movement may be present that could not be observed at the time of inspection.

2.0 Site Conditions

The site comprises a series of disused quarry / colliery tips, situated to the north of the village of Godre'r Graig, near Ystalyfera in the Swansea Valley. The site was divided into three separate areas for the purposes of the inspection as shown on Figure 1 and as outlined below.

Site 1 Quarry and adjacent spoil tip

Site 1 comprises a disused quarry (Cwar Pentwyn) and associated spoil tip. The topography extends from an elevation of around 155mAOD at the rear of a property named 'Glanderi', to approximately 180mAOD at the northern rim of the quarry.

The quarry appears to have been in operation for the extraction of road building material very recently, as evidenced by numerous spoil mounds and a recently re-furbished access track.

Spoil material associated with quarry working and historic coal extraction from three adits was observed to be present along the southern section of the site. Recent tipping of quarry waste has taken place over previous colliery spoil tipping areas and partially over one of the three adits.

The majority of the tip flanks are well vegetated with many mature trees, ferns and brambles. The extent of vegetation prevented the viewing of spoil material in detail.

The dominant drainage feature at Site 1 is a small un-named watercourse, fed by a discharge from the vicinity of the adit locations. This feature has a partially lined invert and flows southeast to join a roadside surface water channel running along the edge of the un-named access road from Graig Road to Pentwyn Farm.

No other significant seepages or flows were observed within the boundary of Site 1.

Site 2 Quarry and adjacent spoil tip

Site 2 comprises a disused un-named quarry and associated spoil tip. The topography extends from an elevation of around 95mAOD at the rear of Godre'r Graig Primary School, to approximately 185mAOD at the northern boundary.

The extent of vegetation and ground cover at Site 2 prevented a close inspection of any spoil or surface features in detail. The majority of vegetation in this area comprised ferns and brambles of up to 1.5m in height and the lack of access routes made inspection very difficult.

Occasional small boulders representing areas of quarry spoil were observed sporadically where vegetation was less extensive but the extent of the spoil could not be proven with accuracy.

The dominant drainage feature at Site 2 appeared to be a watercourse emanating from the vicinity of mine adit reference 274206-026 at NGR 274988E 206957N. A moderate seepage in the vicinity of the adit was observed a forming a small marshy area, subsequently flowing overland and downslope in a south-easterly direction. The watercourse disappeared and reappeared at several locations, probably through the coarse quarry spoil present, appearing again as a spring type feature at approximate NGR 275067E 206915N. The watercourse then flowed in an unlined channel to enter a screened chamber at NGR 275135E 206891N, before entering a final chamber to the rear of Godre'r Graig Primary School at NGR 275157E 206892N. The watercourse then appeared to be culverted beneath the school.

Site 3 Mine entries and associated spoil tips

Site 3 comprises a series of mine entries (all adits) along with a series of linear spoil tips at the base of a ridgeline. All of the adit mouths appeared to have collapsed many years ago. Although shown as a 'horseshoe' shaped feature on the original information supplied by ESP, the tips appear to comprise a narrower, linear form. The topography extends from an elevation of around 150mAOD to approximately 165mAOD.

The tip flanks are well vegetated with an extensive cover of ferns and brambles with occasional mature trees. The dense vegetation gave rise to only minor exposures of colliery spoil material.

There were no obvious drainage features observed within the area.

Inspection of the British Geological Survey sheet for the area indicates the solid strata underlying each site to comprise typical Coal Measures formations, comprising sandstones with interbedded siltstones, mudstones and coal seams.

There are 10 recorded mine entries within the site boundaries. The locations of these are shown on Figure 10, with details given below:

Reference	Type	Owner	Treatment Details
274206-011	Adit	CA	No record of treatment.
274206-025	Adit	CA	No record of treatment (water issuing).
274206-019	Adit	CA	No record of treatment.
274206-026	Adit	CA	No record of treatment (water issuing).
275207-024	Adit	CA	No record of treatment.
275207-023	Adit	CA	No record of treatment.
275207-022	Adit	CA	No record of treatment.
275207-021	Adit	CA	No record of treatment.
275207-020	Adit	CA	No record of treatment.
275207-019	Adit	CA	No record of treatment.

None of the mine entries were observed as being open. Two were observed as issuing water (identified in the table above).

3.0 History

Inspection of historic Ordnance Survey plans dating from 1877 indicates the overall site to have initially developed with the formation of two small quarries, one named Cwar Pentwyn (Site 1) and the other un-named and described as an ‘old quarry’ (Site 2). A mine entry (adit) is shown as an ‘old coal level’ at the south west corner of Site 1 with a small spoil tip immediately adjacent. Mounds of quarry waste are shown to the south and east of both quarries at Sites 1 and 2.

The 1898 plan shows Cwar Pentwyn to have expanded slightly, with a corresponding increase in spoil mounds to the south and east.

Both quarries appear to be disused on the 1918 Edition plan, with Godre’r Graig School having been constructed the period between surveys.

The 1962 Edition plan shows both quarries as disused and also indicated a row of mine entries (adits) and small spoil mounds at Site 3. These appear to have short lived ventures.

Recent quarrying activity was evident at Site 1, with access tracks having been created and numerous mounds of spoil deposited over the site.

4.0 Observations

Inspection on the 13th June 2019 began at the south-western extremity of Site 1, at the access track leading to Pentwyn Farm and the entrance to Cwar Pentwyn (photographs 1 and 2). It was noted that flows from the mine adits above were entering the roadside drainage channel along the Pentwyn Farm access road (photograph 3). The quarry access track was well used and mounds of what appeared to be quarried material were present over the location of the mine adits and the colliery spoil tip to the south of the track (photographs 4, 5 and 9).

The recorded adit positions in this area were evidenced by flows entering a partially lined channel, conveying water to the roadside channel along Pentwyn Farm access road (photographs 6 and 7).

The flanks of the colliery and quarry spoil mounds were very steep and densely vegetated, preventing a close inspecting of material and topography (photographs 8, 17, 18 and 19).

Very little evidence of recent instability was observed, with the exception of a small degraded shallow slip at approximate NGR 274910E 206861N (photograph 20) and some areas of soil creep.

The inspection then viewed the floor and high walls of Cwar Pentwyn. Recent quarrying activity appeared to have taken place, with mounds of excavated material present. Evidence of human activity was also observed as a 'Lazy Spa' type pool, tent and camp bed were present, along with electricity extension cables leading downslope toward the properties named 'Glanderi' and 'Darren View' (photographs 11 to 16).

The inspection route then accessed the area encompassed by Site 2, crossing a derelict fence-line and heading east across an area of dense fern and bramble vegetation with a sporadic cover of trees. The density of vegetation prevented close inspection of materials or topography and access was extremely difficult (photographs 22, 24 and 25).

Occasional exposures of small boulders were present, and a number of dry short gully type features were observed, covered in dense vegetation and generally orientated downslope.

At the northern boundary of the site, the overgrown remains of a former access track, presumably leading to the un-named quarry, appeared to be present (photograph 23).

A spring was observed emanating from the vicinity of mine adit reference 274206-026 at NGR 274988E 206957N (photograph 21). The spring was observed as forming a small marshy area, subsequently flowing overland and downslope in a south-easterly direction.

The watercourse disappeared and reappeared at several locations, probably through the coarse quarry spoil present, appearing again as a spring type feature at NGR 275067E 206915N (photograph 29). The watercourse then flowed in an unlined channel to enter a screened chamber at NGR 275135E 206891N (photograph 30), before entering a final chamber to the rear of Godre'r Graig Primary School at NGR 275157E 206892N (photograph 36). The watercourse then appeared to be culverted beneath the school.

The inspection route then turned north east and viewed the series of recorded mine adits above Site 3, the entrances to which appeared to have collapsed many years ago. The colliery tips associated with these mine entries comprised a liner low mound of spoil forming a ridgeline at the head of Site 3 (photographs 26 to 28).

The inspection route traversed the slope behind Godre’r Graig Primary School, viewing the route of the watercourse referenced above and the drainage chambers to the rear of the school. A stone filled cut off drain with several manhole chambers was observed in the grazing field to the rear of the school, along with a spring located at approximate NGR 275164E 206992N. Flows from the spring were captured by the stone cut off drain (photographs 33, 35 and 37).

A derelict stable and several stands of Japanese Knotweed were observed present in this area (photographs 32 to 34).

The approximate route is shown on Figure 11.

5.0 Consequences of Failure

Site 1

Very little evidence of recent instability was observed, with the exception of a small degraded shallow slip at approximate NGR 274910E 206861N and occasional areas of soil creep Surcharging of existing historic colliery and quarry spoil materials could take place following recent deposition of materials. A significant failure of the spoil heaps would impact on the access road to Pentwyn Farm and the properties along the access road. Blockage of the water course emanating from the mine entries could lead to a build-up of pore pressure and saturation of the spoil, leading to failure.

Site 2

No evidence of recent movement was observed within this area, however the dense vegetation coverage prevented detailed inspection. Occasional exposures of small boulders were present, and a number of dry short gully type features were observed, suggesting that localised minor movement, probably by surface water erosion, is taking place. A change in flow from the spring adjacent the mine adit at the crest of the site could potentially lead to more significant erosion and minor slope failures, although the likely coarse and free draining nature of the quarry spoil would provide some mitigation in terms of slope stability. A major failure of the quarry spoil could potentially reach Godre’r Graig School. Although unlikely, a slope stability analysis based on available information supported by ground investigation data would be beneficial to assess the extent and likelihood of such a failure.

Blockages of the drainage infrastructure to the rear of Godre’r Graig Primary School would result in flooding and potential slope instability.

Site 3

Evidence of slow soil creep and falls of rock from the escarpment above the line of adits was observed but these likely to present a low risk to public safety.

A significant failure of the tip complex could result in a flow of material downslope to the east with the potential to reach Godre’r Graig Cemetery. This scenario is considered to have a low probability.

6.0 Recommendations

In order to ensure the risk of instability and public safety remains low, the following recommendations are provided for consideration:

- Investigate ownership of Site 1 and establish what measures, if any, have been taken with regard to placing recent materials over historic spoil materials.

- Investigate activity within Cwar Pentwyn to establish if planning or quarry regulations have been breached.

- Ensure drainage system from adit positions at Cwar Pentwyn is maintained.

- Consider clearing vegetation to allow inspection of drainage routes at Site 2.

- Ensure drainage infrastructure to the rear of Godre'r Graig Primary School is regularly inspected and maintained.

- Consider undertaking a slope stability analysis for Site 2 based on available information supplemented by ground investigation.

- Consider spraying of Japanese Knotweed to rear of school.

- Undertake an inspection during winter, when vegetation has died back to allow a more detailed viewing of the site with less vegetation constraints. The requirement for further inspections should be determined following the winter inspection.

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Appendices

Figures

Photographs

Figure 1 – Site Locations

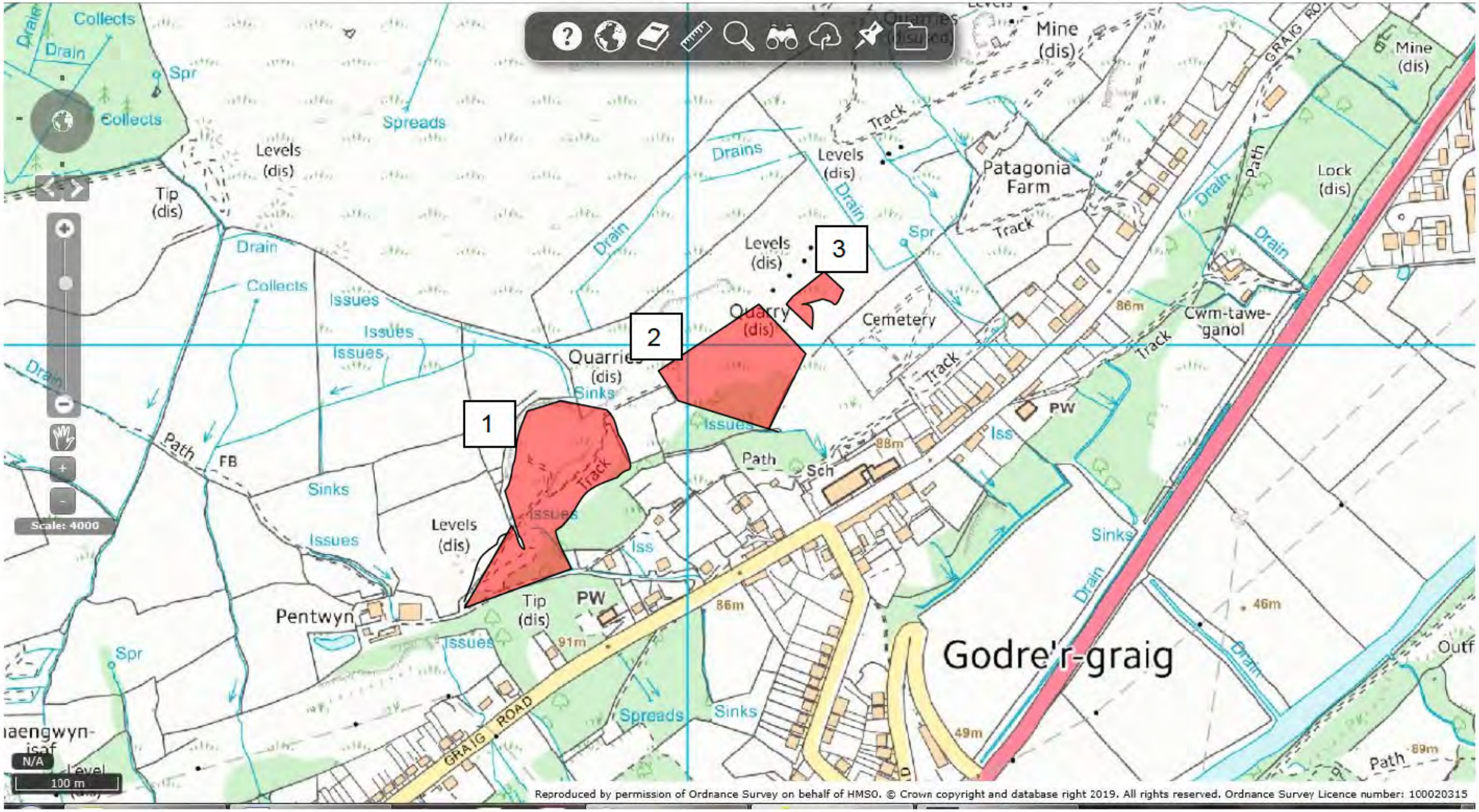

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Figure 2 – Google Earth Image

Figure 3 – Contour Plan

Figure 4 – LIDAR Relief Map

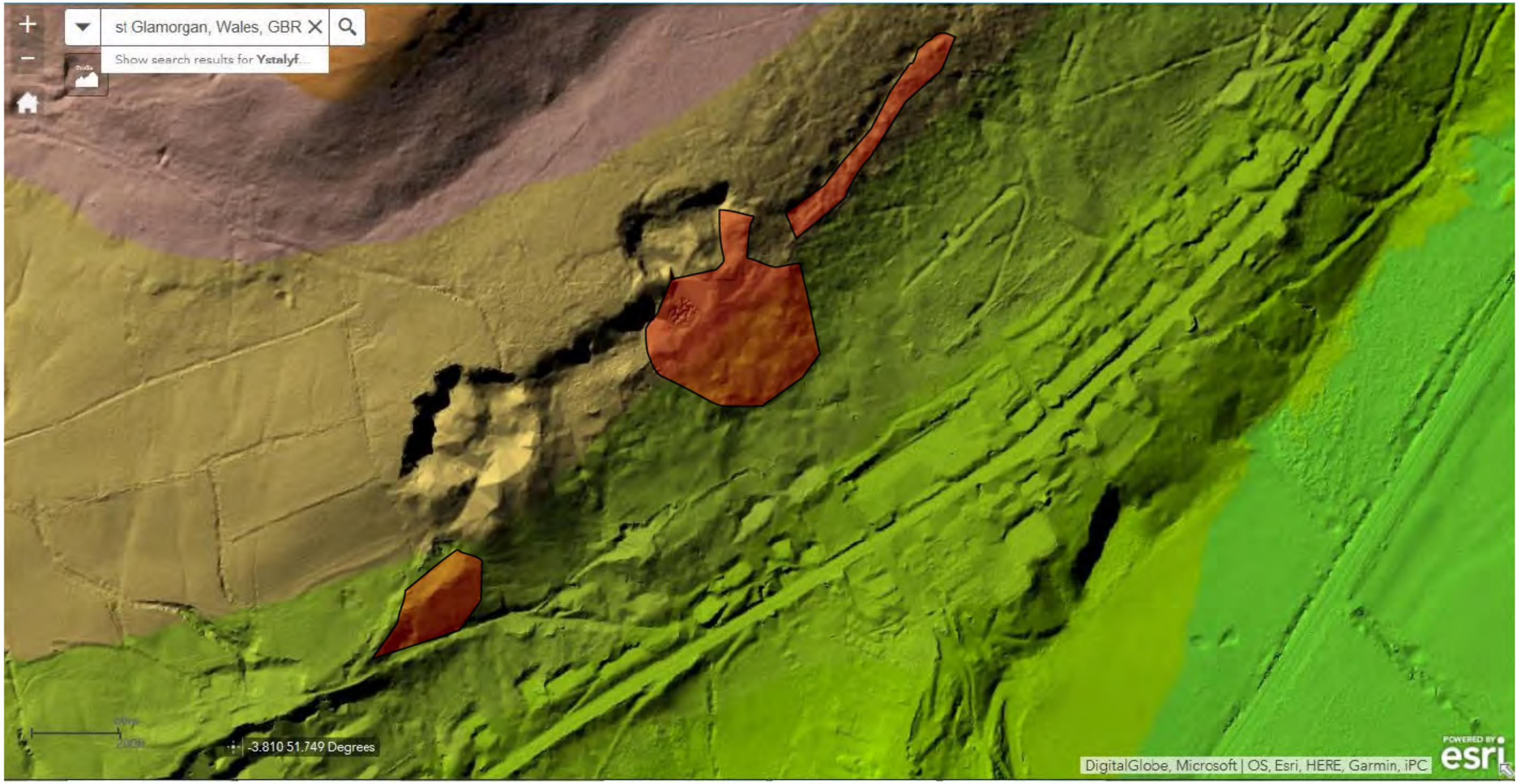

Figure 5 – Geological Plan

Figure 6 – 1877 Ordnance Survey (www.old-maps.co.uk)

Figure 7 – 1898 Ordnance Survey (www.old-maps.co.uk)

Figure 8 – 1918 Ordnance Survey (partial) (www.old-maps.co.uk)

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Figure 9 – 1962 Ordnance Survey (www.old-maps.co.uk)

Figure 10 – Mining Features

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Figure 11 – Inspection Route

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Photograph 1 – Access road to Pentwyn Farm

Photograph 2 – Access Road to Pentwyn Quarry

Photograph 3 – Flows from adit positions to Pentwyn Farm access track

Photograph 4 – Recent tipping of material at Site 1

Photograph 5 – Recent tipping of material at Site 1

Photograph 6 – Discharge from adit positions at Site 1

Photograph 7 – Discharge from adit positions at Site 1

Photograph 8 – Steep densely vegetated flanks of Site 1

Photograph 9 – Recent tipping of material at Site 1

Photograph 10 – Access track to Pentwyn Quarry

Photograph 11 – High wall of Pentwyn Quarry showing recent tipping

Photograph 12 – Pentwyn Quarry floor

Photograph 13 – Pentwyn Quarry recent excavations

Photograph 14 – 'Lazy Spa' located in quarry floor

Photograph 15 – Recently used shelter in quarry floor

Photograph 16 – Shelter showing electricity cables

Photograph 17 – Steep densely vegetated flanks of Site 1

Photograph 18 – Steep densely vegetated flanks of Site 1

Photograph 19 – Overgrown access path along toe of Site 1

Photograph 20 – Small slip on flank of Site 1

Photograph 21 – Minor watercourse at head of Site 2

Photograph 22 – General view of Site 2 showing dense vegetation coverage

Photograph 23 – Quarry face above Site 2

Photograph 24 – Mid point of Site 2 showing dense undergrowth

Photograph 25 – View down-slope from crest of Site 2

Photograph 26 – View of Site 3 from toe

Photograph 27 – View of Site 3 from toe

Photograph 28 – View of Site 3 showing collapsed adit positions

Photograph 29 – Moderate seepage at SW section of Site 2

Photograph 30 – Inlet chamber to rear of school

Photograph 31 – Field to rear of school

Photograph 32 – Field to rear of school showing Japanese Knotweed

Photograph 33 – Stone filled cut off drain to rear of school

Photograph 34 – Derelict stable to rear of school

Photograph 35 – Strong seepage to rear of school

Photograph 36 – Inlet chamber at rear of school

Photograph 37 – Manhole cover on line of stone filed cut off drain

Photograph 38 – Access gate to field at rear of school

APPENDIX C

TRIAL PIT RECORDS

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

Excavation method/plant: JCB 3CX

Shoring/support: None

TP1

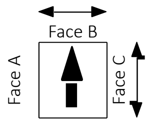
Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e

Excavation date: 21/06/2019
Backfill date: 21/06/2019
Logged by: MTE

Survey details:

Ground Level: 103.0 mOD
Easting: 275135 mE
Northing: 206900 mN
Bearing:

Plan details:



Face Stability:

Good

Groundwater observations:

Groundwater not encountered

Depth	Sample		Test Details		Strata Details			
m	Type	Class	Type	Result	Description	Depth (thickness)	mOD	Legend
					Dark brown clayey gravelly organic SAND. (TOPSOIL)	(0.10) 0.10	102.90	▨
0.30	D				Firm orange-brown mottled grey silty sandy slightly gravelly CLAY. (MADE GROUND)	(0.30) 0.40	102.60	▩
0.50	D				Firm to stiff dark brown very gravelly CLAY with high cobble content. Gravel and cobbles are fine to coarse, rounded to subangular of siltstone and sandstone. (PROBABLE DIAMICTON)	(0.90) 1.0 1.30	101.70	▦
					Probably dense brown very clayey slightly sandy fine to coarse GRAVEL of siltstone, sandstone and fine coal. (PROBABLE DIAMICTON)	(0.50) 1.80	101.20	▦
					End of Trialpit at 1.800m	2.0 3.0		

Weather and environmental conditions:

1. Sunny, dry

Other comments:

1. Coordinates for the centre of the site, and ground level obtained from online resources.
2. Trial pit terminated at a depth of 1.8.
3. Groundwater not encountered.
4. Trial pit sides stable.
5. Trial pit backfilled with arisings.

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

TP2

Excavation method/plant: JCB 3CX

Shoring/support: None

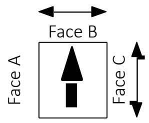
Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e

Excavation date: 21/06/2019
Backfill date: 21/06/2019
Logged by: MTE

Survey details:

Ground Level: 100.0 mOD
Easting: 275135 mE
Northing: 206900 mN
Bearing:

Plan details:



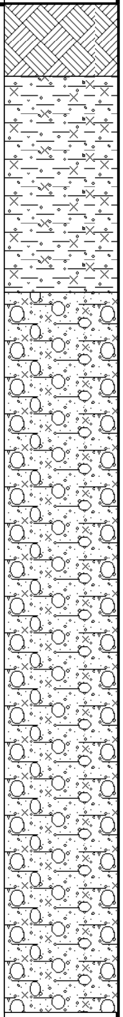
Face Stability:

Good

Groundwater observations:

Seepage at 1.4m

Depth	Sample		Test Details		Strata Details			
m	Type	Class	Type	Result	Description	Depth (thickness)	mOD	Legend
					Dark brown clayey gravelly organic SAND. (TOPSOIL)	(0.20) 0.20	99.80	
					Firm light orange-brown slightly sandy slightly gravelly silty CLAY with roots. Gravel is fine of sandstone. (PROBABLE DIAMICTON)	(0.60) 0.80	99.20	
0.60	D							
					Probably medium dense to dense dark brownish grey very clayey slightly sandy GRAVEL with low cobble content. Gravel and cobbles of rounded to subangular siltstone and sandstone and abundant fine decomposed coal gravel. (PROBABLE DIAMICTON)	(2.00) 2.80	97.20	
1.00	D					1.0		
2.00	B					2.0		
					End of Trialpit at 2.800m	3.0		



Weather and environmental conditions:

1. Sunny, dry

Other comments:

1. Coordinates for the centre of the site, and ground level obtained from online resources.
2. Trial pit terminated at a depth of 2.8m.
3. Seepage of groundwater within Glacial Diamicton at a depth of 1.4m.
4. Trial pit sides stable.
5. Trial pit backfilled with arisings.

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

TP3

Excavation method/plant: JCB 3CX

Shoring/support: None

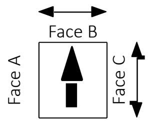
Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e

Excavation date: 21/06/2019
Backfill date: 21/06/2019
Logged by: MTE

Survey details:

Ground Level: 103.0 mOD
Easting: 275135 mE
Northing: 206900 mN
Bearing:

Plan details:



Face Stability:

Good

Groundwater observations:

Seepage at 1.6m

Depth	Sample		Test Details		Strata Details			
m	Type	Class	Type	Result	Description	Depth (thickness)	mOD	Legend
					Dark brown clayey gravelly organic SAND. (TOPSOIL)	(*0.10*)		▨
0.50	D				Firm to stiff orange-brown mottled grey slightly sandy very gravelly CLAY with medium cobble content with roots and rootlets in the upper parts. Gravel and cobbles subrounded to subangular of sandstone, siltstone and rare fine mudstone, abundant fine fragments of coal. (PROBABLE DIAMICTON)	0.10 (*1.20*) 1.0	102.90	▨
1.50	B				Probably medium dense to dense dark brownish grey very clayey slightly sandy GRAVEL with low cobble content. Gravel and cobbles of rounded to subangular siltstone and sandstone and abundant fine decomposed coal gravel. (PROBABLE DIAMICTON)	1.30 2.0 (*1.50*)	101.70	▨
					End of Trialpit at 2.800m	2.80 3.0	100.20	

Weather and environmental conditions:

1. Sunny, dry

Other comments:

1. Coordinates for the centre of the site, and ground level obtained from online resources.
2. Trial pit terminated at a depth of 2.8m.
3. Seepage of groundwater within Glacial Diamicton at a depth of 1.6m.
4. Trial pit sides stable.
5. Trial pit backfilled with arisings.

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

Excavation method/plant: JCB 3CX

Shoring/support: None

TP4

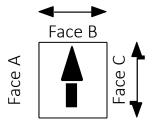
Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e

Excavation date: 21/06/2019
Backfill date: 21/06/2019
Logged by: MTE

Survey details:

Ground Level: 103.0 mOD
Easting: 275135 mE
Northing: 206900 mN
Bearing:

Plan details:



Face Stability:

Good

Groundwater observations:

Groundwater not encountered

Depth	Sample		Test Details		Strata Details			
m	Type	Class	Type	Result	Description	Depth (thickness)	mOD	Legend
0.50	D				Probably loose to medium dense black mottled dark brown slightly gravelly slightly clayey SAND with low cobble content and fragments of plastic and rare ash. Gravel and cobbles angular to rounded of brick, concrete and sandstone. (MADE GROUND)	(*0.90*) 0.90	102.10	▨
1.50	B				Probably medium dense to dense orange-brown silty sandy clayey GRAVEL with low cobble content. Gravel and cobbles generally rounded to subangular, fine to coarse of sandstone and siltstone, fine gravel of black coal. (PROBABLE DIAMICTON)	(*2.00*)		▨
2.50	D					2.90	100.10	
					End of Trialpit at 2.900m			

Weather and environmental conditions:

1. Sunny, dry

Other comments:

1. Coordinates for the centre of the site, and ground level obtained from online resources.
2. Trial pit terminated at a depth of 2.9m.
3. Groundwater not encountered.
4. Minor spalling wthin Mae Ground materials in Trial pit sides.
5. Trial pit backfilled with arisings.

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

Excavation method/plant: JCB 3CX
Shoring/support: None

TP5

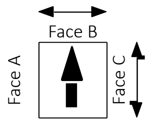
Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e

Excavation date: 21/06/2019
Backfill date: 21/06/2019
Logged by: MTE

Survey details:

Ground Level: 101.0 mOD
Easting: 275135 mE
Northing: 206900 mN
Bearing:

Plan details:



Face Stability:

Good

Groundwater observations:

Groundwater not encountered

Depth	Sample		Test Details		Strata Details			
m	Type	Class	Type	Result	Description	Depth (thickness)	mOD	Legend
					Dark brown very clayey gravelly organic SAND. (TOPSOIL)	(*0.10*) 0.10	100.90	▨
					Firm becoming stiff orange-brown mottled grey silty very gravelly CLAY with medium cobble content. Gravel mainly of fine coal, sandstone and siltstone gravel and cobbles are subrounded to subangular of sandstone. (PROBABLE DIAMICTON)			▨
0.50	D							
						(*1.10*)		
1.00	B					1.0		
					Probably medium dense to dense dark brownish grey very clayey slightly sandy GRAVEL with low cobble content. Gravel and cobbles of rounded to subangular siltstone and sandstone and abundant fine decomposed coal gravel. (PROBABLE DIAMICTON)	1.20	99.80	▨
						(*1.50*) 2.0		
					End of Trialpit at 2.700m	2.70	98.30	
						3.0		

Weather and environmental conditions:

1. Sunny, dry

Other comments:

1. Coordinates for the centre of the site, and ground level obtained from online resources.
2. Trial pit terminated at a depth of 2.7m.
3. Groundwater not encountered.
4. Trial pit sides stable.
5. Trial pit backfilled with arisings.

APPENDIX D

WINDOWLESS SAMPLER RECORDS

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e

Drilling method

Equipment Dart Rig

WS1

Start date: 24/06/2019
End date: 24/06/2019
Backfill date: 24/06/2019

Driller: SGT
Logged by: MTE
Date logged: 24/06/2019

Ground Level: 103.00 mOD
Easting: 275135 m
Northing: 206900 m

Depth	Sample		Test Details		TCR (%)	Water Depth	Casing Depth	Strata Details		Water	Depth		Backfill/ Install-ations
	Type	Class	Type	Result				Description	Legend	Strikes/ Standing	Depth (Thickness)	mOD	
								Dark brown clayey gravelly organic SAND with fragments of brick and plastic. (MADE GROUND)	▨		(0.20) 0.20	102.80	■
								Dark brown and black slightly clayey sandy GRAVEL with high cobble content. Gravel and cobbles angular to rounded, fine to coarse of sandstone, brick and occasional concrete. (MADE GROUND)	▨		(0.40) 0.60	102.40	■
								End of Borehole at 0.600m					

Progress & Standing Water Levels					Water Strikes							Chiselling			Hole Diameter		Casing Diameter	
Date	Time	Hole Depth	Casing Depth	Water Depth	Date	Time	Strike Depth	Casing Depth	Elapsed Minutes	Depth to Water	Depth Sealed	Depth Top	Depth Base	Duration	Hole Depth	Hole Diameter	Casing Diameter	Casing Depth

General Remarks

1. Coordinates for the centre of the site, and ground level obtained from online resources.
2. Service pit excavated to a depth of 0.6m, whereupon terminetaed due to cobbles and boulders.
3. Groundwater not encountered.
4. Service pit backfilled with arisings.

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e

Drilling method
Equipment Dart Rig

WS1A

Start date: 24/06/2019
End date: 24/06/2019
Backfill date: 24/06/2019
Driller: SGT
Logged by: MTE
Date logged: 24/06/2019
Ground Level: 103.00 mOD
Easting: 275135 m
Northing: 206900 m

Depth	Sample		Test Details		TCR (%)	Water Depth	Casing Depth	Strata Details		Water	Depth		Backfill/ Install-ations
	Type	Class	Type	Result				Description	Legend	Strikes/ Standing	Depth (Thickness)	mOD	
								Dark brown clayey gravelly organic SAND with fragments of brick. (MADE GROUND)			(0.10) 0.10	102.90	
1.00	D							Loose to medium dense brown, dark brown and black very clayey sandy angular fine to coarse GRAVEL with low cobble content and partings of soft black sandy silt of coal and clay. Gravel and cobbles of sandstone and brick. (MADE GROUND)			(1.60) 1.70	101.30	
			S	10 (2,3/3,2,2,3)									
2.00	D		S	8 (1,2/2,2,2,2)				Soft quickly becoming firm brown mottled grey sandy very gravelly CLAY with low cobble content. Gravel and cobbles subrounded to subangular of sandstone, siltstone and rare fine mudstone, abundant fine fragments of coal. (PROBABLE DIAMICTON)			(0.90) 2.60	100.40	
3.00	D		S	37 (3,3/5,4,10,18)				Medium dense to very dense dark brownish grey clayey slightly sandy GRAVEL with medium cobble content. Gravel and cobbles of rounded to subangular siltstone and sandstone and abundant fine coal gravel. (PROBABLE DIAMICTON)			(1.40) 4.00	99.00	
			S	50 (12,16/50 for 125mm)				End of Borehole at 4.000m					

Progress & Standing Water Levels					Water Strikes							Chiselling			Hole Diameter		Casing Diameter	
Date	Time	Hole Depth	Casing Depth	Water Depth	Date	Time	Strike Depth	Casing Depth	Elapsed Minutes	Depth to Water	Depth Sealed	Depth Top	Depth Base	Duration	Hole Depth	Hole Diameter	Casing Diameter	Casing Depth

General Remarks

1. Coordinates for the centre of the site, and ground level obtained from online resources.
2. Service pit excavated to a depth of 1.2m.
3. Borehole drilled until refusal, at a depth of 4m.
4. Groundwater not encountered.
5. Groundwater monitoring standpipes installed to a depth of 4m with a response zone between 1m to 4m.

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

WS2

Start date:	24/06/2019	**Driller:**	SGT
End date:	24/06/2019	**Logged by:**	MTE
Backfill date:	24/06/2019	**Date logged:**	24/06/2019

Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e

Drilling method

Equipment Dart Rig

Ground Level:	101.00 mOD
Easting:	275135 m
Northing:	206900 m

Depth	Sample Type	Sample Class	Test Type	Test Result	TCR (%)	Water Depth	Casing Depth	Strata Description	Legend	Water Strikes/ Standing	Depth (Thickness)	mOD	Backfill/ Install-ations
								Dark brown clayey gravelly organic SAND. (MADE GROUND)			(0.20) 0.20	100.80	
								Very dark brown clayey gravelly organic SAND with roots. (MADE GROUND)			(0.20) 0.40	100.60	
								Medium dense brown clayey gravelly silty SAND with occasional pottery fragments. (MADE GROUND)			(1.20)		
			S	24 (6,6/24 for 245mm)									
1.50	D										1.60	99.40	
								Firm to stiff brown mottled grey sandy very gravelly CLAY with low cobble content. Gravel and cobbles subrounded to subangular of sandstone, siltstone and rare fine mudstone, abundant fine fragments of coal. (PROBABLE DIAMICTON)			(0.40)		
1.90	D												
			S	21 (5,6/5,5,5,6)							2.00	99.00	
								Stiff to very stiff dark grey slightly sandy very gravelly CLAY with medium cobble content. Gravel and cobbles of rounded to subangular siltstone and sandstone and abundant fine coal gravel. (PROBABLE DIAMICTON)					
3.00	D		S	22 (6,6/5,5,6,6)							3		
											(3.00)		
			S	20 (6,5/5,5,5,5)							4		

Progress & Standing Water Levels

Date	Time	Hole Depth	Casing Depth	Water Depth

Water Strikes

Date	Time	Strike Depth	Casing Depth	Elapsed Minutes	Depth to Water	Depth Sealed
24/06/2019	12:00	4.80	0.00	0.00	0.00	

Chiselling

Depth Top	Depth Base	Duration

Hole Diameter

Hole Depth	Hole Diameter

Casing Diameter

Casing Diameter	Casing Depth

General Remarks

1. Coordinates for the centre of the site, and ground level obtained from online resources.
2. Service pit excavated to a depth of 1.2m.
3. Borehole drilled until refusal, at a depth of 5m.
4. Groundwater tentitively struck at a depth of 4.8m.
5. Groundwater monitoring standpipes installed to a depth of 5m with a response zone between 1m to 5m.

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

WS2

Project Name: Godre'r Graig Primary School	**Drilling method**		
Site Location: Godre'r Graig	**Equipment** Dart Rig		
Client: Neath Port Talbot CBC	**Ground Level:**	101.00 mOD	
Project No: 7234e	**Easting:**	275135 m	
	Northing:	206900 m	

Start date:	24/06/2019	**Driller:**	SGT
End date:	24/06/2019	**Logged by:**	MTE
Backfill date:	24/06/2019	**Date logged:**	24/06/2019

Depth	Sample		Test Details		TCR (%)	Water Depth	Casing Depth	Strata Details		Water	Depth		Backfill/ Install-ations
	Type	Class	Type	Result				Description	Legend	Strikes/ Standing	Depth (Thickness)	mOD	
								Stiff to very stiff dark grey slightly sandy very gravelly CLAY with medium cobble content. Gravel and cobbles of rounded to subangular siltstone and sandstone and abundant fine coal gravel. (PROBABLE DIAMICTON)	▨	→			▨
			S	50 (0 for 0mm/50 for 115mm)				End of Borehole at 5.000m			5.00	96.00	
											6		
											7		
											8		

Progress & Standing Water Levels

Date	Time	Hole Depth	Casing Depth	Water Depth

Water Strikes

Date	Time	Strike Depth	Casing Depth	Elapsed Minutes	Depth to Water	Depth Sealed
24/06/2019	12:00	4.80	0.00	0.00	0.00	

Chiselling

Depth Top	Depth Base	Duration

Hole Diameter

Hole Depth	Hole Diameter

Casing Diameter

Casing Diameter	Casing Depth

General Remarks

1. Coordinates for the centre of the site, and ground level obtained from online resources.
2. Service pit excavated to a depth of 1.2m.
3. Borehole drilled until refusal, at a depth of 5m.
4. Groundwater tentitively struck at a depth of 4.8m.
5. Groundwater monitoring standpipes installed to a depth of 5m with a response zone between 1m to 5m.

Earth Science Partnership

Consulting Engineers | Geologists | Environmental Scientists

WS3

Start date:	24/06/2019	**Driller:**	SGT
End date:	24/06/2019	**Logged by:**	MTE
Backfill date:	24/06/2019	**Date logged:**	24/06/2019

Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e

Drilling method
Equipment Dart Rig
Ground Level: 100.00 mOD
Easting: 275135 m
Northing: 206900 m

Depth	Sample		Test Details		TCR	Water	Casing	Strata Details		Water	Depth		Backfill/ Installations
	Type	Class	Type	Result	(%)	Depth	Depth	Description	Legend	Strikes/ Standing	Depth (Thickness)	mOD	
								Dark brown clayey gravelly organic SAND. (MADE GROUND)			(0.30) 0.30	99.70	
0.80	D							Soft orange-brown mottled grey gravelly slightly sandy CLAY. (MADE GROUND) Suspected land drain encountered in pit			(0.80) 1.10	98.90	
			S	12 (1,1/3,3,3,3)				Soft quickly becoming firm and then stiff brown mottled grey very sandy gravelly CLAY with low cobble content and sandy partings. Gravel and cobbles subrounded to subangular of sandstone, siltstone and rare fine mudstone, abundant fine fragments of coal. (PROBABLE DIAMICTON)			(0.90) 2.00	98.00	
1.80	D												
			S	25 (3,4/6,5,7,7)				Medium dense to very dense dark brownish grey clayey slightly sandy GRAVEL with medium cobble content. Gravel and cobbles of rounded to subangular siltstone and sandstone and abundant fine coal gravel. (PROBABLE DIAMICTON)			(1.00) 3.00	97.00	
2.80	D												
			S	50 (4,5/50 for 170mm)				End of Borehole at 3.000m					

Progress & Standing Water Levels					Water Strikes							Chiselling			Hole Diameter		Casing Diameter	
Date	Time	Hole Depth	Casing Depth	Water Depth	Date	Time	Strike Depth	Casing Depth	Elapsed Minutes	Depth to Water	Depth Sealed	Depth Top	Depth Base	Duration	Hole Depth	Hole Diameter	Casing Diameter	Casing Depth

General Remarks

1. Coordinates for the centre of the site, and ground level obtained from online resources.
2. Service pit excavated to a depth of 1.2m.
3. Borehole drilled until refusal, at a depth of 2.8m.
4. Groundwater not encountered.
5. Groundwater monitoring standpipes installed to a depth of 2.8m with a response zone between 1.5m to 2.8m.

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e

Drilling method
Equipment Dart Rig

WS4

Start date:	25/06/2019	**Driller:**	SGT
End date:	25/06/2019	**Logged by:**	MTE
Backfill date:	25/06/2019	**Date logged:**	25/06/2019

Ground Level: 102.00 mOD
Easting: 275135 m
Northing: 206900 m

Depth	Sample Type	Sample Class	Test Type	Test Result	TCR (%)	Water Depth	Casing Depth	Description	Legend	Water Strikes/ Standing	Depth (Thickness)	mOD	Backfill/ Install-ations
								Dark brown clayey gravelly organic SAND. (TOPSOIL)			(0.10) 0.10	101.90	
0.80	D		S	24 (5,7/6,6,6,6)				Firm becoming stiff light orange-brown slightly sandy very gravelly silty CLAY with roots. Gravel is fine of coal and sandstone. (PROBABLE DIAMICTON)			(1.20) 1.30	100.70	
1.80	D							Firm to stiff brown mottled grey sandy very gravelly CLAY with low cobble content. Gravel and cobbles subrounded to subangular of sandstone, siltstone and abundant fine fragments of coal. (PROBABLE DIAMICTON)			(1.60) 2.90	99.10	
3.00	D		S	24 (21 for 5mm/24 for 10mm)				Medium dense becoming very dense dark brownish grey clayey slightly sandy GRAVEL with medium cobble content. Gravel and cobbles of rounded to subangular siltstone and sandstone and abundant fine coal gravel. (PROBABLE DIAMICTON)		→	(0.80) 3.70	98.30	
			S	50 (0 for 0mm/50 for 50mm)				End of Borehole at 3.700m					

Progress & Standing Water Levels

Date	Time	Hole Depth	Casing Depth	Water Depth

Water Strikes

Date	Time	Strike Depth	Casing Depth	Elapsed Minutes	Depth to Water	Depth Sealed
25/06/2019	12:00	3.40	0.00	0.00	0.00	

Chiselling

Depth Top	Depth Base	Duration

Hole Diameter

Hole Depth	Hole Diameter

Casing Diameter

Casing Diameter	Casing Depth

General Remarks

1. Coordinates for the centre of the site, and ground level obtained from online resources.
2. Service pit excavated to a depth of 1.2m.
3. Borehole drilled until refusal, at a depth of 3.7m.
4. Groundwater tentitively struck at 3.4m.
5. Groundwater monitoring standpipes installed to a depth of 3.4m with a response zone between 0.7m to 3.7m.

Earth Science Partnership
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Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e

Drilling method

Equipment Dart Rig

Ground Level: 100.00 mOD
Easting: 275135 m
Northing: 206900 m

WS5

Start date: 25/06/2019
End date: 25/06/2019
Backfill date: 25/06/2019
Driller: SGT
Logged by: MTE
Date logged: 25/06/2019

Depth	Sample		Test Details		TCR (%)	Water Depth	Casing Depth	Strata Details		Water	Depth		Backfill/ Install-ations
	Type	Class	Type	Result				Description	Legend	Strikes/ Standing	Depth (Thickness)	mOD	
								Dark brown clayey gravelly organic SAND. (TOPSOIL)			(0.10) 0.10	99.90	
								Firm brown mottled grey very sandy gravelly CLAY with low cobble content. Gravel and cobbles subrounded to subangular of sandstone, siltstone and abundant fine fragments of coal. (PROBABLE DIAMICTON)			(0.90) 1.00	99.00	
0.50	B												
								Medium dense to dense dark brownish grey clayey silty very sandy GRAVEL with low cobble content. Gravel and cobbles of rounded to subangular siltstone and sandstone and abundant fine coal gravel. (PROBABLE DIAMICTON)			(1.70) 2.70	97.30	
			S	24 (4,5/5,5,7,7)									
2.50	B												
			S	50 (0 for 0mm/50 for 125mm)				End of Borehole at 2.700m					

Progress & Standing Water Levels					Water Strikes							Chiselling			Hole Diameter		Casing Diameter	
Date	Time	Hole Depth	Casing Depth	Water Depth	Date	Time	Strike Depth	Casing Depth	Elapsed Minutes	Depth to Water	Depth Sealed	Depth Top	Depth Base	Duration	Hole Depth	Hole Diameter	Casing Diameter	Casing Depth

General Remarks

1. Coordinates for the centre of the site, and ground level obtained from online resources.
2. Service pit excavated to a depth of 1.2m.
3. Borehole drilled until refusal, at a depth of 2.7m.
4. Groundwater not encountered.
5. Groundwater monitoring standpipes installed to a depth of 2.7m with a response zone between 0.7m to 2.7m.

Earth Science Partnership
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WS6

Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e

Drilling method
Equipment Dart Rig

Start date: 25/06/2019
End date: 25/06/2019
Backfill date: 25/06/2019

Driller: SGT
Logged by: MTE
Date logged: 25/06/2019

Ground Level: 102.00 mOD
Easting: 275135 m
Northing: 206900 m

Depth	Sample		Test Details		TCR (%)	Water Depth	Casing Depth	Strata Details		Water	Depth		Backfill/ Install-ations
	Type	Class	Type	Result				Description	Legend	Strikes/ Standing	Depth (Thickness)	mOD	
								Dark brown clayey gravelly organic SAND. (TOPSOIL)			(0.20) 0.20	101.80	
0.50	D							Firm light orange-brown slightly sandy slightly gravelly silty CLAY with roots. Gravel is fine of sandstone. (PROBABLE DIAMICTON)			(0.60) 0.80	101.20	
			S	34 (4,5/7,9,9,9)				Firm quickly becoming very stiff brown mottled grey very sandy very gravelly CLAY with low cobble content. Gravel and cobbles subrounded to subangular of sandstone, siltstone and abundant fine fragments of coal. (PROBABLE DIAMICTON)					
1.50	B										(1.50)		
			S	35 (7,8/10,8,7,10)							2.30	99.70	
2.50	B							Dense with loose to medium dense horizon at 4m to 5m, dark brown and grey clayey sandy GRAVEL with low cobble content. Gravel and cobbles of rounded to subangular siltstone and sandstone and abundant fine coal gravel. (PROBABLE DIAMICTON)					
			S	34 (5,5/6,8,12,8)									
											(2.70)		
4.00	B		S	9 (5,3/3,4,1,1)						→			

Progress & Standing Water Levels					Water Strikes							Chiselling			Hole Diameter		Casing Diameter	
Date	Time	Hole Depth	Casing Depth	Water Depth	Date	Time	Strike Depth	Casing Depth	Elapsed Minutes	Depth to Water	Depth Sealed	Depth Top	Depth Base	Duration	Hole Depth	Hole Diameter	Casing Diameter	Casing Depth
					25/06/2019	12:00	4.00	0.00	0.00	0.00								

General Remarks

1. Coordinates for the centre of the site, and ground level obtained from online resources.
2. Service pit excavated to a depth of 1.2m.
3. Borehole drilled until refusal, at a depth of 5m.
4. Groundwater tentively struck at 4m.
5. Groundwater monitoring standpipes installed to a depth of 5m with a response zone between 1m to 5m.

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e

Drilling method

Equipment Dart Rig

Ground Level: 102.00 mOD
Easting: 275135 m
Northing: 206900 m

WS6

Start date: 25/06/2019
End date: 25/06/2019
Backfill date: 25/06/2019

Driller: SGT
Logged by: MTE
Date logged: 25/06/2019

Depth	Sample		Test Details		TCR (%)	Water Depth	Casing Depth	Strata Details		Water	Depth		Backfill/ Install-ations
	Type	Class	Type	Result				Description	Legend	Strikes/ Standing	Depth (Thickness)	mOD	
								Dense with loose to medium dense horizon at 4m to 5m, dark brown and grey clayey sandy GRAVEL with low cobble content. Gravel and cobbles of rounded to subangular siltstone and sandstone and abundant fine coal gravel. (PROBABLE DIAMICTON)					
			S	10 (1,1/2,3,3,2)				End of Borehole at 5.000m			5.00	97.00	
											6		
											7		
											8		

Progress & Standing Water Levels					Water Strikes							Chiselling			Hole Diameter		Casing Diameter	
Date	Time	Hole Depth	Casing Depth	Water Depth	Date	Time	Strike Depth	Casing Depth	Elapsed Minutes	Depth to Water	Depth Sealed	Depth Top	Depth Base	Duration	Hole Depth	Hole Diameter	Casing Diameter	Casing Depth
					25/06/2019	12:00	4.00	0.00	0.00	0.00								

General Remarks

1. Coordinates for the centre of the site, and ground level obtained from online resources.
2. Service pit excavated to a depth of 1.2m.
3. Borehole drilled until refusal, at a depth of 5m.
4. Groundwater tentively struck at 4m.
5. Groundwater monitoring standpipes installed to a depth of 5m with a response zone between 1m to 5m.

APPENDIX E

GEOTECHNICAL TEST RESULTS

UKAS TESTING
2788

Laboratory Report

GSTL

GEO Site & Testing Services Ltd

Contract Number: 45079

Client Ref:	**7234e**	Report Date:	**30-07-2019**
Client PO:	**8217**		

Client **Earth Science Partnership**
33 Cardiff Road
Taff's Well
Cardiff
CF15 7RB

Contract Title:	**Godre'r Graig School**
For the attention of:	**Mat Elcock**
Date Received:	**22-07-2019**
Date Commenced:	**22-07-2019**
Date Completed:	**30-07-2019**

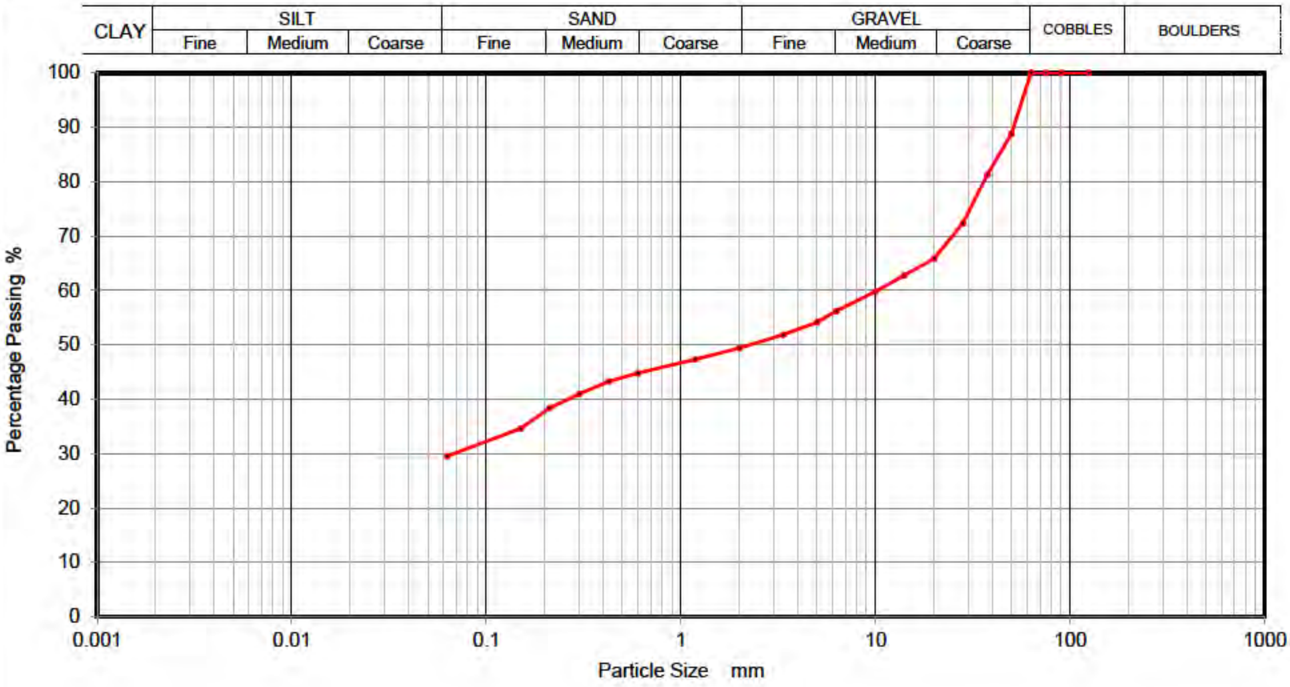
Test Description	Qty
PSD Wet Sieve method BS 1377:1990 - Part 2 : 9.2 - * UKAS	2
Disposal of samples for job	1

Notes: **Observations and Interpretations are outside the UKAS Accreditation**
*** - denotes test included in laboratory scope of accreditation**
 # - denotes test carried out by approved contractor
@ - denotes non accredited tests

This certificate is issued in accordance with the accreditation requirements of the United Kingdom Accreditation Service. The results reported herein relate only to the material supplied to the laboratory. This certificate shall not be reproduced except in full, without the prior written approval of the laboratory.

Approved Signatories:
Emma Sharp (Office Manager) - Paul Evans (Quality/Technical Manager) - Richard John (Advanced Testing Manager)
Sean Penn (Administrative/Accounts Assistant) - Shaun Jones (Laboratory manager) - Wayne Honey (Administrative/Quality Assistant)

GSTL	**PARTICLE SIZE DISTRIBUTION** **BS 1377 Part 2:1990** **Wet Sieve, Clause 9.2**	Contract Number	**Godre'r Graig School**
		Borehole/Pit No.	**TP4**
Site Name	**45079**	Sample No.	
Soil Description	Brown fine to coarse sandy silty/ clayey fine to coarse GRAVEL	Depth Top	**1.50**
		Depth Base	
Date Tested	25/07/2019	Sample Type	**B**



Sieving		**Sedimentation**	
Particle Size mm	% Passing	Particle Size mm	% Passing
125	100		
90	100		
75	100		
63	100		
50	89		
37.5	81		
28	72		
20	66		
14	63		
10	60		
6.3	56		
5	54		
3.35	52		
2	49		
1.18	47		
0.6	45		
0.425	43		
0.3	41		
0.212	38		
0.15	35		
0.063	30		

Sample Proportions	% dry mass
Cobbles	0
Gravel	51
Sand	19
Silt and Clay	30

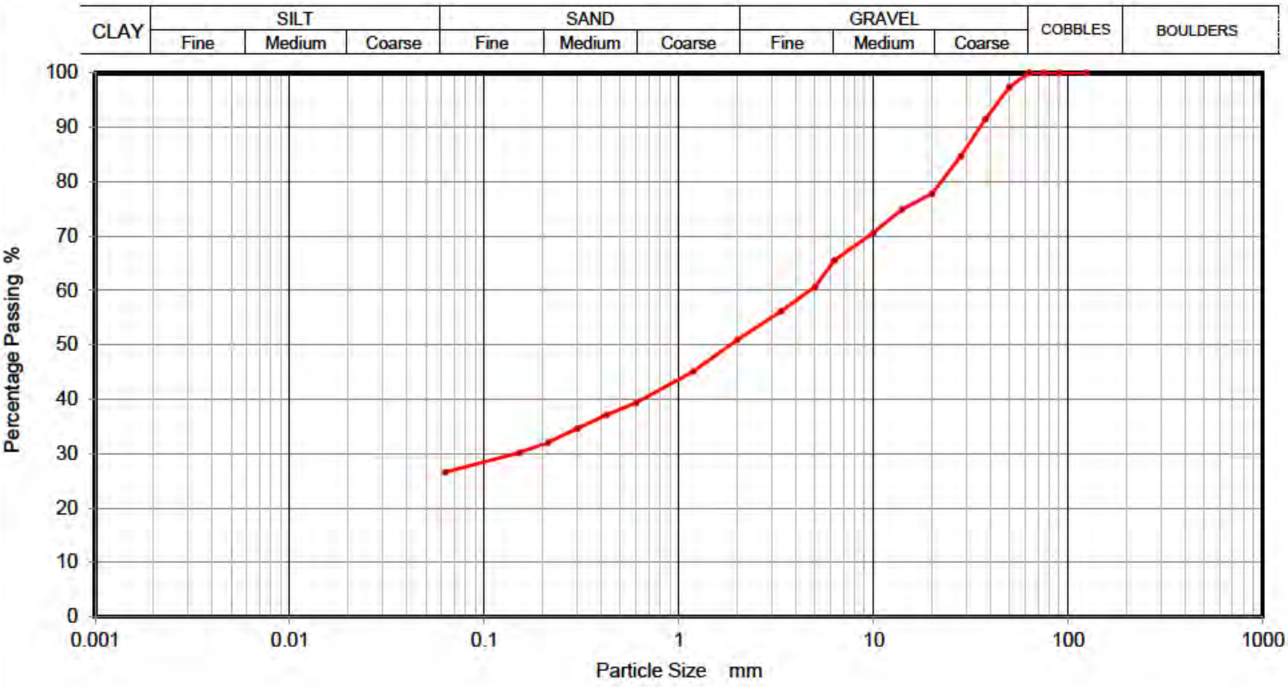
Remarks

Preparation and testing in accordance with BS1377 unless noted below

Operators	Checked	29/07/2019	Wayne Honey	W. Honey
RO/MH	Approved	30/07/2019	Paul Evans	P Evans

UKAS TESTING
2788

GSTL	**PARTICLE SIZE DISTRIBUTION** **BS 1377 Part 2:1990** **Wet Sieve, Clause 9.2**	Contract Number	**Godre'r Graig School**
		Borehole/Pit No.	**WS5**
Site Name	**45079**	Sample No.	
Soil Description	Brown fine to coarse sandy silty/ clayey fine to coarse GRAVEL	Depth Top	**2.50**
		Depth Base	
Date Tested	25/07/2019	Sample Type	**B**



Sieving		**Sedimentation**	
Particle Size mm	% Passing	Particle Size mm	% Passing
125	100		
90	100		
75	100		
63	100		
50	97		
37.5	91		
28	85		
20	78		
14	75		
10	71		
6.3	66		
5	61		
3.35	56		
2	51		
1.18	45		
0.6	39		
0.425	37		
0.3	35		
0.212	32		
0.15	30		
0.063	27		

Sample Proportions	% dry mass
Cobbles	0
Gravel	49
Sand	24
Silt and Clay	27

Remarks

Preparation and testing in accordance with BS1377 unless noted below

Operators	Checked	29/07/2019	Wayne Honey	W. Honey
RO/MH	Approved	30/07/2019	Paul Evans	P Evans

UKAS TESTING 2788

APPENDIX F

AERIAL PHOTOGRAPHS REVIEWED

Aerial Photographs Evaluated

Stereo Pairs

Date	Run	Photo No.	Height
3 August 1945	3G/TUD/T19	5075-6	?
22 May 1948	541/41	4173-4	16600’
17 May 1952	540/758	5031-3	?
14 April 1955	F22 58/RAF/1715	0302-4	16,600’
21 April 1960	RAF58/3506	0180#	?
14 April 1962	OS/62/14	036/038	?
16 May 1973	73 175	027-8	12.700’
24 April 1973	75 037	106-7	12,000’
9 June 1975	75 211	149-50	12,700’
7 April 1978	78 009	023-4	12.300’
30 May 1982	82 136	108-9	6000’
30 Aug 1983	167	071-2	?
8 June 1984	196	408-9	?
14 June 1989	89 279	034-5	6,300’
14 June 1989	89 279	051#	6,300’
7 Sept 1989	89 408	?	8,300’
11 April 1994	13 94	197-9	?
9 April 1997	304.825	057-8	8900’

 # single image

APPENDIX B EXTRACTS FROM HISTORICAL MAPS

esp
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SCIENTISTS

Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	County Series
Map date:	**1877**
Scale:	1:2,500
Printed at:	1:2,500

N
W E
S

Surveyed 1877
Revised 1877
Edition N/A
Copyright N/A
Levelled N/A

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INSIGHTS

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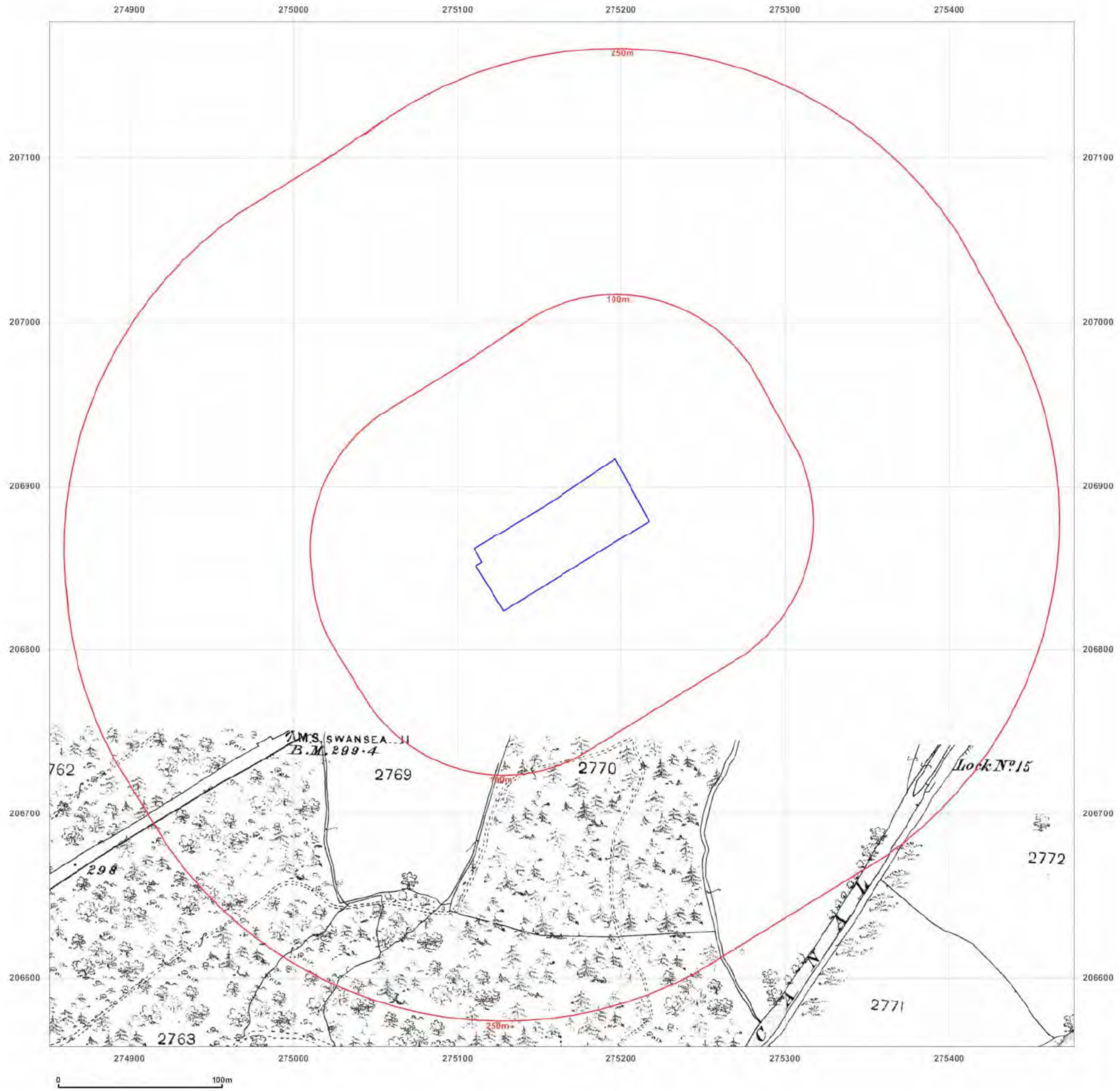
enquiries@earthsciencepartnership.com

Production date: 20 May 2019

Map legend available at:
www.groundsure.com/sites/default/files/groundsure_legend.pdf



esp

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	County Series
Map date:	**1887**
Scale:	1:2,500
Printed at:	1:2,500

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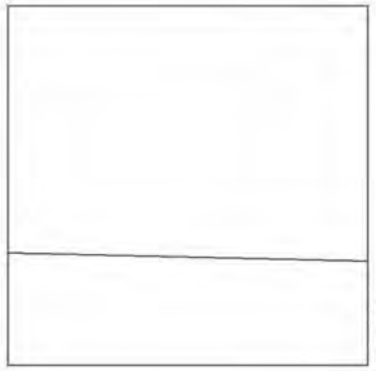

Surveyed 1887
Revised 1887
Edition N/A
Copyright N/A
Levelled N/A

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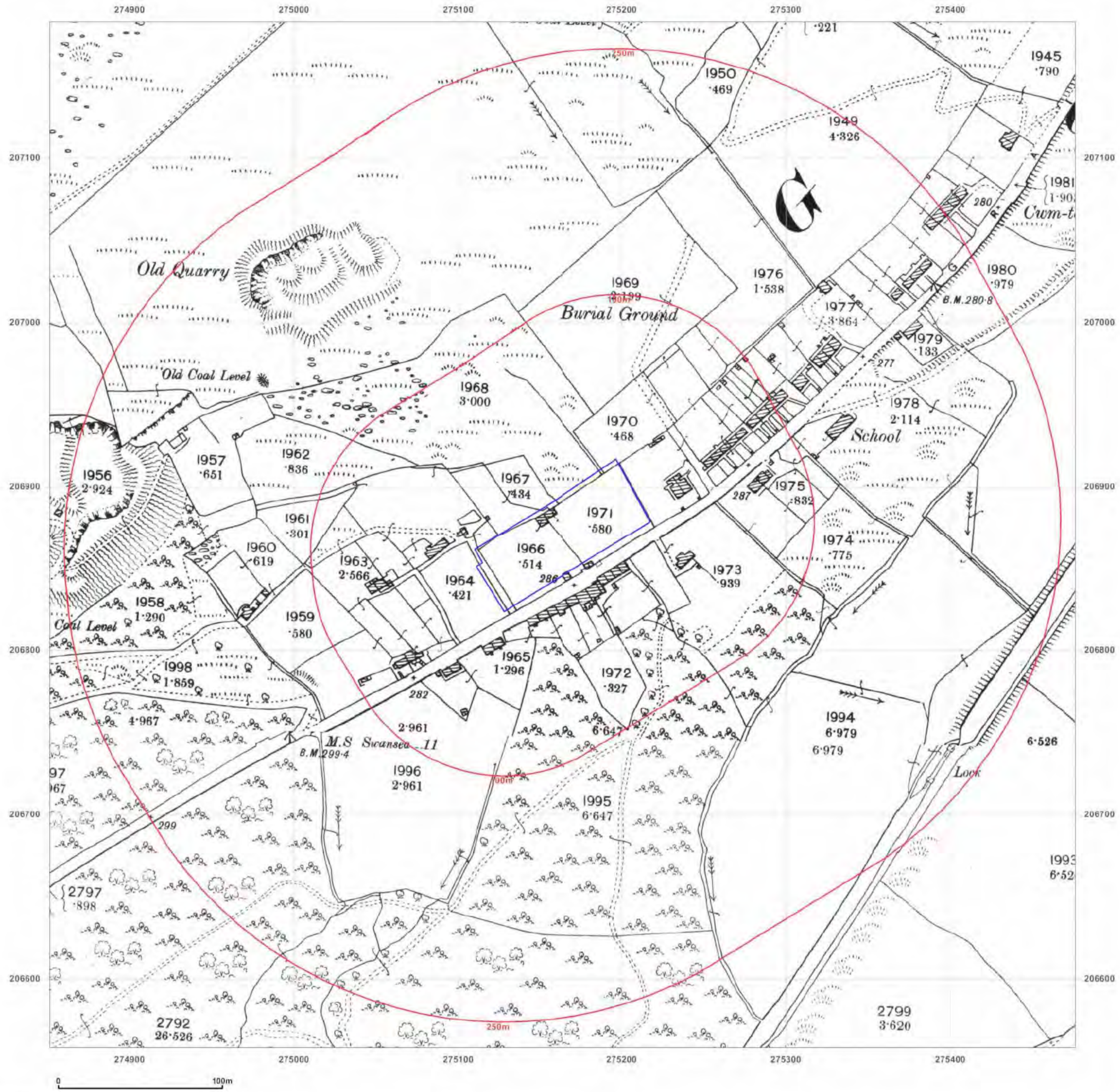

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	County Series
Map date:	**1899**
Scale:	1:2,500
Printed at:	1:2,500

N
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Surveyed 1899
Revised 1899
Edition N/A
Copyright N/A
Levelled N/A

Surveyed 1899
Revised 1899
Edition N/A
Copyright N/A
Levelled N/A

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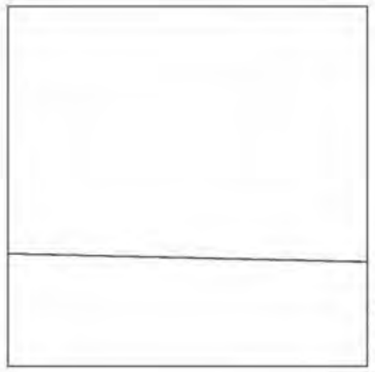
Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	County Series
Map date:	**1918**
Scale:	1:2,500
Printed at:	1:2,500

Surveyed 1918
Revised 1918
Edition N/A
Copyright N/A
Levelled N/A



Surveyed 1918
Revised 1918
Edition N/A
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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	National Grid
Map date:	**1960**
Scale:	1:2,500
Printed at:	1:2,500

N
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Surveyed 1960
Revised 1960
Edition N/A
Copyright 1962
Levelled 1956

Surveyed 1960
Revised 1960
Edition N/A
Copyright 1962
Levelled 1956

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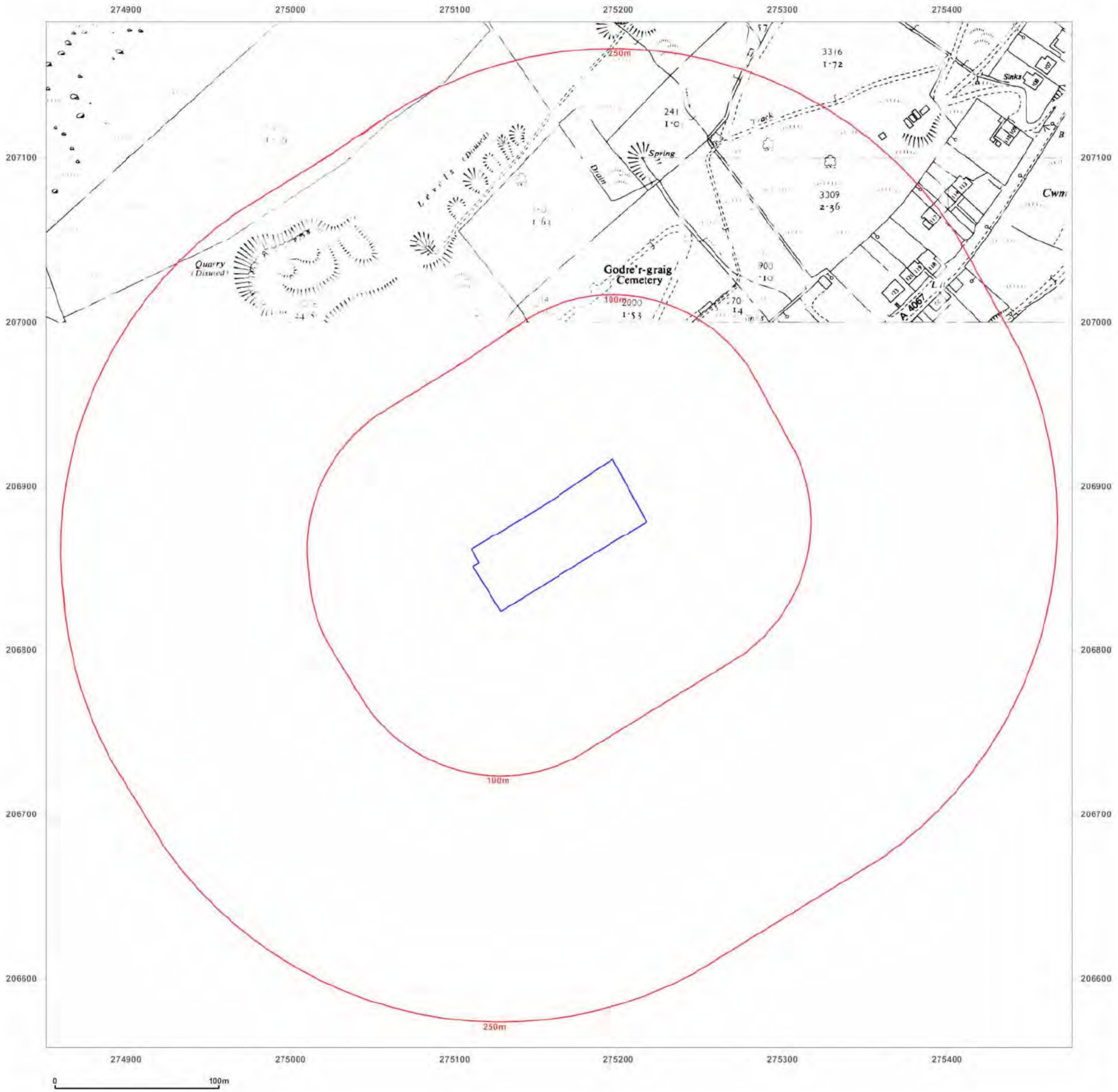
Production date: 20 May 2019

Map legend available at:
www.groundsure.com/sites/default/files/groundsure_legend.pdf



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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	National Grid
Map date:	**1962**
Scale:	1:2,500
Printed at:	1:2,500

Surveyed N/A
Revised N/A
Edition N/A
Copyright N/A
Levelled N/A

Surveyed N/A
Revised N/A
Edition N/A
Copyright N/A
Levelled N/A

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Production date: 20 May 2019

Map legend available at:
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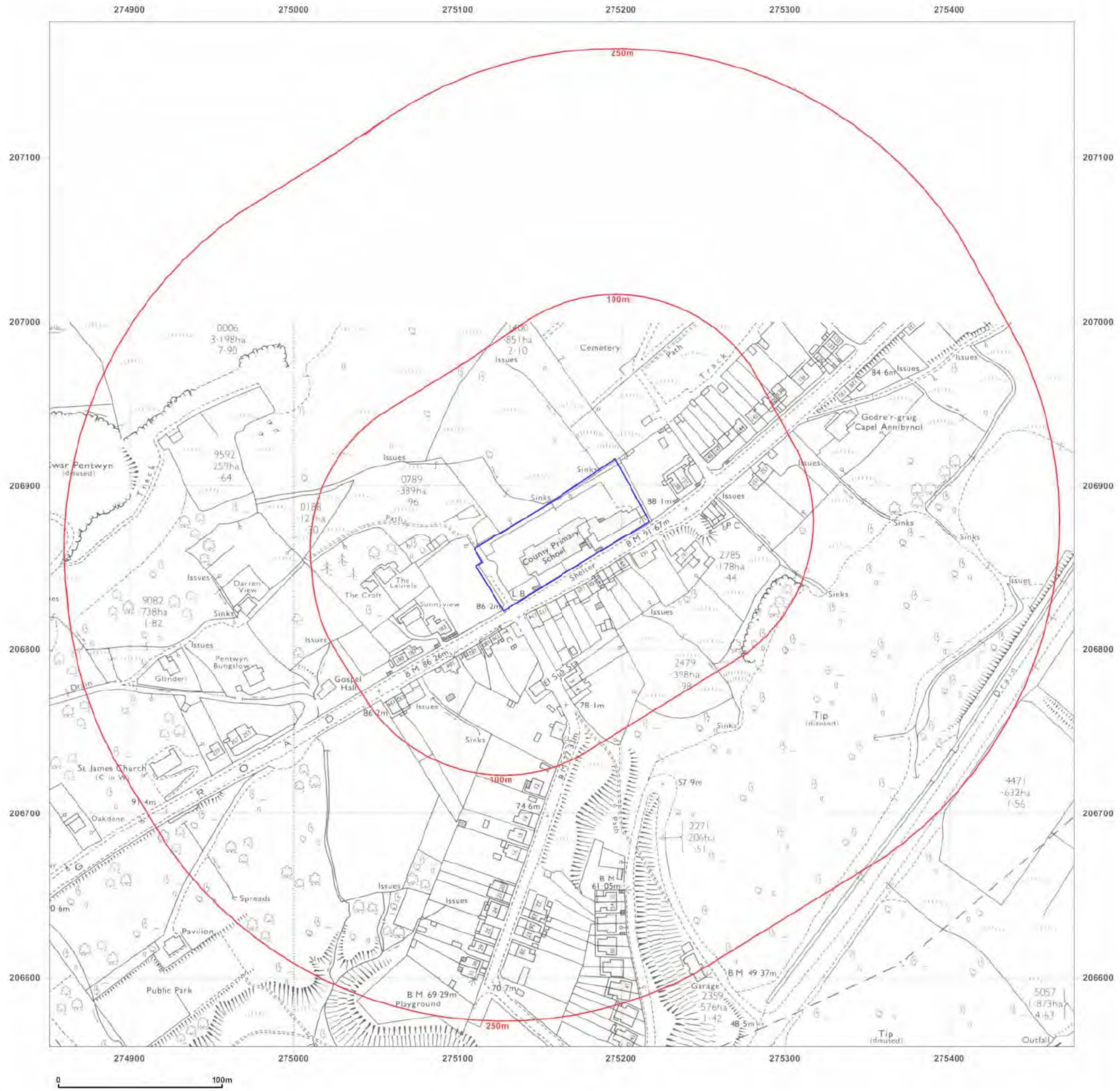

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SCIENTISTS

Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref: 8060_7234e
Report Ref: ESP-6040430
Grid Ref: 275163, 206870

Map Name: National Grid

Map date: **1971**

Scale: 1:2,500

Printed at: 1:2,500

N
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Surveyed 1971
Revised 1971
Edition N/A
Copyright 1972
Levelled 1963

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Production date: 20 May 2019

Map legend available at:
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esp

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GEOLOGISTS
SCIENTISTS

Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref: 8060_7234e
Report Ref: ESP-6040430
Grid Ref: 275163, 206870

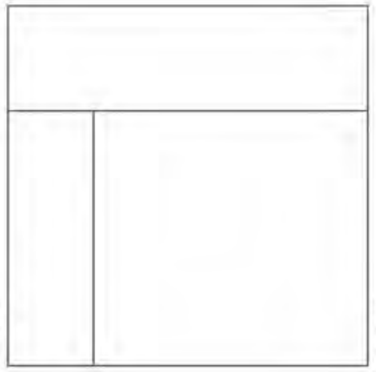
Map Name: National Grid

Map date: **1972**

Scale: 1:2,500

Printed at: 1:2,500

N
W E
S



Surveyed N/A
Revised N/A
Edition N/A
Copyright N/A
Levelled N/A

Surveyed N/A
Revised N/A
Edition N/A
Copyright N/A
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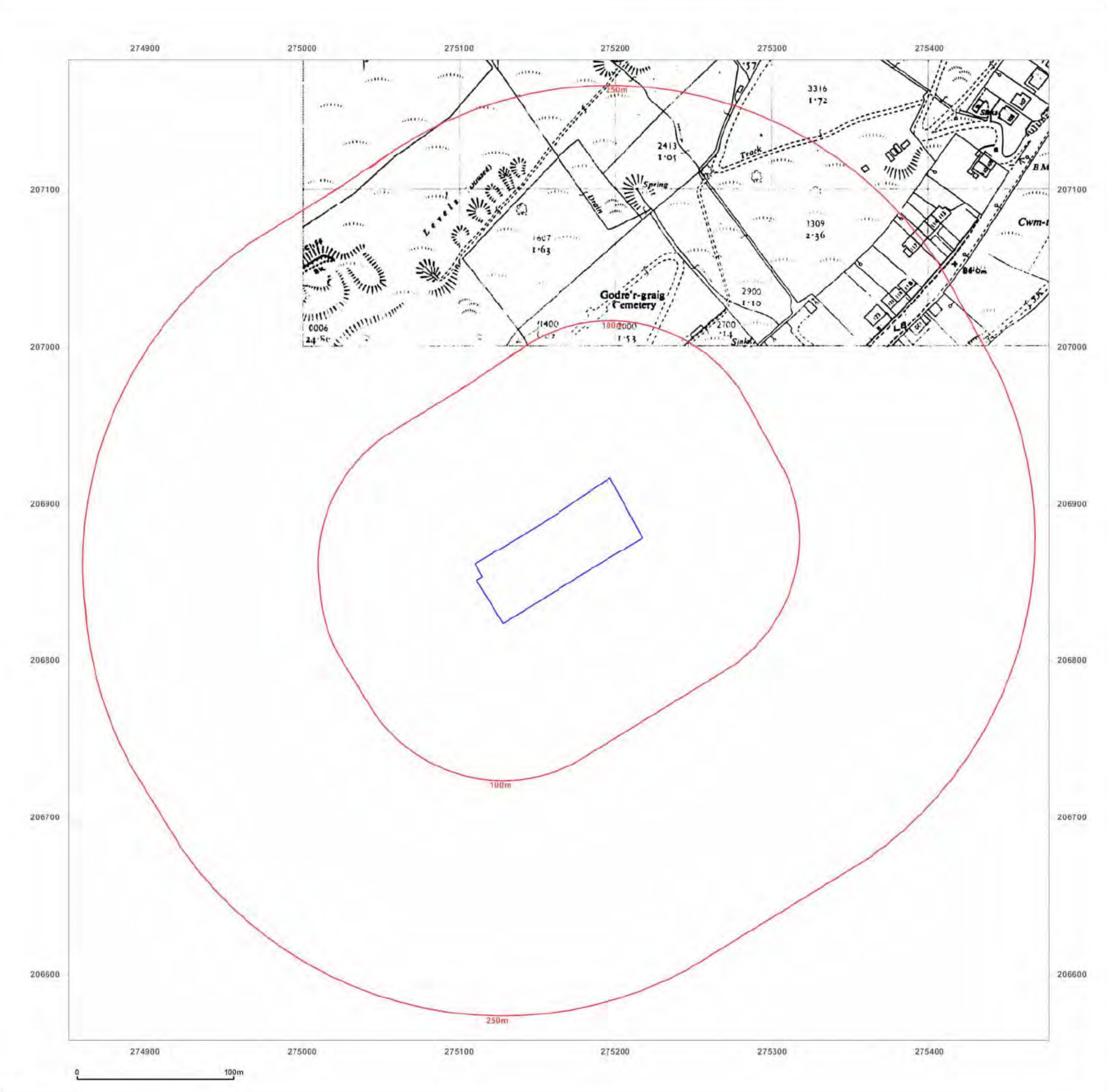

esp
ENGINEERS
GEOLOGISTS
SCIENTISTS

Site Details:

GODRE GRAIG PRIMARY
SCHOOL, GODRE'R GRAIG
PRIMARY SCHOOL, GRAIG
ROAD, GODRE'R GRAIG, SA9
2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	National Grid
Map date:	**1979**
Scale:	1:2,500
Printed at:	1:2,500

N
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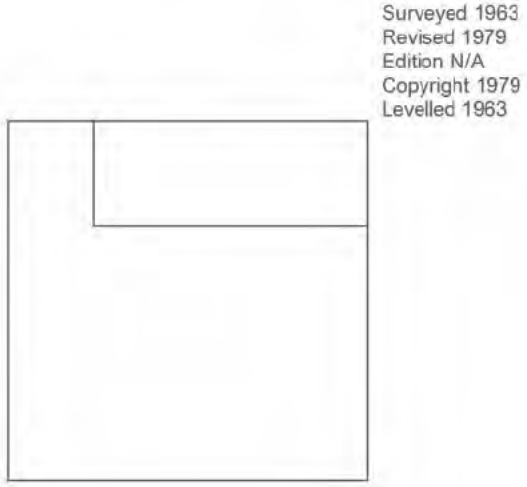

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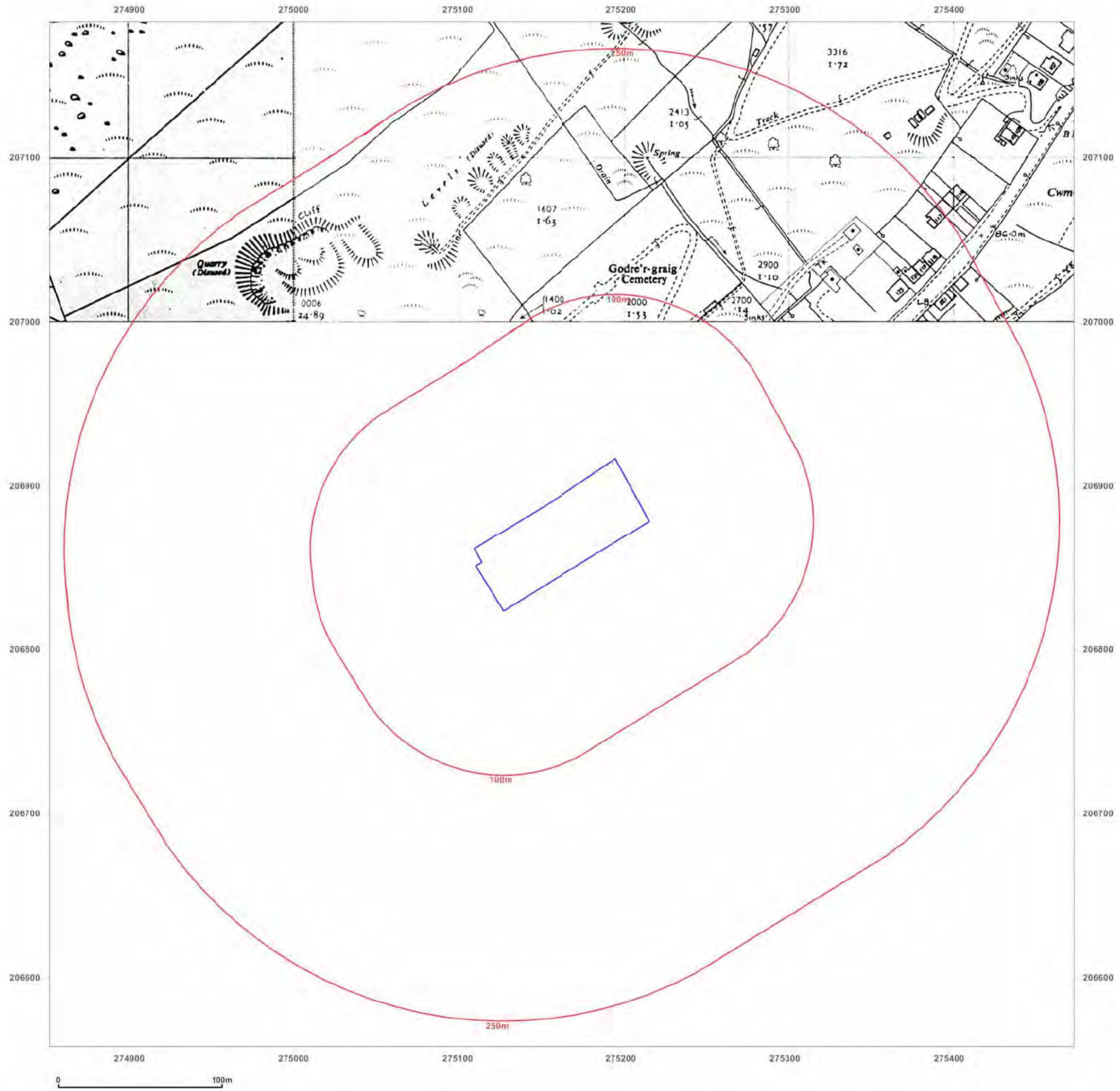

esp
ENGINEERS
GEOLOGISTS
SCIENTISTS

Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	National Grid
Map date:	**1986-1987**
Scale:	1:2,500
Printed at:	1:2,500

N
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Surveyed 1962
Revised 1986
Edition N/A
Copyright 1986
Levelled 1962

Surveyed 1963
Revised 1987
Edition N/A
Copyright 1987
Levelled 1963

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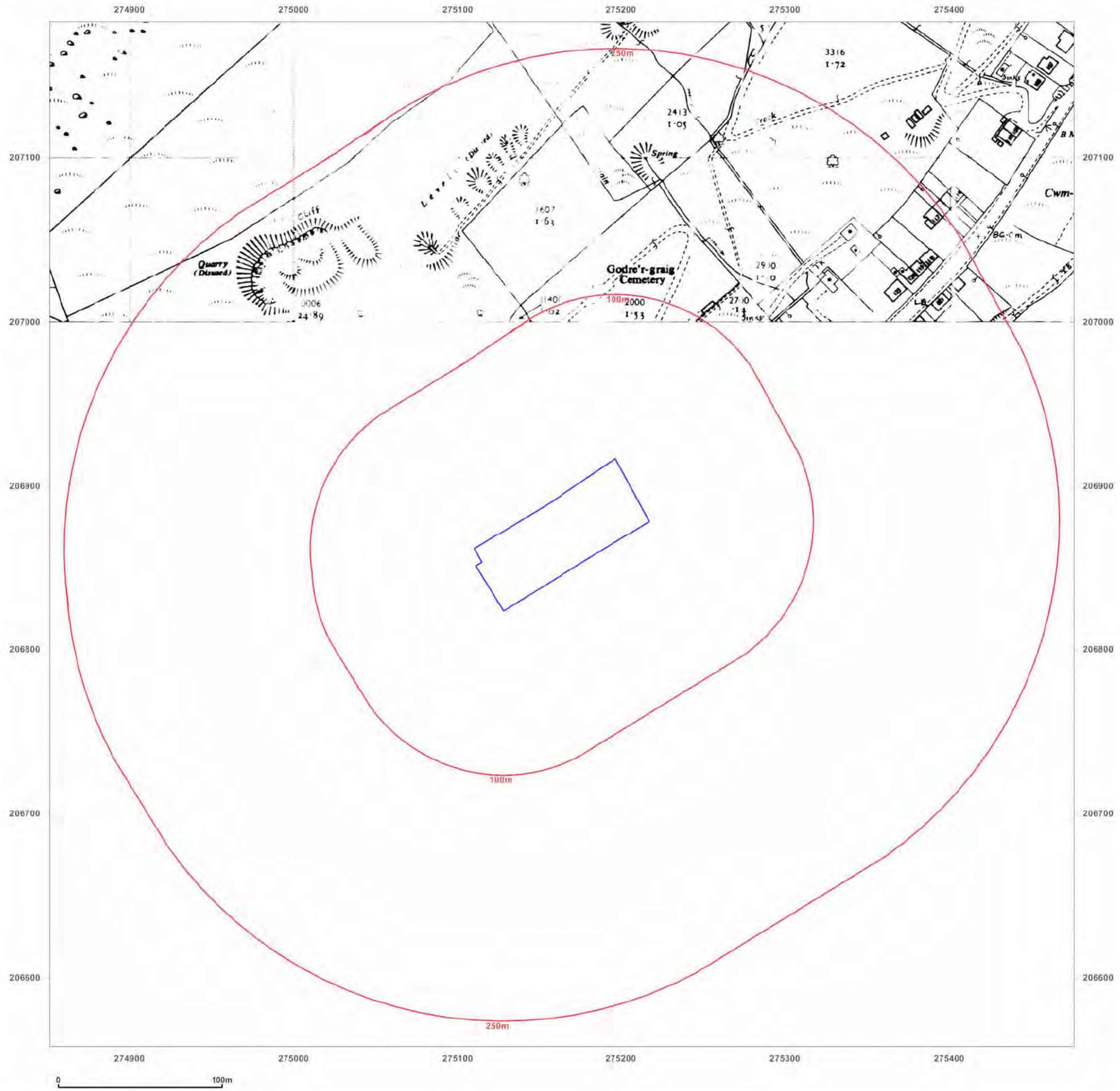

esp
ENGINEERS
GEOLOGISTS
SCIENTISTS

Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	National Grid
Map date:	**1986-1987**
Scale:	1:2,500
Printed at:	1:2,500

N
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Surveyed N/A
Revised N/A
Edition N/A
Copyright N/A
Levelled N/A

Surveyed N/A
Revised N/A
Edition N/A
Copyright N/A
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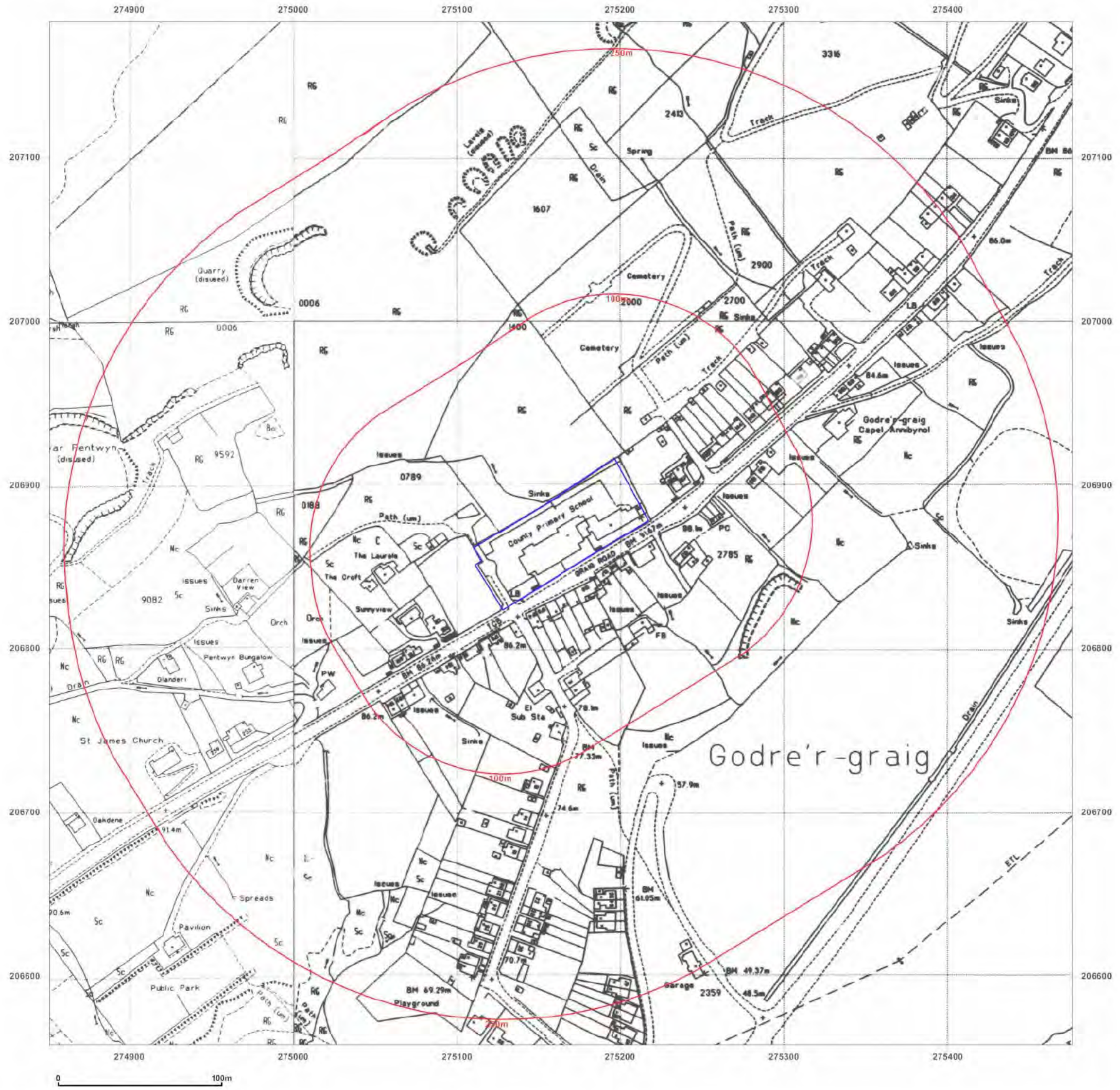

esp
ENGINEERS
GEOLOGISTS
SCIENTISTS

Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	National Grid
Map date:	**1993**
Scale:	1:2,500
Printed at:	1:2,500

N
W E
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Surveyed 1993
Revised N/A
Edition N/A
Copyright 1993
Levelled N/A

Surveyed 1993
Revised N/A
Edition N/A
Copyright 1993
Levelled N/A

Surveyed 1993
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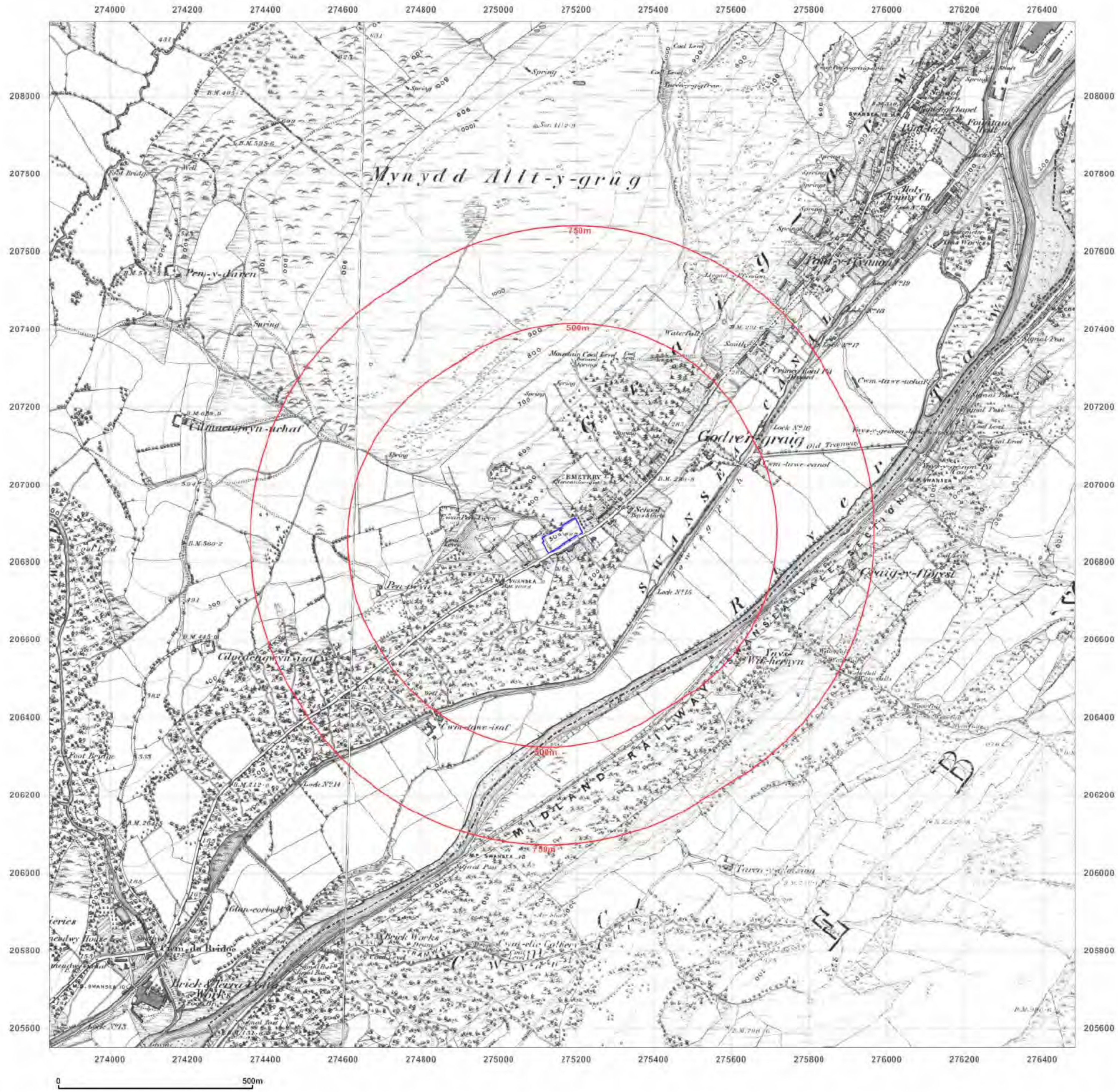

esp

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	County Series
Map date:	**1877**
Scale:	1:10,560
Printed at:	1:10,560

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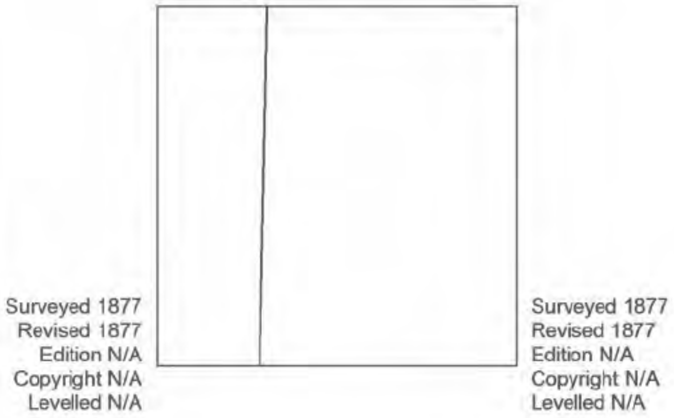

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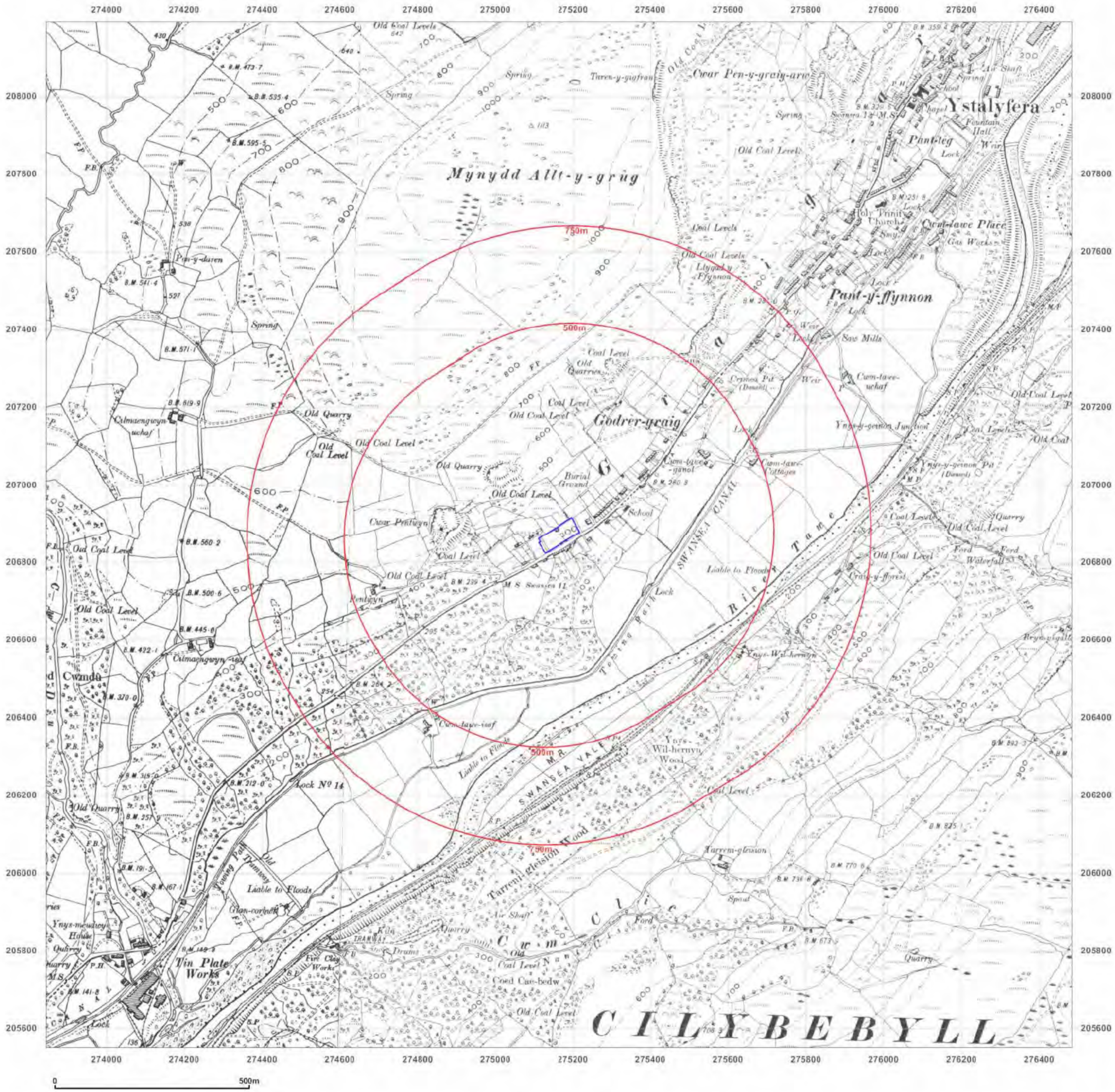

esp
ENGINEERS
GEOLOGISTS
SCIENTISTS

Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	County Series
Map date:	**1897**
Scale:	1:10,560
Printed at:	1:10,560

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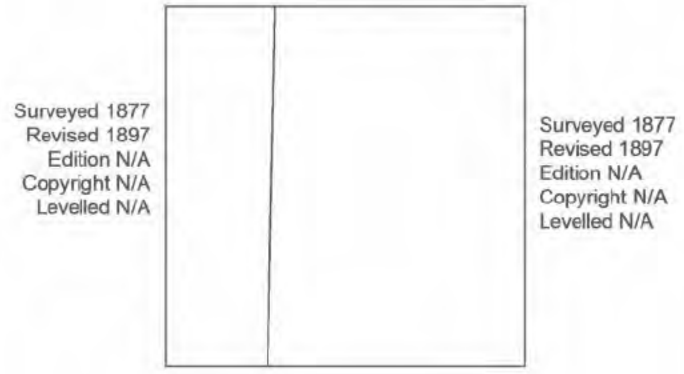

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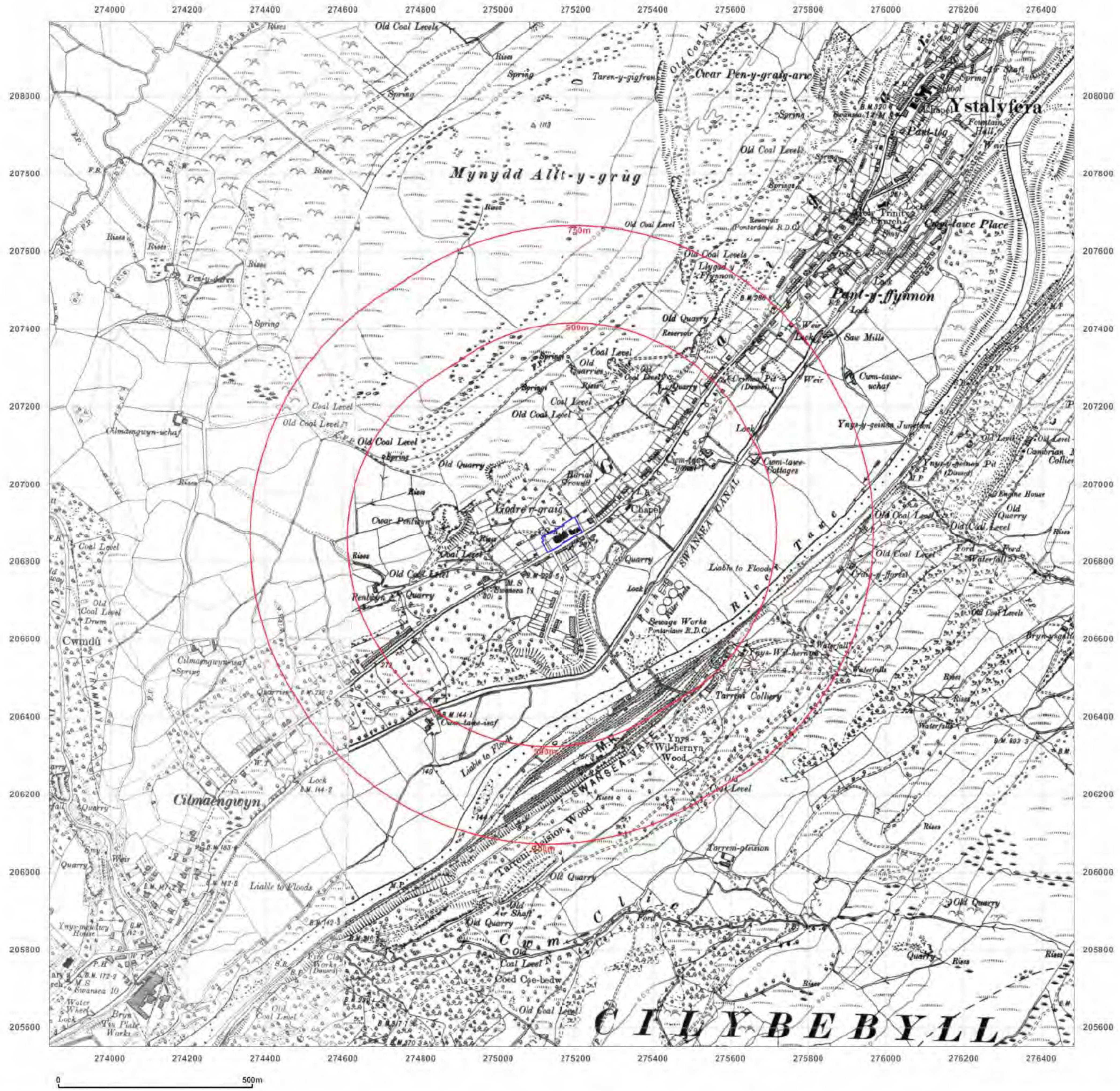

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	County Series
Map date:	1913
Scale:	1:10,560
Printed at:	1:10,560

N
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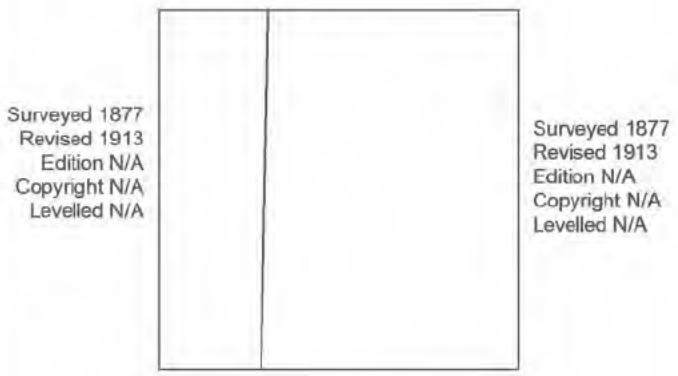

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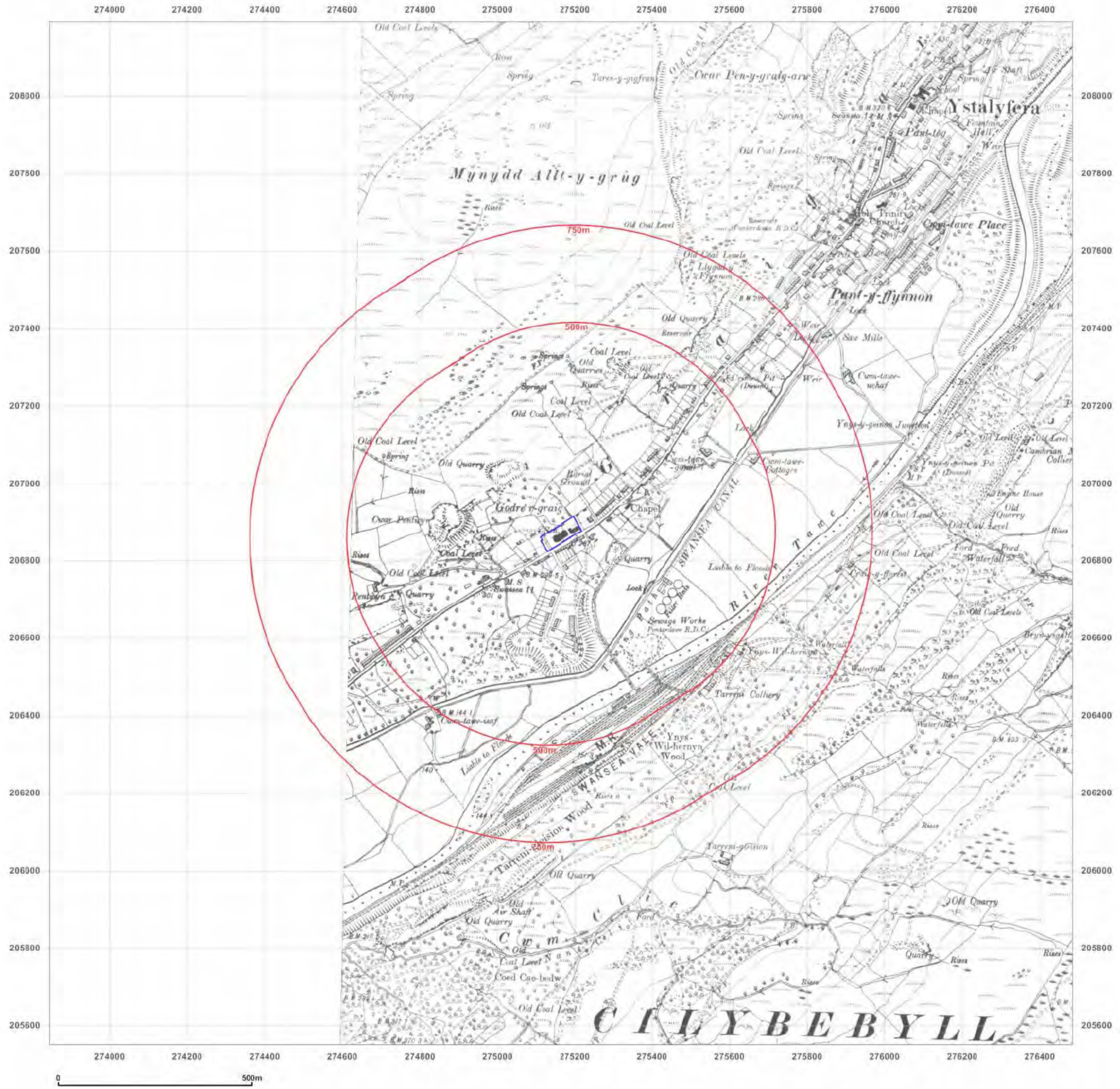

esp

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	County Series
Map date:	**1913**
Scale:	1:10,560
Printed at:	1:10,560

N
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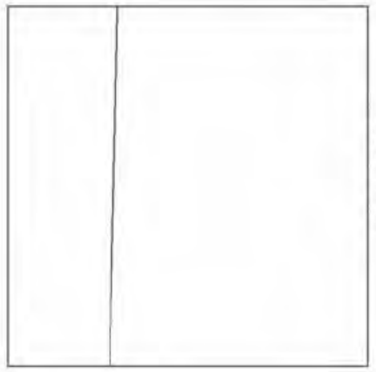

Surveyed 1877
Revised 1913
Edition N/A
Copyright N/A
Levelled N/A

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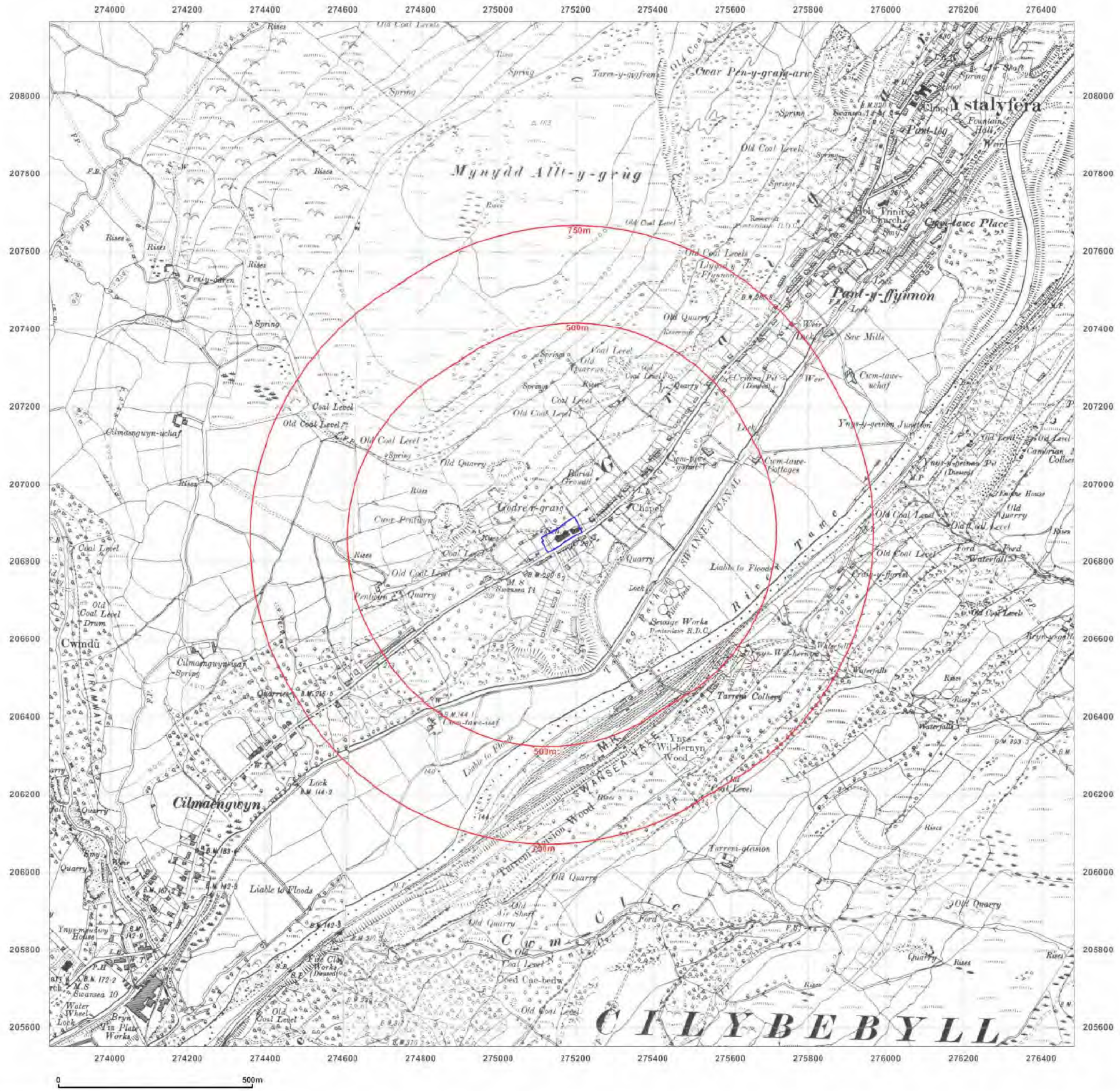

esp

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref: 8060_7234e
Report Ref: ESP-6040430
Grid Ref: 275163, 206870

Map Name: County Series

Map date: **1921**

Scale: 1:10,560

Printed at: 1:10,560

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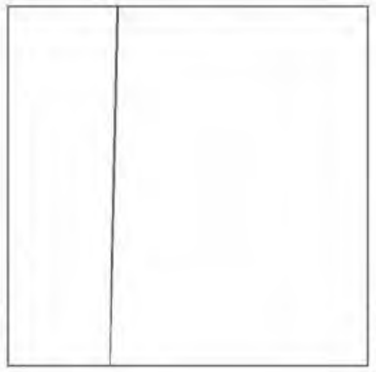

Surveyed 1877
Revised 1921
Edition N/A
Copyright N/A
Levelled N/A

Surveyed 1877
Revised 1921
Edition N/A
Copyright N/A
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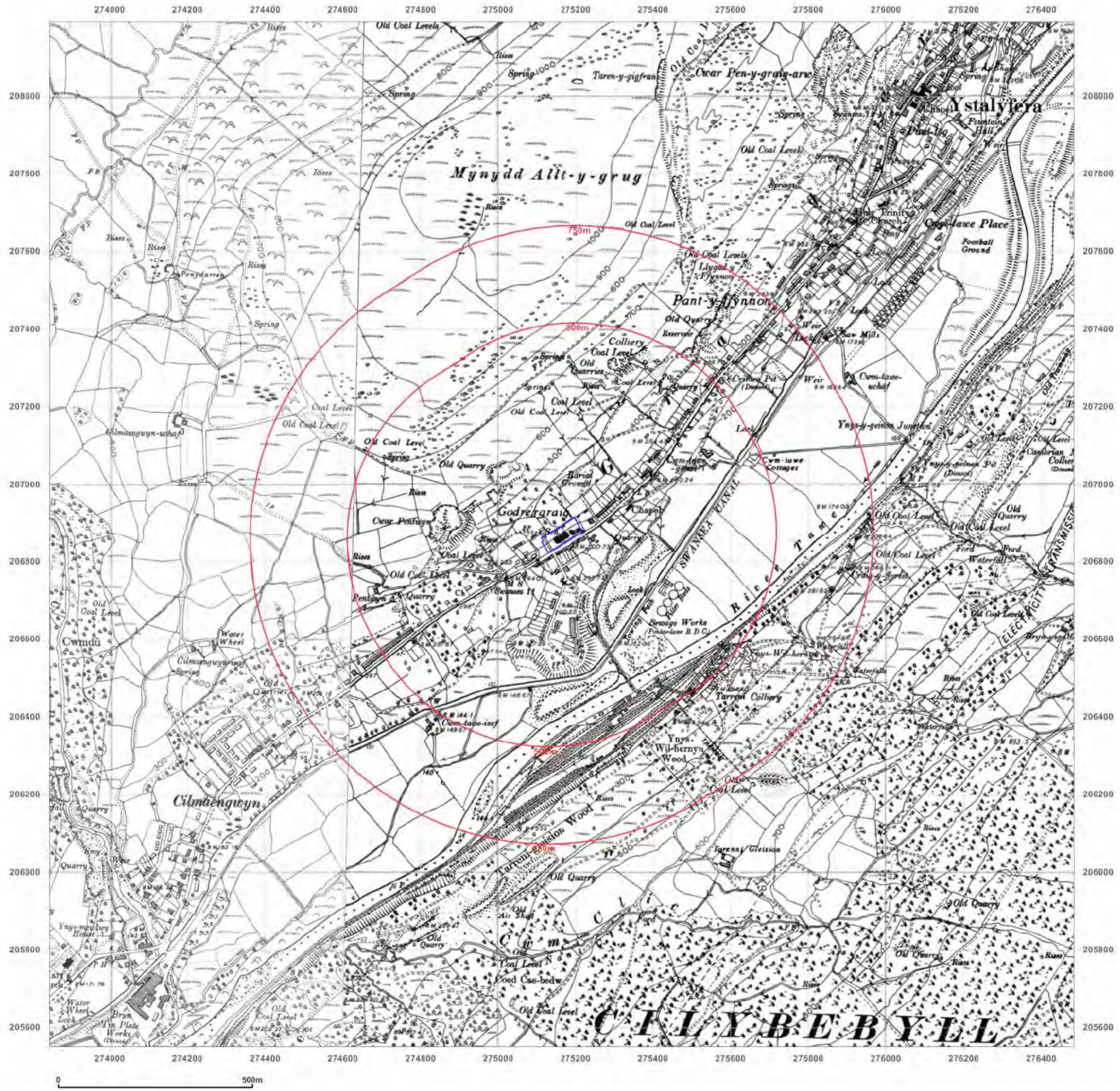

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	County Series
Map date:	**1948**
Scale:	1:10,560
Printed at:	1:10,560

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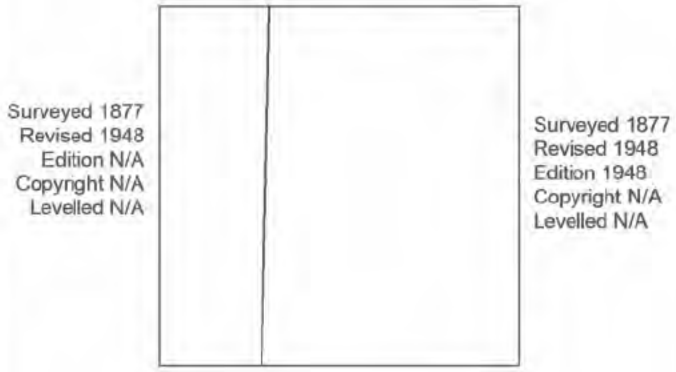

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Production date: 20 May 2019

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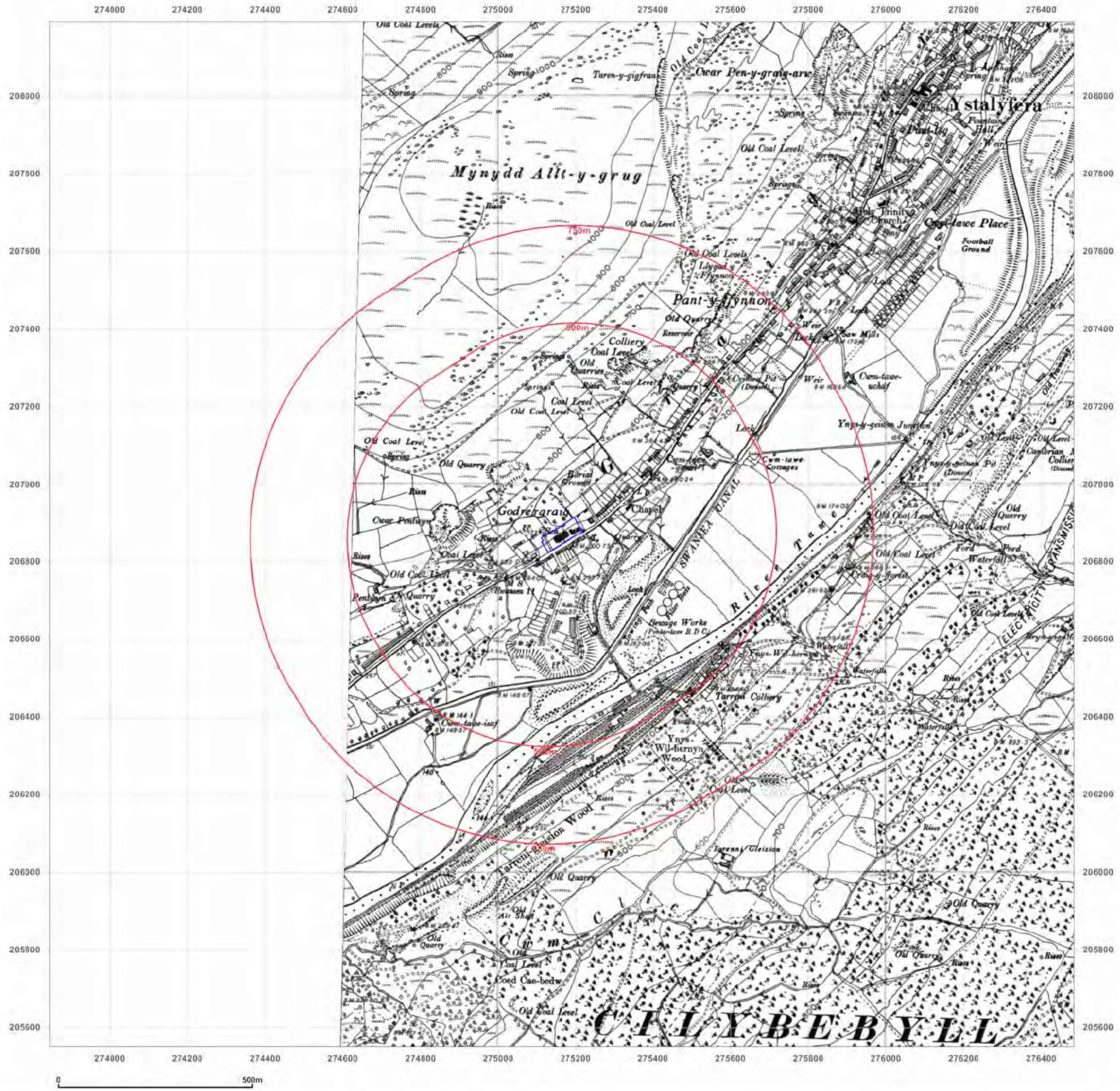

esp

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GEOLOGISTS
SCIENTISTS

Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	County Series
Map date:	**1948**
Scale:	1:10,560
Printed at:	1:10,560

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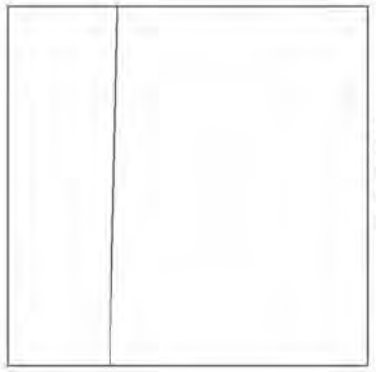

Surveyed 1877
Revised 1948
Edition N/A
Copyright N/A
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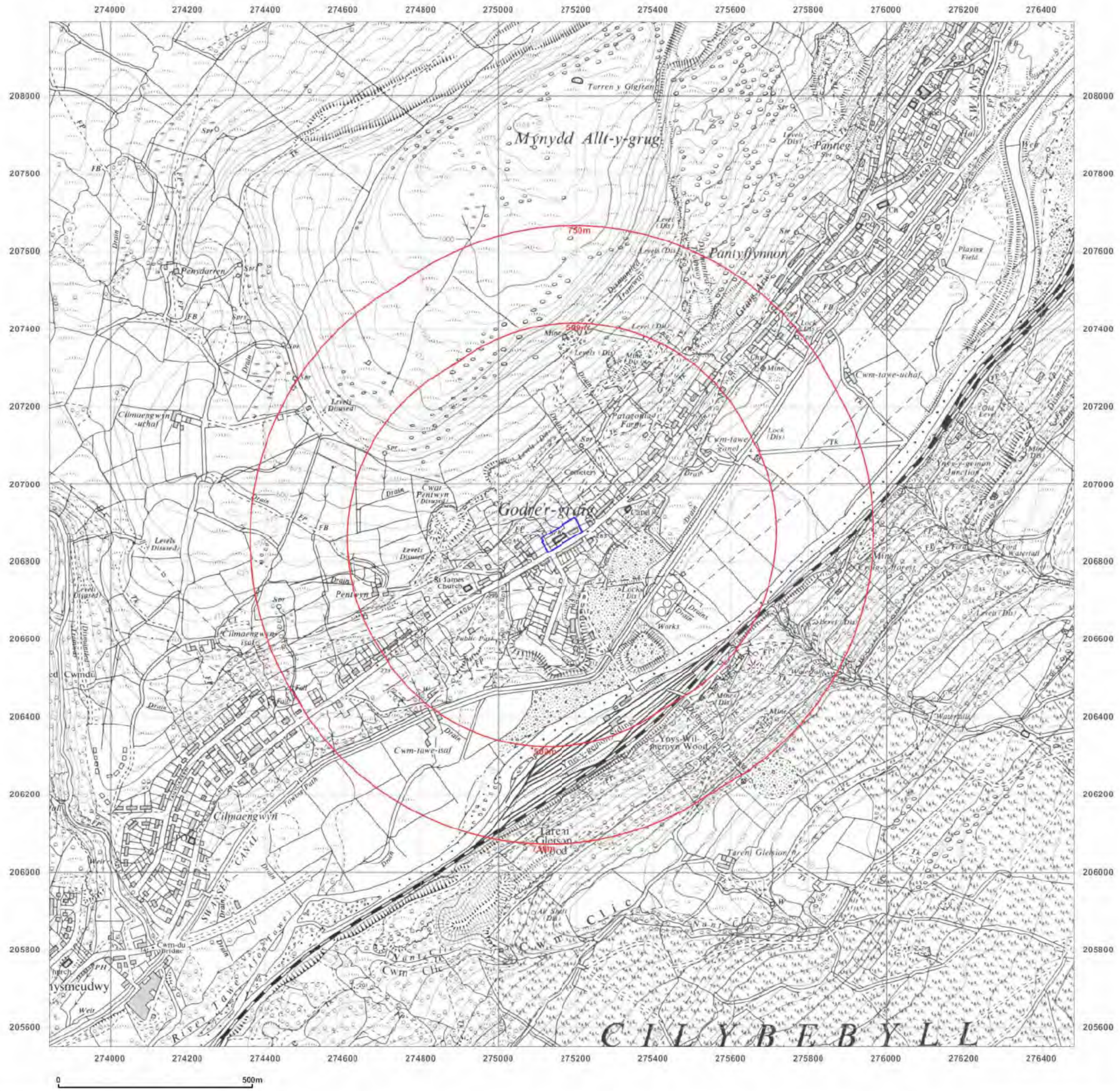

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	Provisional
Map date:	**1964-1965**
Scale:	1:10,560
Printed at:	1:10,560

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Surveyed 1963 Revised 1964 Edition N/A Copyright 1965 Levelled N/A	Surveyed 1965 Revised 1965 Edition N/A Copyright N/A Levelled N/A

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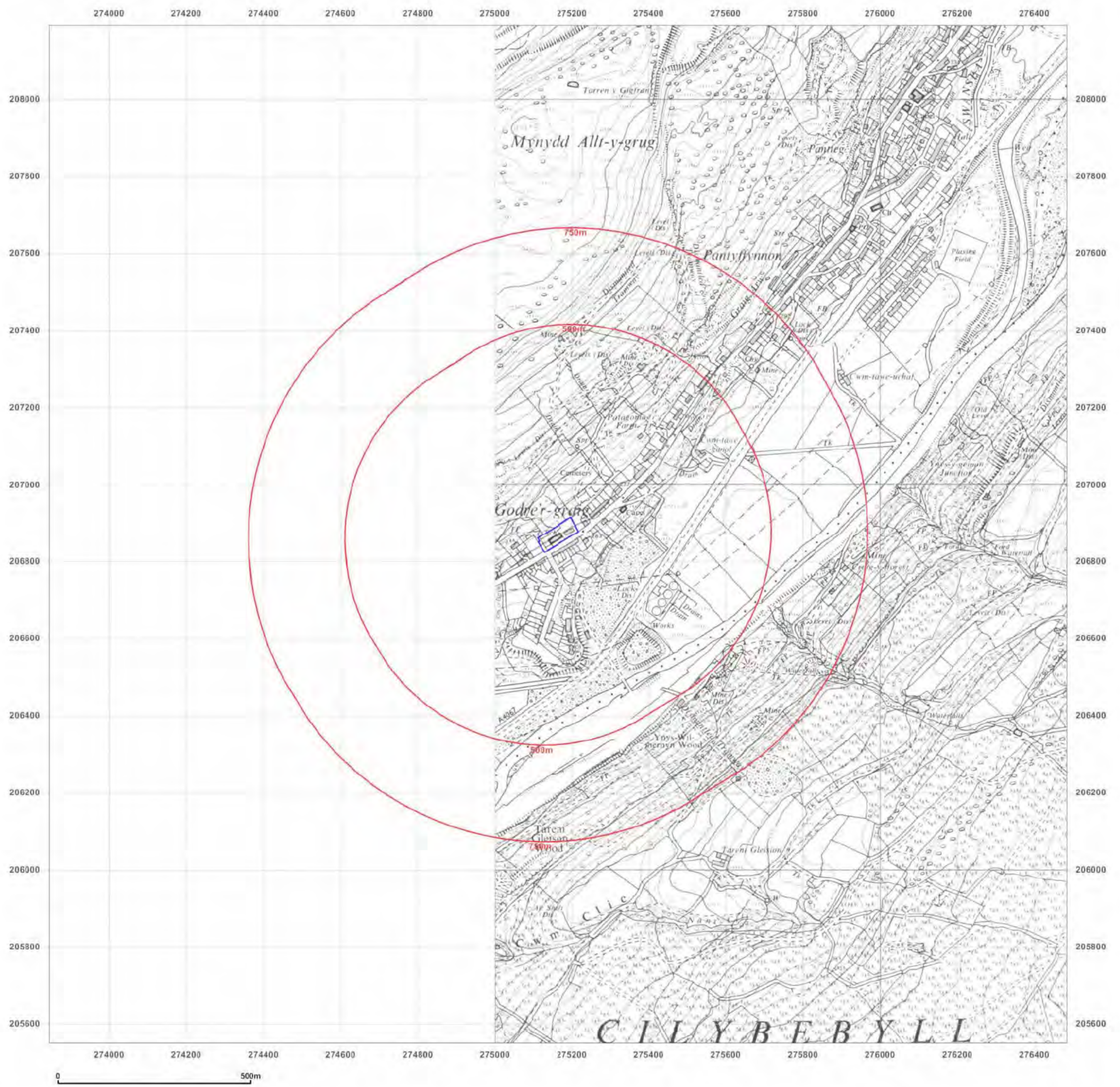

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	Provisional
Map date:	**1980**
Scale:	1:10,560
Printed at:	1:10,560

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Revised 1980
Edition N/A
Copyright N/A
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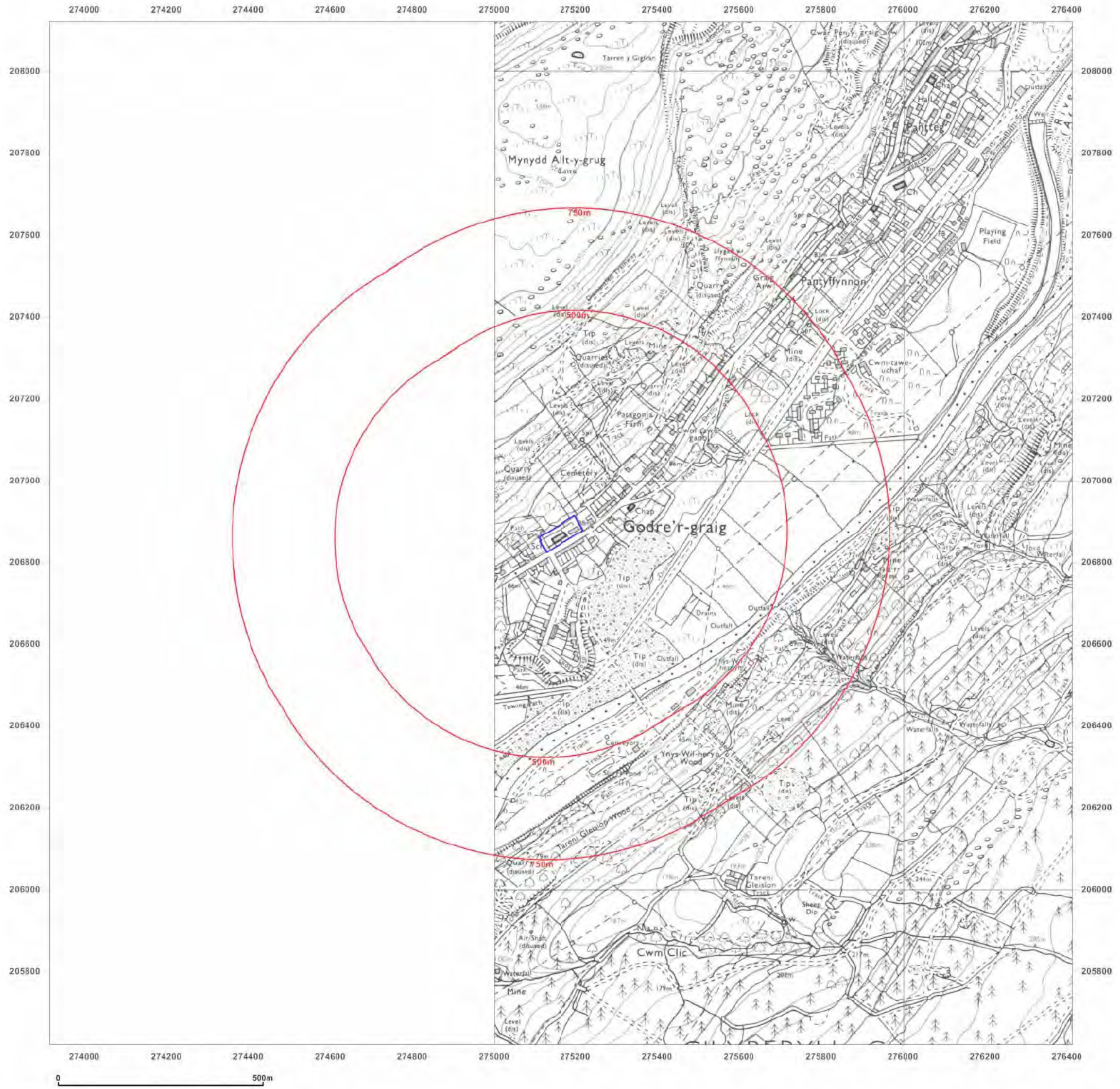

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ENGINEERS
GEOLOGISTS
SCIENTISTS

Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	National Grid
Map date:	**1983**
Scale:	1:10,000
Printed at:	1:10,000

N
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Revised 1983
Edition N/A
Copyright N/A
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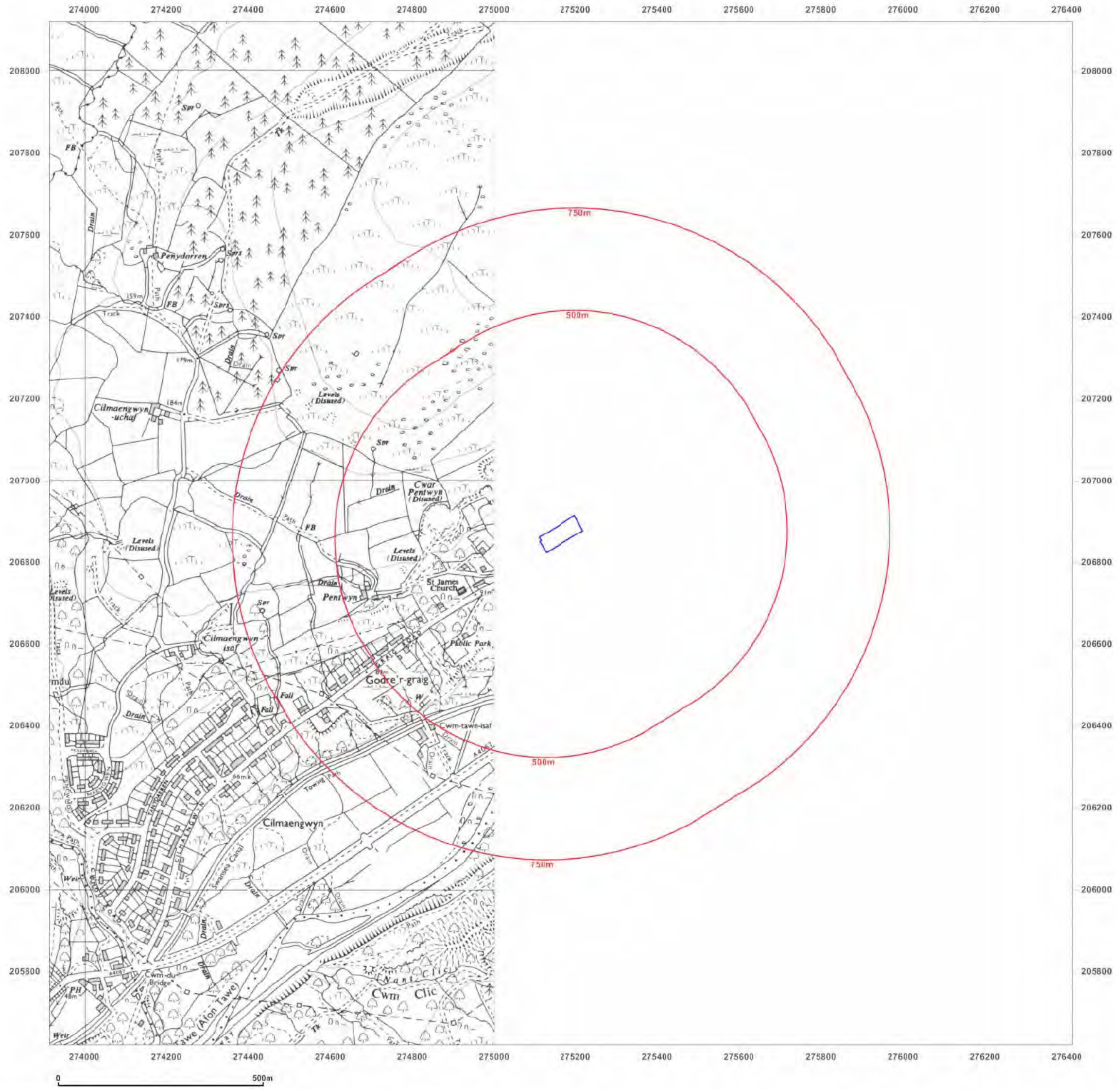

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref: 8060_7234e
Report Ref: ESP-6040430
Grid Ref: 275163, 206870

Map Name: National Grid

Map date: **1990**

Scale: 1:10,000

Printed at: 1:10,000

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Revised 1990
Edition N/A
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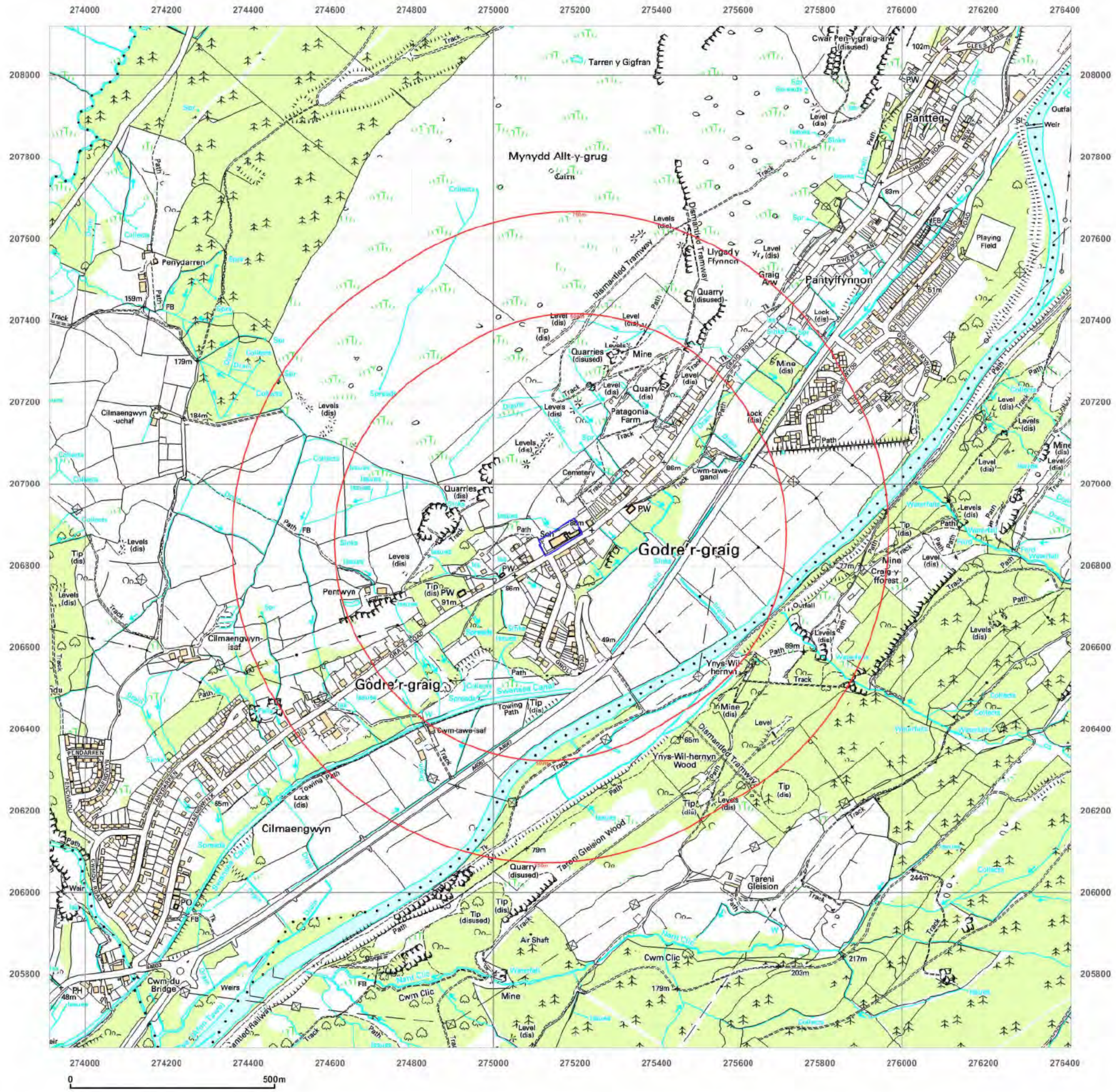

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	1:10,000 Raster
Map date:	**2002**
Scale:	1:10,000
Printed at:	1:10,000

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2002

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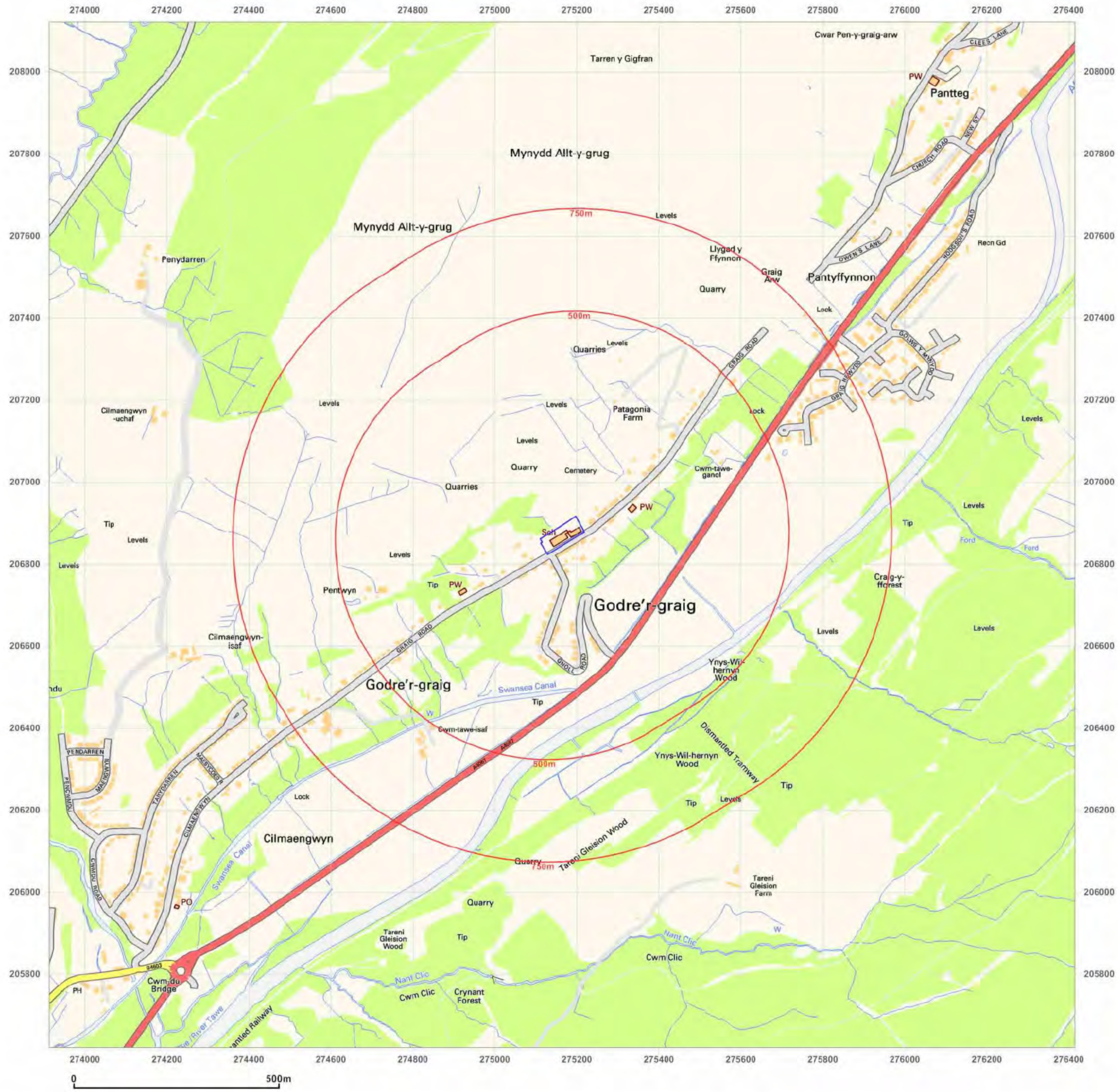

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SCIENTISTS

Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	National Grid
Map date:	**2010**
Scale:	1:10,000
Printed at:	1:10,000

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2010

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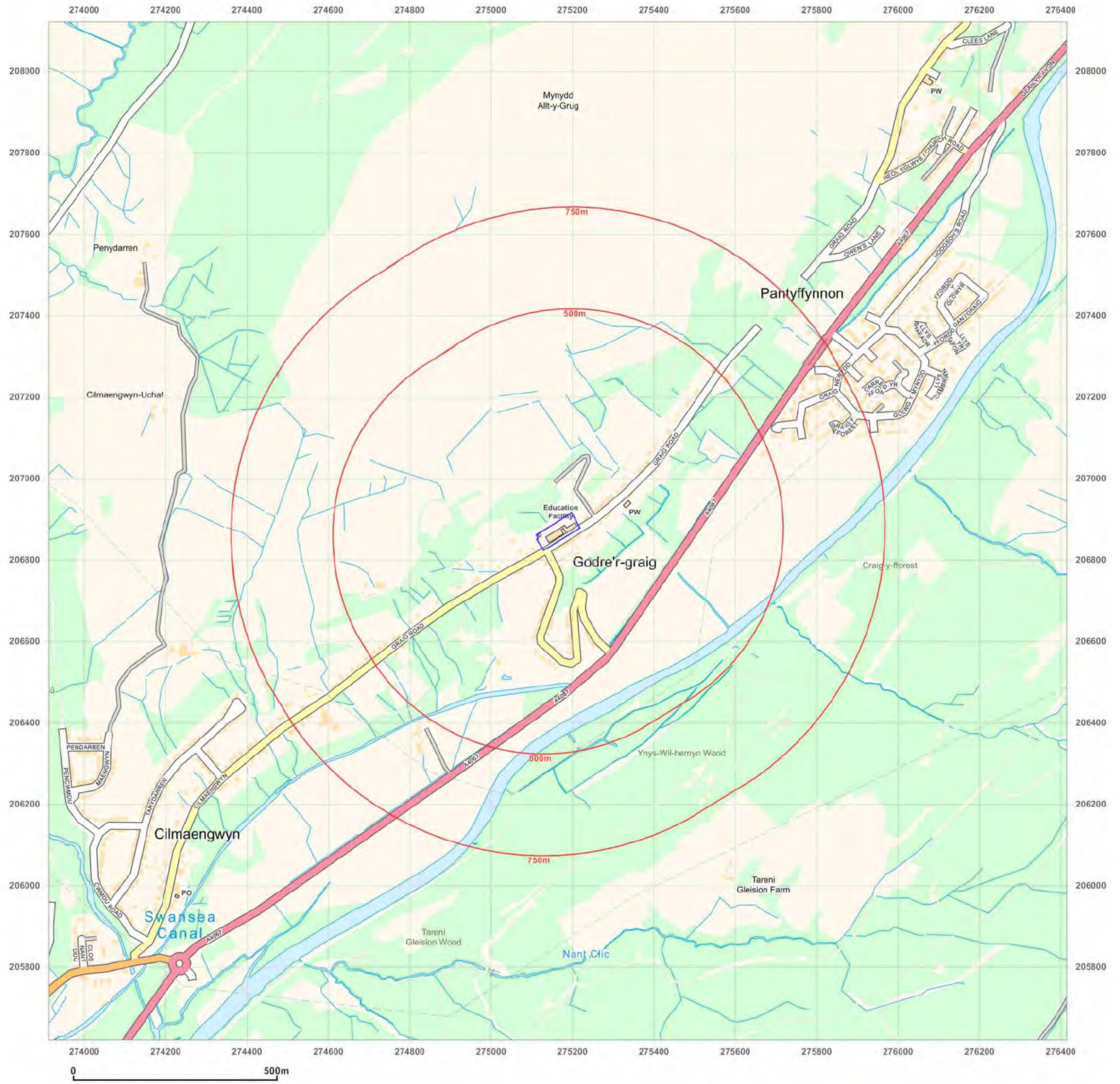

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Site Details:

GODRE GRAIG PRIMARY SCHOOL, GODRE'R GRAIG PRIMARY SCHOOL, GRAIG ROAD, GODRE'R GRAIG, SA9 2NY

Client Ref:	8060_7234e
Report Ref:	ESP-6040430
Grid Ref:	275163, 206870

Map Name:	National Grid
Map date:	**2014**
Scale:	1:10,000
Printed at:	1:10,000

2014

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APPENDIX C AERIAL PHOTOS REVIEWED

3 August 1945

22nd May 1948

27 May 1952

14th April 1955

21st April 1960

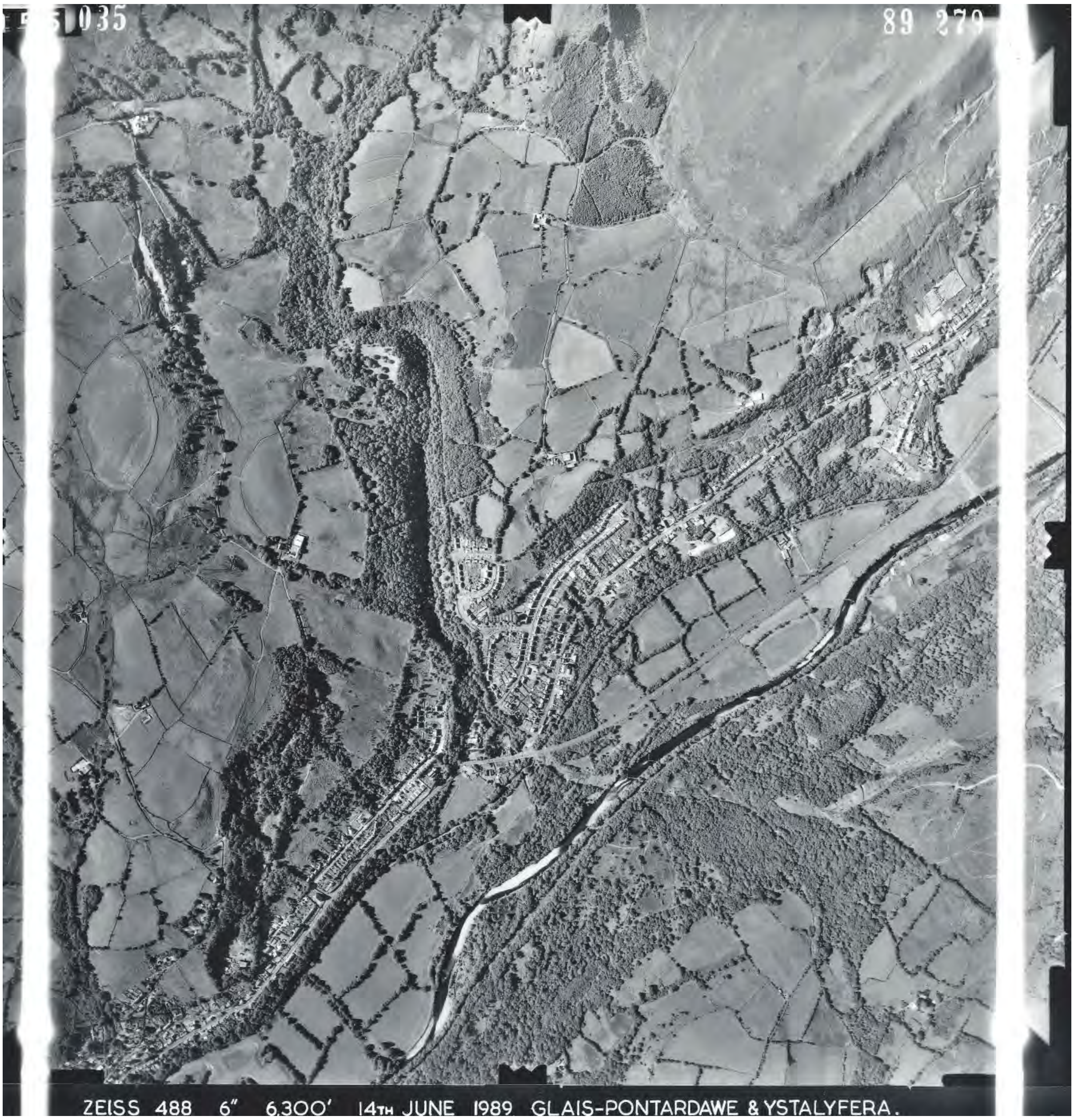
16th May 1973

24th April 1975

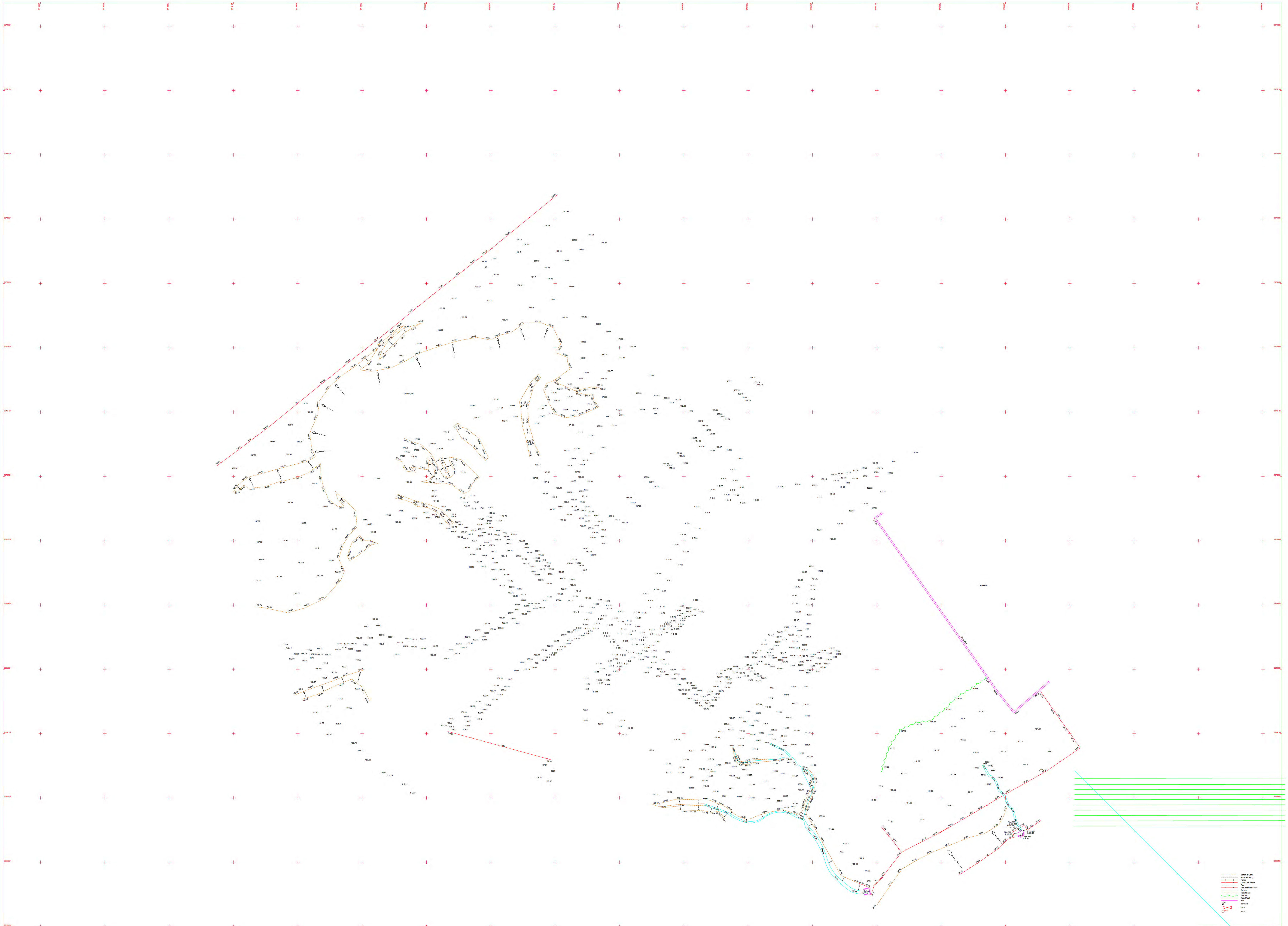
9th June 1975

30 August 1983

14 June 1989


035
89 279
ZEISS 488 6" 6,300' 14TH JUNE 1989 GLAIS-PONTARDAWE & YSTALYFERA.

APPENDIX D TOPOGRAPHIC SURVEY



JOHN VINCENT SURVEYS LTD
NIBERIAN HOUSE
MONASTERY ROAD
NEATH ABBEY BUSINESS PARK
NEATH SA10 7DR

GODRE'R GRAIG

SWANSEA VALLEY

SITE SURVEY

EARTH SCIENCE PARTNERSHIP
33 CARDIFF ROAD
TAFFS WELL
CARDIFF
CF15 7RB

APPENDIX E TRIAL PIT RECORDS

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

TP101

Excavation method/plant: 8 Tonne Tracked Excavator

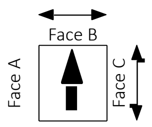
Shoring/support: None

Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e.02

Excavation date: 15/10/2019
Backfill date: 15/10/2019
Logged by: EK/MTE

Survey details:
Ground Level: 159.7 mOD
Easting: 275012 mE
Northing: 206976 mN
Bearing:

Plan details:



Face Stability:
Unstable

Groundwater observations:
Groundwater not encountered

Depth	Sample		Test Details		Strata Details			
m	Type	Class	Type	Result	Description	Depth (thickness)	mOD	Legend
					Dark greyish black sandy medium to coarse angular sandstone GRAVEL with abundant rootlets (MADE GROUND - TOPSOIL)	(0.20) 0.20	159.47	▨
0.60	B				Probably loose grey mottled pale brown clayey sandy GRAVEL with high cobble content and boulders and frequent rootlets. Gravel is fine to coarse angular sandstone. Cobbles and boulders are interlocking angular up to 600mm in diameter of generally fresh dark purplish grey sandstone with occasional orange surface weathering (MADE GROUND - COARSE DISCARD)	(0.60) 0.80	158.87	▨
1.00	B				Probably loose grey and pale brown slightly clayey slightly sandy GRAVEL with high cobble and boulder content. Gravel is fine to coarse (predominantly coarse) angular sandstone. Cobbles and boulders are interlocking angular up to 700mm in diameter of generally fresh dark purplish grey sandstone with occasional orange surface weathering. Cobbles and boulders are generally horizontal in orientation. (MADE GROUND - COARSE DISCARD)	(1.90)		▨
2.00	B					2.70	156.97	
2.90	B				Probably loose pale brown silty clayey sandy GRAVEL with low cobble content. Gravel is fine to coarse (predominantly coarse) subangular and angular sandstone. Material is wet. (MADE GROUND - COARSE DISCARD)	(0.20) 2.90	156.77	▨

End of Trialpit at 2.900m

Weather and environmental conditions:

1. Rain, overcast

Other comments:

1. Co-ordinates and ground levels interpolated from topographical survey.
2. Trial pit terminated at a depth of 2.90m due to unstable sides collapsing.
3. Minor spalling of sidewalls from 1.0m depth. Side walls becoming unstable during excavation below 1.50m with increased instability with depth.
4. Groundwater not encountered - soils wet below 2.5m depth.
4. Trial pit backfilled with arisings upon completion.

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

TP102

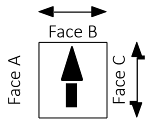
Excavation method/plant: 8 Tonne Tracked Excavator
Shoring/support: None

Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e.02

Excavation date: 15/10/2019
Backfill date: 15/10/2019
Logged by: EK/MTE

Survey details:
Ground Level: 159.0 mOD
Easting: 275053 mE
Northing: 207006 mN
Bearing:

Plan details:



Face Stability:
Unstable

Groundwater observations:
Groundwater encountered below 3.0m depth

Depth	Sample		Test Details		Strata Details			
m	Type	Class	Type	Result	Description	Depth (thickness)	mOD	Legend
0.10	B				Dark greyish black sandy medium to coarse angular sandstone GRAVEL with abundant rootlets (MADE GROUND - TOPSOIL)	(0.15) 0.15	158.89	▨
0.50 - 1.00	B				Probably loose grey mottled pale brown slightly clayey sandy GRAVEL with high cobble and boulder content and occasional rootlets. Gravel is fine to coarse (predominantly medium to coarse) angular sandstone. Cobbles and boulders are interlocking angular up to 400mm in diameter and between 30 to 100mm thick of generally fresh dark purplish grey sandstone with occasional orange surface weathering (MADE GROUND - COARSE DISCARD)	(0.85) 1.00	158.04	▨
1.50 - 2.00	B				Probably loose dark grey and pale brown slightly clayey slightly sandy GRAVEL and COBBLES with boulders. Gravel is to coarse (predominantly medium to coarse) angular sandstone. Cobbles and boulders are interlocking angular up to 600mm in diameter and between 30 to 100m thick of generally fresh dark purplish grey sandstone with occasional orange surface weathering. Material is wet. (MADE GROUND - COARSE DISCARD)	(1.00) 2.00	157.04	▨
					Probably loose grey mottled pale brown slightly clayey slightly sandy GRAVEL with medium cobble and boulder content and pockets of clay. Gravel is fine to coarse angular sandstone. Cobbles and boulders are interlocking angular up to 400mm in diameter of generally fresh dark purplish grey sandstone with occasional orange surface weathering (MADE GROUND - COARSE DISCARD)	(0.40) 2.40	156.64	▨
2.60	B				Probably loose pale grey mottled orange sandy very silty very clayey GRAVEL with low cobble content. Gravel is fine to coarse subangular and angular sandstone and fine angular coal. Cobbles are angular to subrounded sandstone (MADE GROUND - COARSE DISCARD)	(0.40) 2.80	156.24	▨
2.90	B				Probably loose black slightly silty slightly clayey sandy fine to coarse GRAVEL of weathered coal with medium cobble content. Material is wet. Coal encountered as a discontinuous layer with a subangular sandstone boulder at 2.8m depth (MADE GROUND - COARSE DISCARD)	(0.20) 3.00	156.04	▨
3.80 - 4.30	B				Probably loose pale brown clayey silty sandy GRAVEL with low cobble content. Gravel is fine to coarse subangular and angular sandstone. Material is wet (MADE GROUND - COARSE DISCARD)			▨

Weather and environmental conditions:
1. Rain, overcast

Other comments:
1. Co-ordinates and ground levels interpolated from topographical survey.
2. Trial pit terminated at a depth of 5.0m depth due to limitations of excavator.
3. Spalling of side walls occurred within coarse strata between depths of 0.50m to 2.00m and 3.00m to 4.00m.
4. Soils becoming saturated below 2.40m. Groundwater strike at approximately 3.0m depth with moderate ingress recorded.
4. 50mm groundwater monitoring well installed in the trial pit with a response zone between 3.0 and 5.0m depth. Trial pit backfilled with arisings upon completion.

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

Excavation method/plant: 8 Tonne Tracked Excavator

Shoring/support: None

TP102

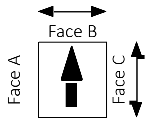
Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e.02

Excavation date: 15/10/2019
Backfill date: 15/10/2019
Logged by: EK/MTE

Survey details:

Ground Level: 159.0 mOD
Easting: 275053 mE
Northing: 207006 mN
Bearing:

Plan details:



Face Stability:

Unstable

Groundwater observations:

Groundwater encountered below 3.0m depth

Depth	Sample		Test Details		Strata Details			
m	Type	Class	Type	Result	Description	Depth (thickness)	mOD	Legend
					Probably loose pale brown clayey silty sandy GRAVEL with low cobble content. Gravel is fine to coarse subangular and angular sandstone. Material is wet (MADE GROUND - COARSE DISCARD)	(*2.00*)		▨
					End of Trialpit at 5.000m	5.005.0	154.04	
						6.0		
						7.0		

Weather and environmental conditions:

1. Rain, overcast

Other comments:

1. Co-ordinates and ground levels interpolated from topographical survey.
2. Trial pit terminated at a depth of 5.0m depth due to limitations of excavator.
3. Spalling of side walls occurred within coarse strata between depths of 0.50m to 2.00m and 3.00m to 4.00m.
4. Soils becoming saturated below 2.40m. Groundwater strike at approximately 3.0m depth with moderate ingress recorded.
4. 50mm groundwater monitoring well installed in the trial pit with a response zone between 3.0 and 5.0m depth. Trial pit backfilled with arisings upon completion.

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

TP103

Excavation method/plant: 13 Tonne Tracked Excavator

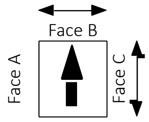
Shoring/support: None

Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e.02

Excavation date: 16/10/2019
Backfill date: 16/10/2019
Logged by: EK/MTE

Survey details:
Ground Level: 124.2 mOD
Easting: 275116 mE
Northing: 206980 mN
Bearing:

Plan details:



Face Stability:
Partially unstable

Groundwater observations:
Groundwater encountered at 3.6m depth

Depth	Sample		Test Details		Strata Details			
m	Type	Class	Type	Result	Description	Depth (thickness)	mOD	Legend
					Dark greyish black gravelly SAND with abundant rootlets and vegetation (MADE GROUND - TOPSOIL)	(0.10) 0.10	124.15	▨
0.30	B				Probably loose pale brownish grey sandy very clayey GRAVEL with high cobble content and traces of coal and organic matter. Gravel is fine to coarse subangular and angular sandstone. Large angular sandstone boulder approximately 1m in diameter recorded (MADE GROUND - COARSE DISCARD)	(0.40) 0.50	123.75	▨
					at 0.4m depth: 100mm band of soft dark greyish black slightly gravelly sandy CLAY with traces of decomposed vegetation and fine coal.			
0.60	B				Soft to firm orangeish brown mottled grey silty slightly sandy slightly gravelly CLAY with medium cobble content. Gravel is fine to coarse, subrounded to angular sandstone. Cobbles are subangular to angular sandstone (Probable DIAMICTON)	(0.70) 1.20	123.05	▨
1.50	B				Probably loose brownish grey occasionally mottled orange sandy clayey GRAVEL with medium cobble and boulder content. Gravels are fine to coarse, predominantly angular and occasional subrounded to subangular sandstone. Cobbles and boulders are angular to subangular, fresh dark grey and purple sandstone with occasional orange surface weathering (Possible weathered PENNANT SANDSTONE FORMATION - Grade E)	(1.10) 2.30	121.95	▨
3.50	B				Probably dense dark grey occasionally mottled orange clayey GRAVEL with high cobble and boulder content. Gravels are fine to coarse, predominantly angular and occasional subrounded to subangular sandstone. Cobbles and boulders are angular to subangular, fresh dark grey and purple sandstone with occasional orange surface weathering. Pockets of stiff grey clay throughout with traces of coal. Material is wet from 2.8m depth. (Possible Weathered PENNANT SANDSTONE FORMATION - Grade E)	(1.30) 3.60	120.65	▨
					End of Trialpit at 3.600m			

Weather and environmental conditions:

1. Dry, Sunny

Other comments:

1. Co-ordinates and ground levels interpolated from topographical survey.
2. Trial pit terminated at a depth of 3.60m depth..
3. Minor spalling recorded up to 0.5m depth within coarse material.
4. Soils becoming saturated below 2.8m. Groundwater seepage from side walls between 1.0 and 2.3m depth. Slow groundwater ingress recorded at base of trial pit at 3.6m depth.
5. Trial pit backfilled with arisings upon completion.

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

Excavation method/plant: 13 Tonne Tracked Excavator

Shoring/support: None

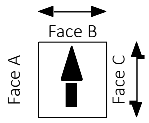
TP104

Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e.02

Excavation date: 16/10/2019
Backfill date: 16/10/2019
Logged by: EK/MTE

Survey details:
Ground Level: 120.8 mOD
Easting: 275096 mE
Northing: 206945 mN
Bearing:

Plan details:



Face Stability:
Partially unstable

Groundwater observations:
Minor seepage recorded at 2.3m depth

Depth	Sample		Test Details		Strata Details			
m	Type	Class	Type	Result	Description	Depth (thickness)	mOD	Legend
					Dark greyish black gravelly SAND with abundant rootlets and vegetation (MADE GROUND - TOPSOIL)	(0.20) 0.20	120.59	▨
1.00	B				Probably loose greyish pale brown clayey sandy GRAVEL with medium cobble content with some boulders up to 700mm diameter. Gravel is fine to coarse, subangular sandstone. Cobbles and boulders are angular fresh grey and purple sandstone with occasional orange surface weathering. Cobbles and boulders orientated both vertically and horizontally throughout (MADE GROUND - TIP SOIL)	(2.10) 2.30	118.49	▨
2.50	B				Soft bluish grey mottled orangeish brown silty CLAY with abundant rootlets throughout and rare traces of coal (Probable DIAMICTON).	(0.60) 2.90	117.89	▨
3.30	B				Firm brown mottled grey slightly gravelly sandy very silty CLAY with rare rootlets and low cobble and boulder content (Probable DIAMICTON)	(0.50) 3.40	117.39	▨
					Probably dense dark grey sandy clayey GRAVEL with high cobble and boulder content and rare coal traces. Gravels are fine to coarse, predominantly angular and occasional subrounded to subangular sandstone. Cobbles and boulders are angular to subangular, fresh dark grey and purple sandstone with occasional orange surface weathering (Probable weathered PENNANT SANDSTONE FORMATION - Grade E)			▨

Weather and environmental conditions:

1. Dry, Sunny

Other comments:

1. Co-ordinates and ground levels interpolated from topographical survey.
2. Trial pit terminated at a depth of 5.5m depth due to limitations of excavator.
3. Spalling of side walls occurred within coarse strata between depths of 0.1 and 2.0m.
4. Minor seepage recorded at 2.3m depth below a large boulder. Pockets of saturated material below 3.45m.
5. 50mm groundwater monitoring well installed in the trial pit with a response zone between 3.5 and 5.5m depth. Trial pit backfilled with arisings upon completion.

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

Excavation method/plant: 13 Tonne Tracked Excavator

Shoring/support: None

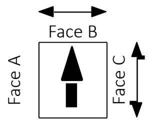
TP104

Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e.02

Excavation date: 16/10/2019
Backfill date: 16/10/2019
Logged by: EK/MTE

Survey details:
Ground Level: 120.8 mOD
Easting: 275096 mE
Northing: 206945 mN
Bearing:

Plan details:



Face Stability:
Partially unstable

Groundwater observations:
Minor seepage recorded at 2.3m depth

Depth	Sample		Test Details		Strata Details			
m	Type	Class	Type	Result	Description	Depth (thickness)	mOD	Legend
					Probably dense dark grey sandy clayey GRAVEL with high cobble and boulder content and rare coal traces. Gravels are fine to coarse, predominantly angular and occasional subrounded to subangular sandstone. Cobbles and boulders are angular to subangular, fresh dark grey and purple sandstone with occasional orange surface weathering (Probable weathered PENNANT SANDSTONE FORMATION - Grade E)	(*2.10*)		▨
4.50	B							
						5.0		
					End of Trialpit at 5.500m	5.50	115.29	
						6.0		
						7.0		

Weather and environmental conditions:

1. Dry, Sunny

Other comments:

1. Co-ordinates and ground levels interpolated from topographical survey.
2. Trial pit terminated at a depth of 5.5m depth due to limitations of excavator.
3. Spalling of side walls occurred within coarse strata between depths of 0.1 and 2.0m.
4. Minor seepage recorded at 2.3m depth below a large boulder. Pockets of saturated material below 3.45m.
5. 50mm groundwater monitoring well installed in the trial pit with a response zone between 3.5 and 5.5m depth. Trial pit backfilled with arisings upon completion.

APPENDIX F1 CABLE PERCUSSION DRILLHOLE RECORDS

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

Project Name: Godre'r Graig Primary School	**Drilling method**		
Site Location: Godre'r Graig	**Equipment** Cut-down Rig		
Client: Neath Port Talbot CBC	**Ground Level:**	157.00 mOD	
Project No: 7234e.02	**Easting:**	275044 m	
	Northing:	206992 m	

BH01

Start date:	28/10/2019	**Driller:**	Jacksons - DS
End date:	29/10/2019	**Logged by:**	EK
Backfill date:	29/10/2019	**Date logged:**	29/10/2019

Depth	Sample		Test Details		TCR (%)	Water Depth	Casing Depth	Strata Details		Water	Depth		Backfill/ Install-ations
	Type	Class	Type	Result				Description	Legend	Strikes/ Standing	Depth (Thickness)	mOD	
0.00 - 0.50	B							Vegetation and topsoil over; greyish brown slightly clayey sandy GRAVEL with medium cobble content and abundant rootlets and vegetation. Gravel is fine to coarse, subangular to subrounded fresh grey sandstone (MADE GROUND - COARSE DISCARD)			(0.50) 0.50	156.50	
1.00	B		S	21 (3,3/4,5,7,5)			1.00	Medium dense dark grey sandy GRAVEL with medium cobble content. Gravel fine to coarse, angular to subrounded fresh grey sandstone. Cobbles are angular to subangular predominantly fresh with occasional orange staining sandstone (MADE GROUND - COARSE DISCARD)			(2.50)		
1.00 - 1.50	D												
2.00	B		S	11 (3,3/4,3,1,3)			2.00						
2.00 - 2.50	D												
3.00	B		S	5 (1,1/1,1,1,2)			3.00	Soft greyish brown mottled orange sandy gravelly CLAY with low cobble content. Gravel is fine to coarse, angular to subrounded sandstone with fine coal gravels. Soils are damp. (MADE GROUND - COARSE DISCARD)			3.00 (1.00)	154.00	
3.00 - 3.50	D												
4.00	B		S	24 (1,4/6,6,6,6)			4.00	Stiff dark grey mottled orange/brown sandy silty gravelly CLAY. Gravel is angular sandstone with occasional orange weathering (Possible weathered PENNANT SANDSTONE FORMATION - Grade E)			4.00 (1.00)	153.00	
4.00 - 4.50	D												
5.00	D		S	50 (4,12/50 for 125mm)			4.00	Very stiff friable dark grey mottled orange gravelly CLAY (Probable weathered PENNANT SANDSTONE FORMATION - Grade D)			5.00 (0.30)	152.00	
5.30	D							End of Borehole at 5.300m			5.30	151.70	

Progress & Standing Water Levels					Water Strikes							Chiselling			Hole Diameter		Casing Diameter	
Date	Time	Hole Depth	Casing Depth	Water Depth	Date	Time	Strike Depth	Casing Depth	Elapsed Minutes	Depth to Water	Depth Sealed	Depth Top	Depth Base	Duration	Hole Depth	Hole Diameter	Casing Diameter	Casing Depth
												5.00	5.30	01:00	4.00 5.30	250 150	250	4.00

General Remarks

1. Co-ordinates and ground levels interpolated from topographical survey.
2. Borehole refused at 5.3m depth on possible bedrock/obstruction.
3. Groundwater not encountered.
4. 70mm inclinometer casing installed to 5.3m depth with bentonite/cement surround.

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e.02

Drilling method

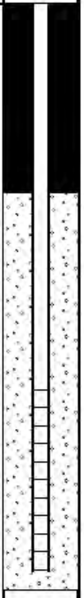
Equipment Cut-down Rig

BH02

Start date: 30/10/2019
End date: 30/10/2019
Backfill date: 30/10/2019

Driller: Jacksons - DS
Logged by: EK
Date logged: 30/10/2019

Ground Level: 157.90 mOD
Easting: 275054 m
Northing: 207001 m

Depth	Sample		Test Details		TCR (%)	Water Depth	Casing Depth	Strata Details		Water	Depth		Backfill/ Install-ations
	Type	Class	Type	Result				Description	Legend	Strikes/ Standing	Depth (Thickness)	mOD	
0.00 - 0.50	B							Vegetation and topsoil over; brown slightly clayey sandy GRAVEL with medium cobble content with abundant rootlets and vegetation. Gravel is fine to coarse, subangular to subrounded fresh grey sandstone (MADE GROUND - COARSE DISCARD)	▨		(1.00)		
1.00	B		S	7 (1,2/2,2,2,1)			1.00	Soft becoming firm greyish brown sandy gravelly CLAY with low cobble content. Gravel fine to coarse, angular to subrounded fresh grey sandstone. Occasional pockets of saturated clay noted throughout. (MADE GROUND - COARSE DISCARD)	▨		1.00	156.90	
1.00 - 2.00	D												
2.00	B		S	15 (2,2/5,4,4,2)			2.00				2 (2.10)		
2.00 - 2.50	D												
3.00	D		S	50 (25 for 75mm/50 for 0mm)			3.00				3		
3.10	D		S	50 (25 for 0mm/50 for 0mm)			3.00	End of Borehole at 3.100m			3.10	154.80	
											4		
											5		
											6		
											7		

Progress & Standing Water Levels					Water Strikes							Chiselling			Hole Diameter		Casing Diameter	
Date	Time	Hole Depth	Casing Depth	Water Depth	Date	Time	Strike Depth	Casing Depth	Elapsed Minutes	Depth to Water	Depth Sealed	Depth Top	Depth Base	Duration	Hole Depth	Hole Diameter	Casing Diameter	Casing Depth
												3.10	3.10	01:00	3.00	250	250	3.00

General Remarks

1. Co-ordinates and ground levels interpolated from topographical survey.
2. Borehole refused at 3.1m depth on possible bedrock/obstruction.
3. Groundwater not encountered.
4. 19mm groundwater monitoring well installed with a response zone between 2.0 and 3.0m depth.

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

BH03

Project Name: Godre'r Graig Primary School	**Drilling method**		
Site Location: Godre'r Graig	**Equipment** Cut-down Rig		
Client: Neath Port Talbot CBC	**Ground Level:** 157.60 mOD		
Project No: 7234e.02	**Easting:** 275051 m		
	Northing: 206998 m		

Start date: 31/10/2019
End date: 31/10/2019
Backfill date: 31/10/2019
Driller: Jacksons - DS
Logged by: EK
Date logged: 31/10/2019

Depth	Sample Type	Sample Class	Test Details Type	Test Details Result	TCR (%)	Water Depth	Casing Depth	Strata Details Description	Legend	Water Strikes/ Standing	Depth (Thickness)	mOD	Backfill/ Install-ations
0.00 - 0.50	B							Vegetation and topsoil over; greyish brown slightly clayey sandy GRAVEL with medium cobble content with abundant rootlets and vegetation. Gravel is fine to coarse, subangular to subrounded fresh grey sandstone (MADE GROUND - COARSE DISCARD)			(1.00) 1.00	156.60	
1.00	D		S	8 (2,2/3,3,1,1)			1.00	Firm brownish grey sandy gravelly CLAY with low cobble content. Gravel fine to coarse, angular to subrounded fresh grey sandstone. Occasional pockets of saturated clay noted throughout. (MADE GROUND - COARSE DISCARD)					
2.00	B		S	8 (2,2/1,2,2,3)			2.00						
2.00 - 3.00	D										(2.60)		
3.00	B		S	50 (1,1/50 for 70mm)			3.00						
3.00 - 3.60	D										3.60	154.00	
3.60	D							Very stiff dark grey mottled orange/brown slightly sandy silty slightly gravelly CLAY. Gravel is angular sandstone with rare orange weathering (MADE GROUND - SPOIL TIP)			(0.60)		
3.80	D		S	50 (25 for 135mm/50 for 35mm)			3.80						
4.00	B										4.20	153.40	
4.20	D		S	50 (25 for 95mm/50 for 85mm)			4.00	End of Borehole at 4.200m					

Progress & Standing Water Levels

Date	Time	Hole Depth	Casing Depth	Water Depth

Water Strikes

Date	Time	Strike Depth	Casing Depth	Elapsed Minutes	Depth to Water	Depth Sealed

Chiselling

Depth Top	Depth Base	Duration
4.00	4.20	02:00

Hole Diameter

Hole Depth	Hole Diameter
4.00	250

Casing Diameter

Casing Diameter	Casing Depth
250	4.00

General Remarks

1. Co-ordinates and ground levels interpolated from topographical survey.
2. Borehole refused at 4.2m depth on possible bedrock/obstruction.
3. Groundwater not encountered.
4. 19mm groundwater monitoring well installed with a response zone between 3.2 and 4.2m depth.

Earth Science Partnership

Consulting Engineers | Geologists | Environmental Scientists

BH04

Start date: 04/11/2019	**Driller:** Jacksons - DS	**Project Name:** Godre'r Graig Primary School	**Drilling method**
End date: 04/11/2019	**Logged by:** EK	**Site Location:** Godre'r Graig	**Equipment** Cut-down Rig
Backfill date: 05/11/2019	**Date logged:** 04/11/2019	**Client:** Neath Port Talbot CBC	**Ground Level:** 143.80 mOD
		Project No: 7234e.02	**Easting:** 275062 m
			Northing: 206971 m

Depth	Sample Type	Sample Class	Test Type	Test Result	TCR (%)	Water Depth	Casing Depth	Strata Description	Legend	Water Strikes/ Standing	Depth (Thickness)	mOD	Backfill/ Install-ations
0.00 - 0.50	B							Vegetation and topsoil over; greyish brown clayey sandy GRAVEL with medium cobble content and abundant rootlets and vegetation. Gravel is fine to coarse, subangular to subrounded fresh grey sandstone and fine coal fragments (MADE GROUND - COARSE DISCARD)			(1.00)		
1.00	B		S	14 (1,3/4,5,3,2)			1.00	Medium dense brownish grey sandy GRAVEL with medium cobble content and occasional pockets of saturated clay. Gravel is fine to coarse, angular to subrounded fresh grey sandstone and fine coal fragments (MADE GROUND - COARSE DISCARD)			1.00	142.80	
1.00 - 2.00	D												
2.00	B		S	12 (2,2/4,4,3,1)			2.00				(2.00)		
2.00 - 2.50	D												
3.00	B		S	8 (1,2/2,2,2,2)			3.00	Soft brownish grey sandy gravelly CLAY with medium cobble content. Gravel is fine to coarse, subangular to subrounded fresh grey sandstone. Cobbles are angular to subrounded predominantly fresh with rare orange staining (MADE GROUND - COARSE DISCARD)			3.00	140.80	
3.00 - 3.50	D										(1.00)		
4.00	B		S	11 (1,2/3,3,2,3)			3.00	Firm and locally soft pale brown mottled orange and black sandy gravelly CLAY. Gravel is fine to coarse, angular to subrounded sandstone with fine coal fragments. Material is wet throughout (MADE GROUND - COARSE DISCARD)			4.00	139.80	
4.00 - 4.50	D												
4.50 - 5.00	B										(1.00)		
5.00	B		S	28 (5,4/5,12,7,4)			3.00	Medium dense brownish grey sandy GRAVEL with low cobble content and occasional pockets of clay. Gravel is fine to coarse predominantly angular to subangular with rare subrounded sandstone (MADE GROUND - COARSE DISCARD)			5.00	138.80	
5.00 - 5.50	D										(1.00)		
6.00	B		S	50 (5,5/50 for 225mm)			3.00	Very stiff dark grey mottled orange/brown sandy silty gravelly CLAY. Gravel is angular sandstone with rare subrounded sandstone and occasional orange weathering (Possible PENNANT SANDSTONE FORMATION - Grade D)			6.00	137.80	
6.00 - 6.50	D										(1.00)		
								Very stiff friable greyish gravelly sandy CLAY. Gravel is angular weak to medium strong weathered sandstone with occasional grey fresh sandstone. (Probable PENNANT SANDSTONE FORMATION - Grade D)			7.00	136.80	
7.20	D		S	50 (5,8/50 for 180mm)			3.00				(0.20) 7.20	136.60	

End of Borehole at 7.200m

Progress & Standing Water Levels

Date	Time	Hole Depth	Casing Depth	Water Depth

Water Strikes

Date	Time	Strike Depth	Casing Depth	Elapsed Minutes	Depth to Water	Depth Sealed

Chiselling

Depth Top	Depth Base	Duration
7.20	7.20	01:00

Hole Diameter

Hole Depth	Hole Diameter
3.00	250
7.20	150

Casing Diameter

Casing Diameter	Casing Depth
250	3.00

General Remarks

1. Co-ordinates and ground levels interpolated from topographical survey.
2. Rig winched to borehole position.
3. Groundwater not encountered.
4. Borehole refused at 5.3m depth on competent bedrock.
5. Vibrating wire piezometer and 70mm inclinometer casing installed to 7.2m depth with bentonite/cement surround.

APPENDIX F2 ROTARY DRILLHOLE RECORDS

Earth Science Partnership
Consulting Engineers | Geologists | Environmental Scientists

Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e.02

Drilling method: Rotary cored
Equipment: Beretta T44

BH05

Start date: 25/11/2019
End date: 27/11/2019
Backfill date: 27/11/2019

Driller: Apex - CY
Logged by: EK
Date logged: 28/11/2019

Ground Level: 157.50 mOD
Easting: 275036 m
Northing: 206985 m

Core Details and SPT Data

Depth (Length)	TCR (%)	SCR (%)	RQD (%)	FI
0.00 - 1.10 (1.10)	82			
1.10 - 2.60 (1.50)	60			
2.60 - 4.10 (1.50)	77			
4.10 - 5.00 (0.90)	56			
5.00 - 5.60 (0.60)	67			
5.60 - 7.00 (1.40)	100	24	0	>20 20 NI 14 NI
7.00 - 8.50 (1.50)	80	49	76	NR NI 8
8.50 - 9.80 (1.30)	85	84	75	5
				13

SPT-N (approx. depth)	
1.0	10 (3,3/3,3,2,2)
2.5	7 (1,1/2,2,1,2)
4.0	13 (5,7/4,3,2,4)
5.5	50 (8,15/50 for 90mm)

Strata Details

Description	Water Strikes/Standing	Depth (Thickness)	mOD
Medium dense dark grey mottled brown slightly sandy clayey GRAVEL with medium cobble content. Gravel is fine to coarse subangular to angular dark grey sandstone (fresh and with occasional orange and purple staining). Occasional sandstone cobbles. (MADE GROUND - COARSE DISCARD). at 0.5 to 0.65m and 1.45 to 1.75m depth: bands of clay rich material noted. at 2.6m depth: becoming loose. at 4.1m depth: becoming medium dense.		4.30 (4.30)	153.20
Firm brown and mottled dark grey silty gravelly CLAY. Gravel is fine to medium subrounded to angular sandstone and siltstone with fine coal fragments (MADE GROUND - COARSE DISCARD) between 4.3 to 4.45m depth: band of thinly laminated clay between 4.6 to 5.0m depth: poor recovery - presumed sandstone cobble		5.25 (0.95)	152.25
	► ►		
Weak thinly laminated friable dark grey mottled orange and black MUDSTONE (PENNANT SANDSTONE FORMATION - Grade C)		5.60 (0.35)	151.90
Medium strong and strong thinly bedded dark grey SILTSTONE with occasional fossilised plant debris. Bedding fractures are generally horizontal and sub-horizontal (<5°), rough stepped and undulating with orange/brown iron oxide staining (PENNANT SANDSTONE FORMATION - Grade B) at 6.7m depth: 50mm band of thinly laminated siltstone.		7.70 (2.10)	149.80
Strong thinly-medium bedded fresh grey micaceous fine grained SANDSTONE with rare fossilised plant debris. Bedding fractures are generally horizontal to sub-horizontal (<5°), smooth, planar and undulating with rare orange iron oxide staining (PENNANT SANDSTONE FORMATION - Grade A)		(2.70)	

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5

Progress & Standing Water Levels

Date	Time	Hole Depth	Casing Depth	Water Depth
26-11-2019	12:00	5.60	5.60	5.3
27-11-2020	12:00	11.10	5.60	Dry

Water Strikes

Date	Time	Strike Depth	Casing Depth	Elapsed Minutes	Depth to Water	Depth Sealed
25/11/2019	12:00	5.30		0.00	0.00	

Hole Diameter

Hole Depth	Hole Diameter
5.30	127
11.10	75

Casing Diameter

Casing Diameter	Casing Depth
127	5.30

General Remarks

1. Co-ordinates and ground levels interpolated from topographical survey.
2. Vibrating wire piezometer and 70mm inclinometer casing installed to 11.1m depth with bentonite/cement surround.
3. Groundwater encountered at 5.3m depth. Groundwater standing at 5.3m the following morning. Borehole dry on morning of installation.
4. Borehole terminated at 11.1m depth.

Earth Science Partnership
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BH05

Start date:	25/11/2019	Driller:	Apex - CY
End date:	27/11/2019	Logged by:	EK
Backfill date:	27/11/2019	Date logged:	28/11/2019

Project Name: Godre'r Graig Primary School
Site Location: Godre'r Graig
Client: Neath Port Talbot CBC
Project No: 7234e.02

Drilling method: Rotary cored
Equipment: Beretta T44

Ground Level:	157.50 mOD
Easting:	275036 m
Northing:	206985 m

Core Details and SPT Data

Depth (Length)	TCR (%)	SCR (%)	RQD (%)	FI	SPT-N
9.80 - 10.40 (0.60)	100	58	0	>20 10	
10.40 - 11.10 (0.70)	100	100	100	7	

Strata Details

Description	Legend	Water Strikes/ Standing	Depth (Thickness)	mOD	Backfill/ Install-ations
Strong thinly-medium bedded fresh grey micaceous fine grained SANDSTONE with rare fossilised plant debris. Bedding fractures are generally horizontal to sub-horizontal (<5°), smooth, planar and undulating with rare orange iron oxide staining (PENNANT SANDSTONE FORMATION - Grade A)			10.40	147.10	
Very strong medium bedded fresh grey micaceous coarse grained SANDSTONE. Bedding fractures are generally horizontal to sub-horizontal (<5°), smooth, planar and undulating (PENNANT SANDSTONE FORMATION - Grade A)			(0.70) 11.10	146.40	

End of Borehole at 11.100m

Depth: 10.5, 11.0, 11.5, 12.0, 12.5, 13.0, 13.5, 14.0, 14.5, 15.0, 15.5, 16.0, 16.5, 17.0, 17.5, 18.0, 18.5, 19.0, 19.5

Progress & Standing Water Levels

Date	Time	Hole Depth	Casing Depth	Water Depth
26-11-2019	12:00	5.60	5.60	5.3
27-11-2020	12:00	11.10	5.60	Dry

Water Strikes

Date	Time	Strike Depth	Casing Depth	Elapsed Minutes	Depth to Water	Depth Sealed
25/11/2019	12:00	5.30		0.00	0.00	

Hole Diameter

Hole Depth	Hole Diameter
5.30	127
11.10	75

Casing Diameter

Casing Diameter	Casing Depth
127	5.30

General Remarks

1. Co-ordinates and ground levels interpolated from topographical survey.
2. Vibrating wire piezometer and 70mm inclinometer casing installed to 11.1m depth with bentonite/cement surround.
3. Groundwater encountered at 5.3m depth. Groundwater standing at 5.3m the following morning. Borehole dry on morning of installation.
4. Borehole terminated at 11.1m depth.

APPENDIX G GROUNDWATER MONITORING DATA

Godre'r Graig
Results of Groundwater Monitoring

Visit 1

Date:	11/11/2019	**Site Status:**	Undeveloped
Time:	10:00	**Ground Condition:**	Unsaturated
Engineer:	EK/BF		
Weather:	Wet		

Well ID	Well Elevation (m OD)	Installed depth (m)	Date of installation	Response Zone (m)	Measured depth (m)	Groundwater depth (m)	Groundwater Elevation (m OD)
TP102	159.0	4.0	15/10/2019	2.0 - 4.0	5.00	4.7	154.3
TP104	120.8	5.5	15/10/2019	3.5 - 5.5	5.50	2	118.8
BH02	158.0	3.0	30/10/2019	2.0 - 3.0	2.80	2.6	155.4
BH03	158.0	4.2	31/10/2019	3.2 - 4.2	4.10	2.6	155.4

Visit 2

Date:	25/11/2019	Site Status:	Undeveloped
Time:	10:00	**Ground Condition:**	Unsaturated
Engineer:	EK		
Weather:	During period of heavy rainfall		

Well ID	Well Elevation (m OD)	Installed depth (m)	Date of installation	Response Zone (m)	Measured depth (m)	Groundwater depth (m)	Groundwater Elevation (m OD)
TP102	159.0	4.0	15/10/2019	2.0 - 4.0	5.00	4.95	154.1
TP104	120.8	5.5	15/10/2019	3.5 - 5.5	5.50	2.1	118.7
BH02	158.0	3.0	30/10/2019	2.0 - 3.0	2.80	2.82	155.2
BH03	158.0	4.2	31/10/2019	3.2 - 4.2	4.10	2.75	155.3

Visit 3

Date:	29/11/2019	Site Status:	Undeveloped
Time:	10:00	**Ground Condition:**	Unsaturated
Engineer:	BF/AB		
Weather:	Cloudy		

Well ID	Well Elevation (m OD)	Installed depth (m)	Date of installation	Response Zone (m)	Measured depth (m)	Groundwater depth (m)	Groundwater Elevation (m OD)
TP102	159.0	4.0	15/10/2019	2.0 - 4.0	5.00	4.7	154.3
TP104	120.8	5.5	15/10/2019	3.5 - 5.5	5.50	1.9	118.9
BH02	158.0	3.0	30/10/2019	2.0 - 3.0	2.90	2.9	155.1
BH03	158.0	4.2	31/10/2019	3.2 - 4.2	4.10	2.9	155.1

Visit 4

Date:	09/12/2019	**Site Status:**	Undeveloped
Time:	11:00	**Ground Condition:**	Unsaturated
Engineer:	BF/AB		
Weather:	Sunny		

Well ID	Well Elevation (m OD)	Installed depth (m)	Date of installation	Response Zone (m)	Measured depth (m)	Groundwater depth (m)	Groundwater Elevation (m OD)
TP102	159.0	4.0	15/10/2019	2.0 - 4.0	5.00	4	155.0
TP104	120.8	5.5	15/10/2019	3.5 - 5.5	5.50	1.9	118.9
BH02	158.0	3.0	30/10/2019	2.0 - 3.0	2.90	2.6	155.4
BH03	158.0	4.2	31/10/2019	3.2 - 4.2	4.10	2.6	155.4

Visit 5

Date:	20/12/2019	Site Status:	Undeveloped
Time:	13:15	**Ground Condition:**	Unsaturated
Engineer:	BF/AB		
Weather:	Breezy		

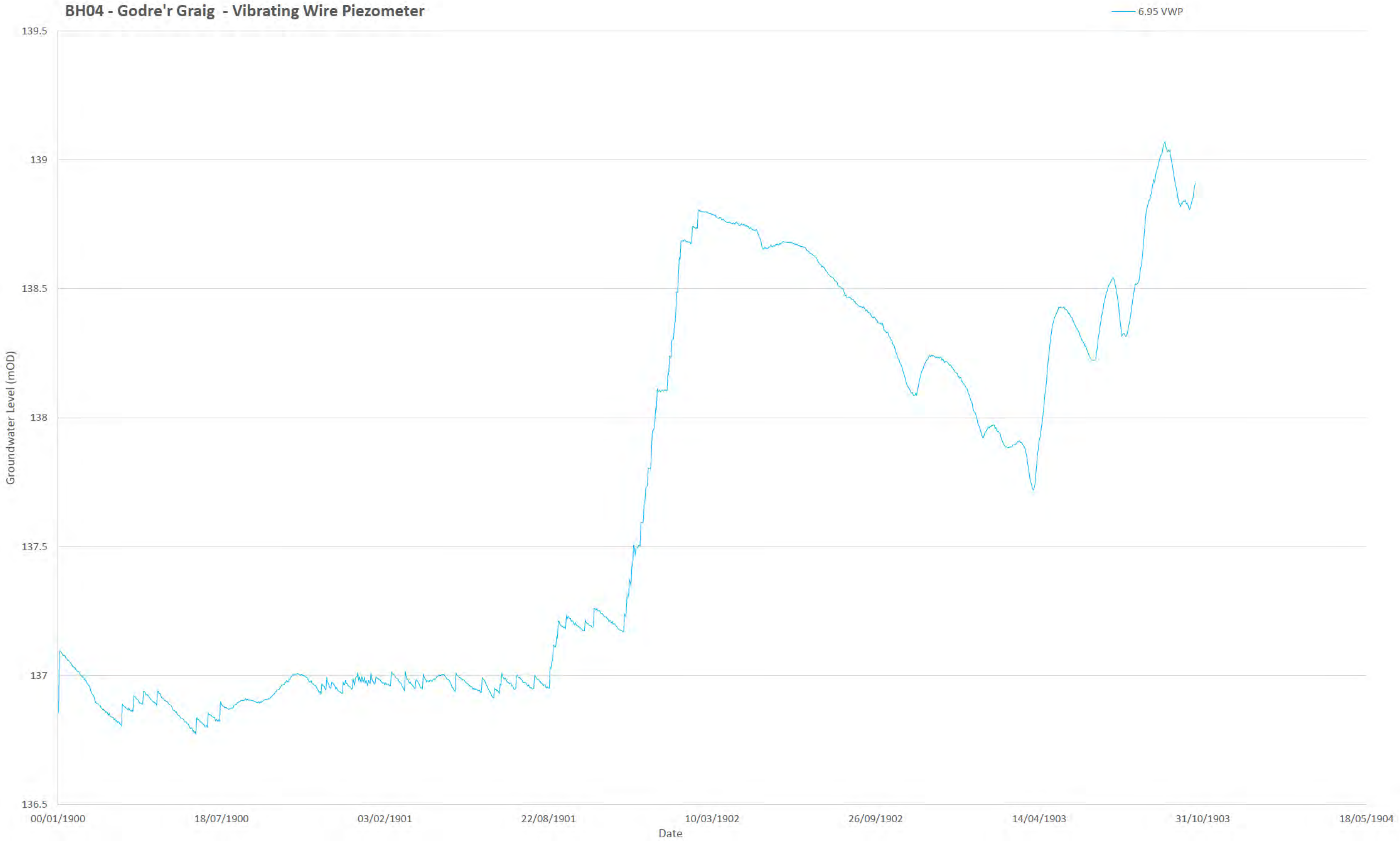
Well ID	Well Elevation (m OD)	Installed depth (m)	Date of installation	Response Zone (m)	Measured depth (m)	Groundwater depth (m)	Groundwater Elevation (m OD)
TP102	159.0	4.0	15/10/2019	2.0 - 4.0	5.00	4.7	154.3
TP104	120.8	5.5	15/10/2019	3.5 - 5.5	5.50	1.8	119.0
BH02	158.0	3.0	30/10/2019	2.0 - 3.0	2.90	2.6	155.4
BH03	158.0	4.2	31/10/2019	3.2 - 4.2	4.10	2.9	155.1

Visit 6

Date:	17/01/2019	Site Status:	Undeveloped
Time:	13:15	Ground Condition:	Unsaturated
Engineer:	AB		
Weather:	Fine		

Well ID	Well Elevation (m OD)	Installed depth (m)	Date of installation	Response Zone (m)	Measured depth (m)	Groundwater depth (m)	Groundwater Elevation (m OD)
TP102	159.0	4.0	15/10/2019	2.0 - 4.0	5.00	4.66	154.3
TP104	120.8	5.5	15/10/2019	3.5 - 5.5	5.50	1.81	119.0
BH02	158.0	3.0	30/10/2019	2.0 - 3.0	2.90	2.6	155.4
BH03	158.0	4.2	31/10/2019	3.2 - 4.2	4.10	2.6	155.4

APPENDIX H INCLONOMETER MONITORING DATA

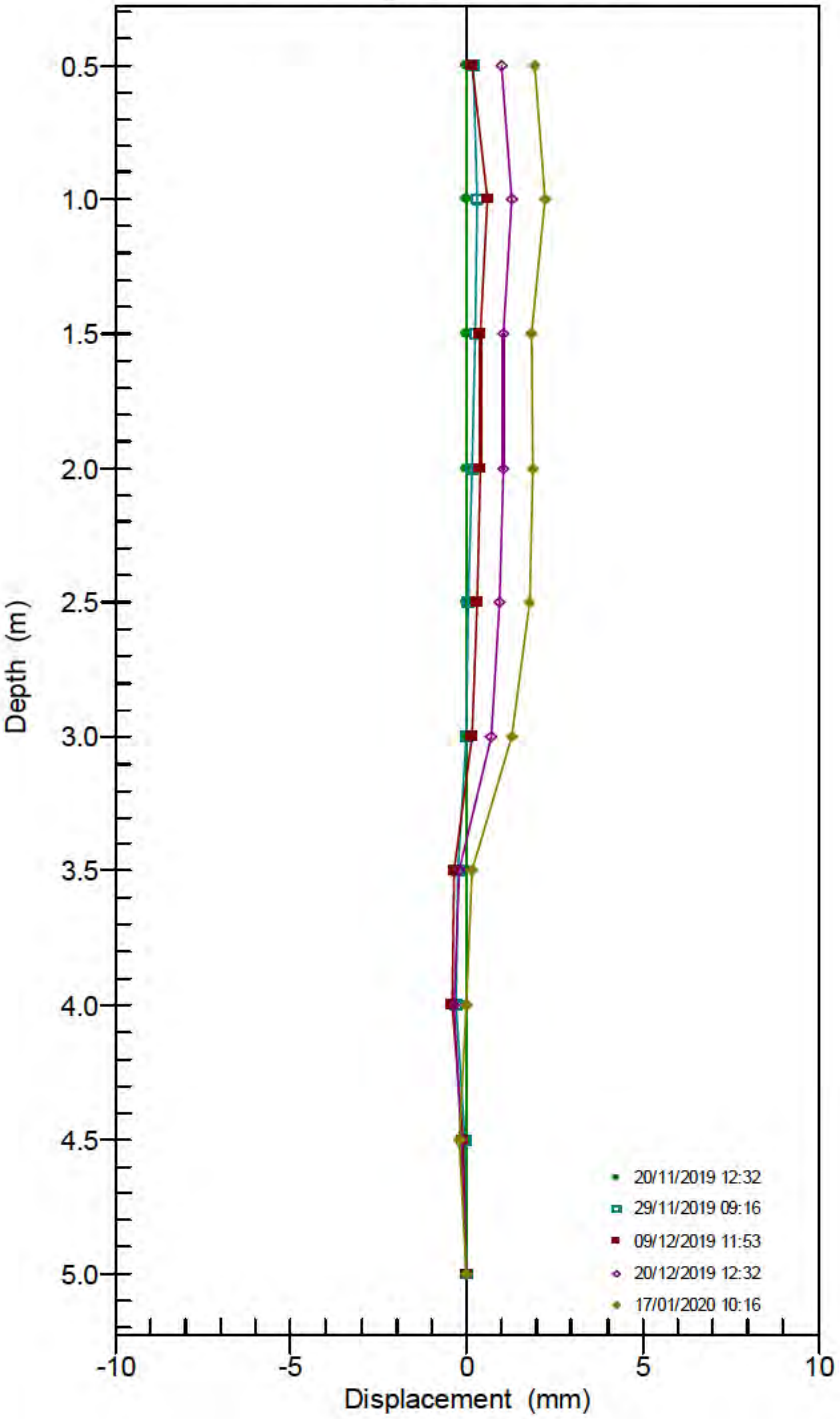

BH04 - Godre'r Graig - Vibrating Wire Piezometer
6.95 VWP
139.5
139
138.5
138
137.5
137
136.5
Groundwater Level (mOD)
00/01/1900
18/07/1900
03/02/1901
22/08/1901
10/03/1902
26/09/1902
14/04/1903
31/10/1903
18/05/1904
Date


BH05 - Godre'r Graig - Vibrating Wire Piezometer
5.7m VWP
Groundwater Level (mOD)
152.3
152.2
152.1
152
151.9
151.8
151.7
151.6
151.5
21/11/2019 00:00
01/12/2019 00:00
11/12/2019 00:00
21/12/2019 00:00
31/12/2019 00:00
10/01/2020 00:00
20/01/2020 00:00
Date

APPENDIX I VIBRATING WIRE PEIZOMETER MONITORING DATA

7234e:BH01 - A Axis Cumulative

Initial survey: 20/11/2019 12:32

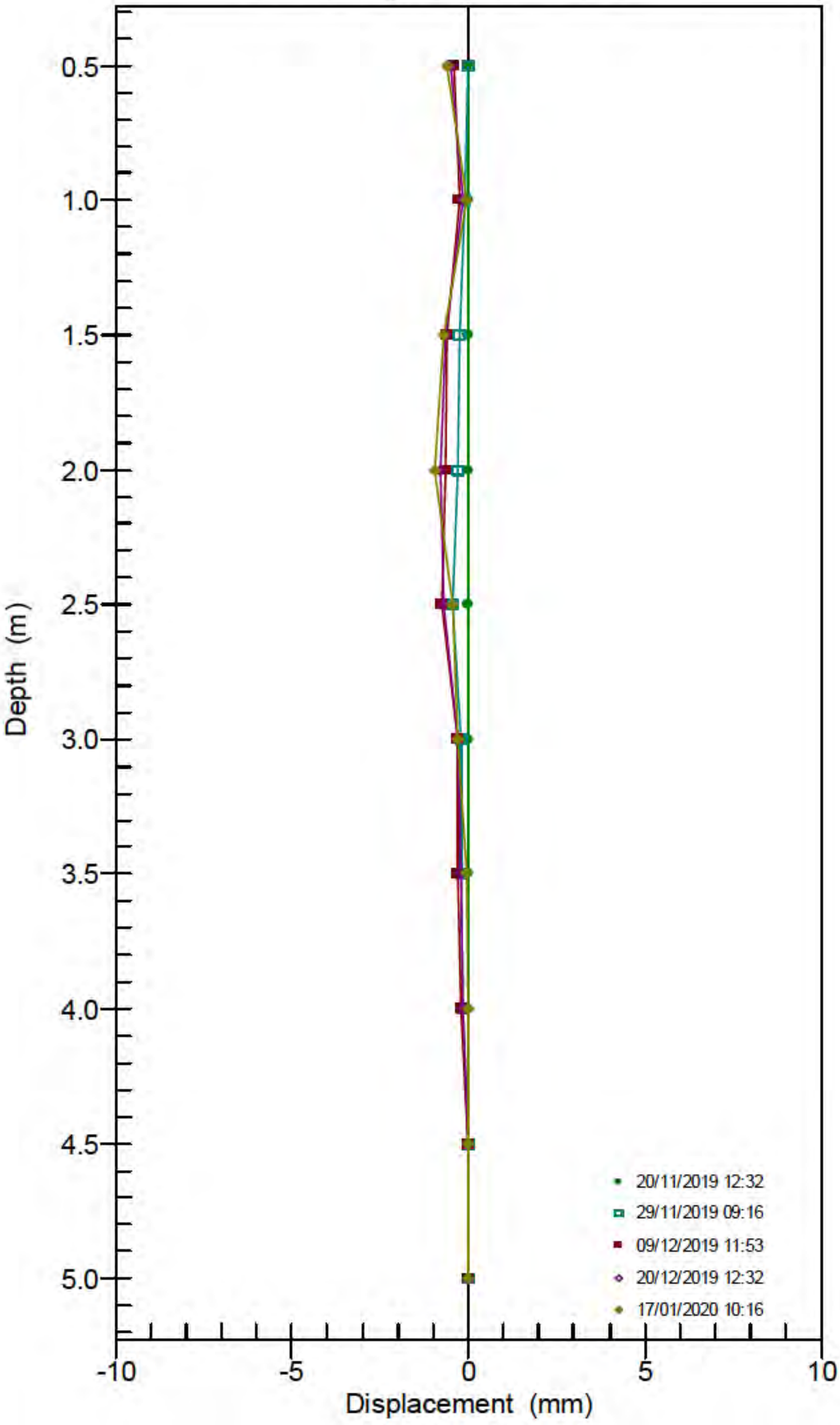


PROJECT:
SITE: 7234e
INSTALLATION: BH01
COMPANY:
CLIENT:

NOTE:

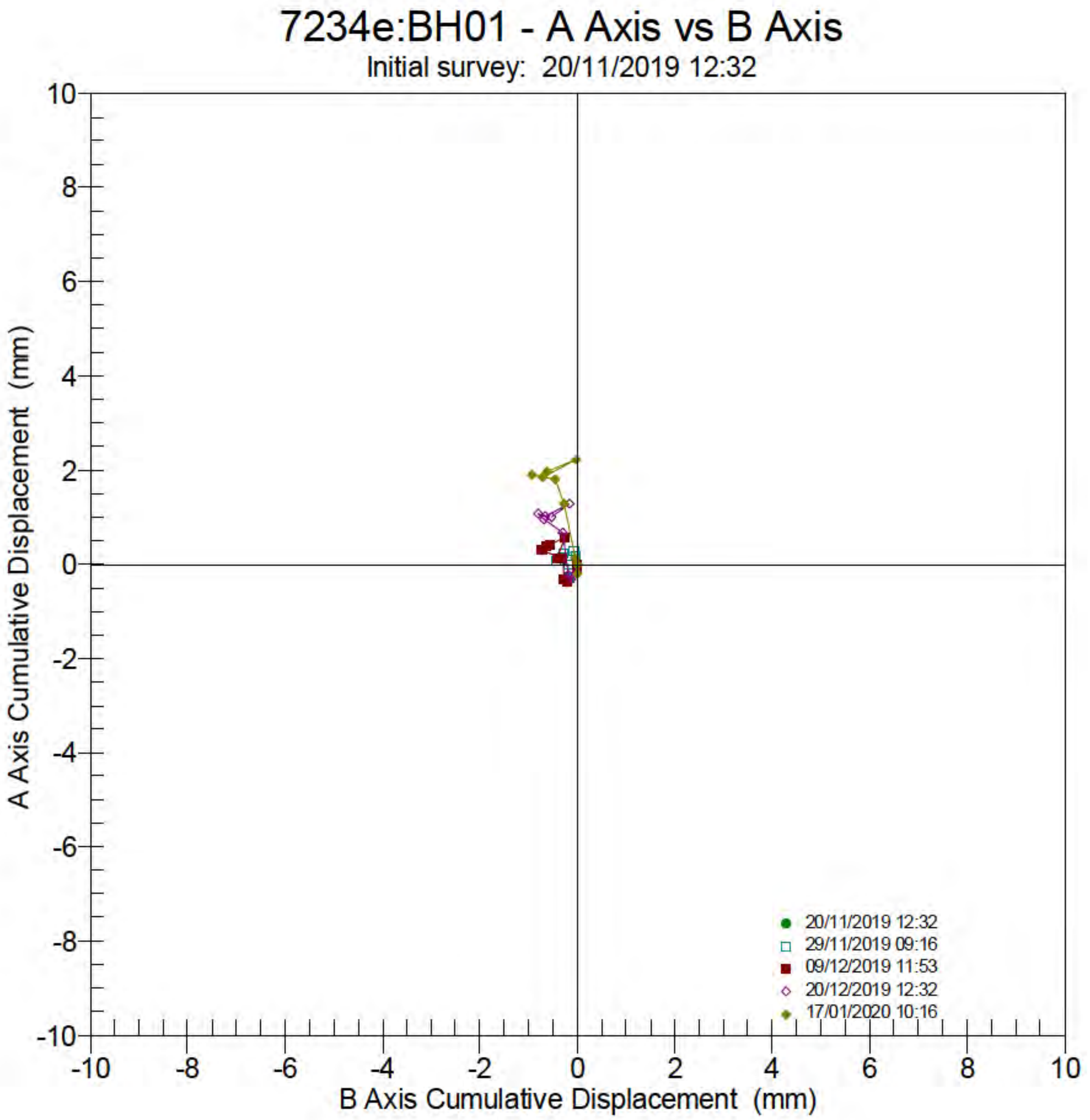
7234e:BH01 - B Axis Cumulative

Initial survey: 20/11/2019 12:32



PROJECT:
SITE: 7234e
INSTALLATION: BH01
COMPANY:
CLIENT:

NOTE:

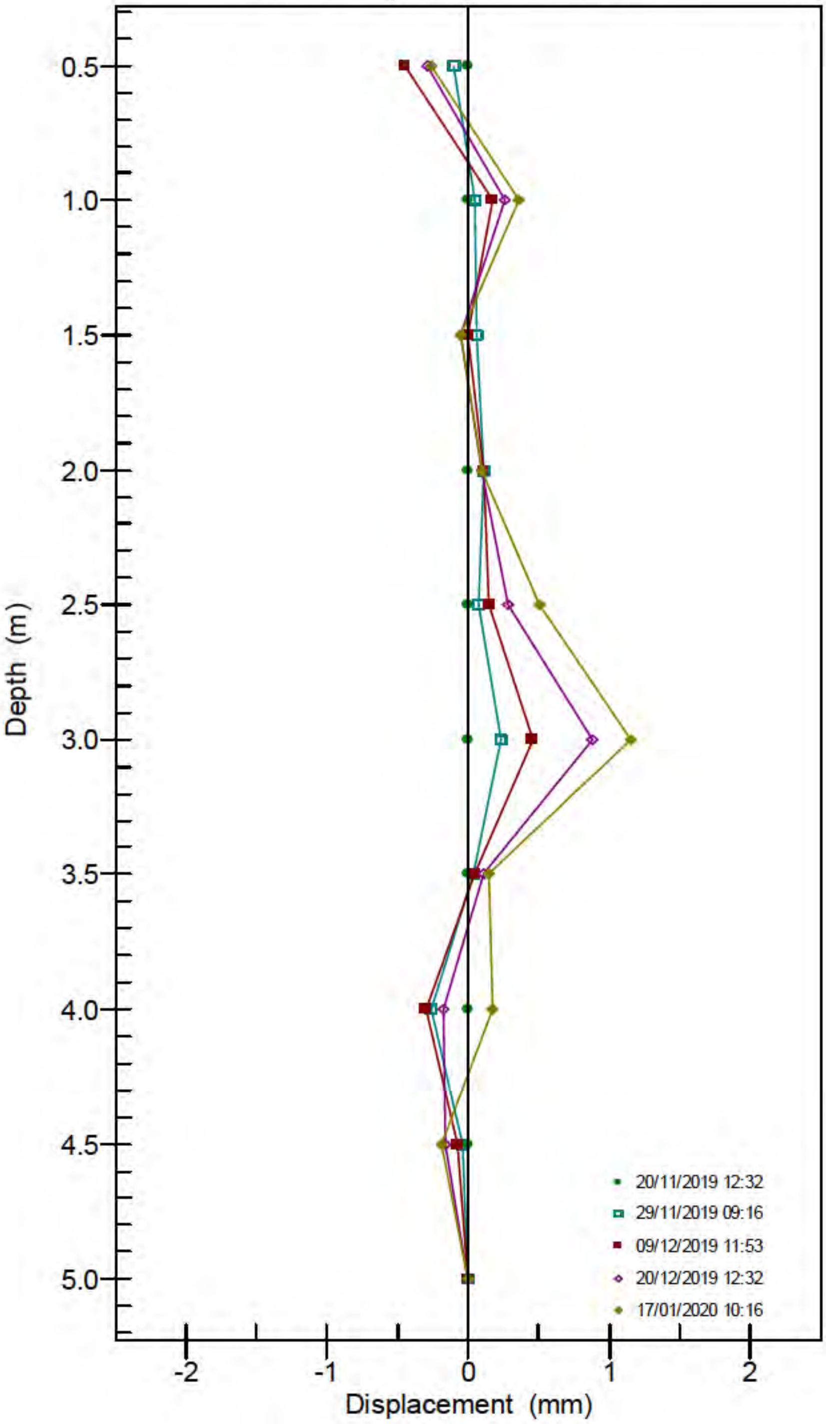


PROJECT:
SITE: 7234e
INSTALLATION: BH01
COMPANY:
CLIENT:

NOTE:

7234e:BH01 - A Axis Incremental

Initial survey: 20/11/2019 12:32

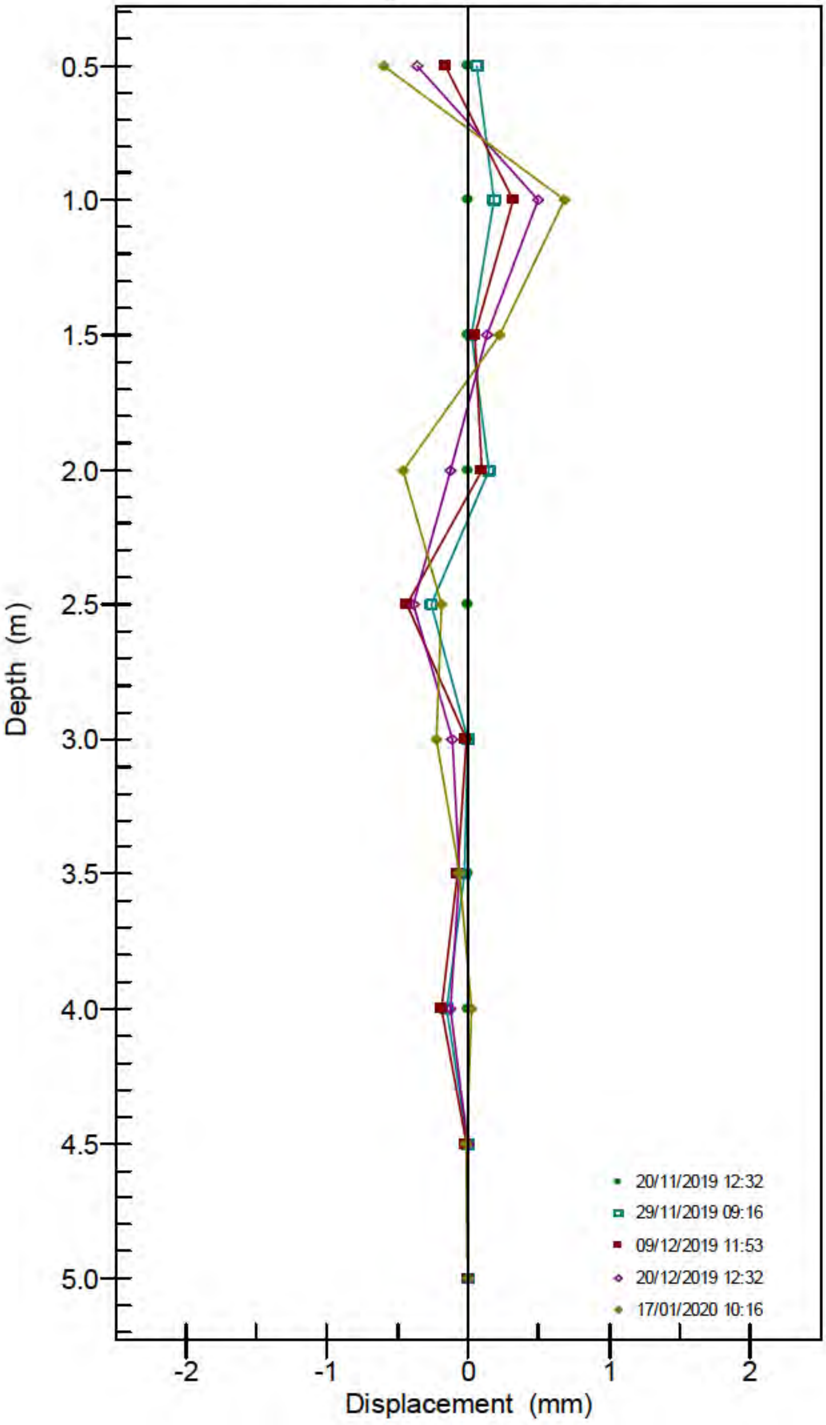


PROJECT:
SITE: 7234e
INSTALLATION: BH01
COMPANY:
CLIENT:

NOTE:

7234e:BH01 - B Axis Incremental

Initial survey: 20/11/2019 12:32

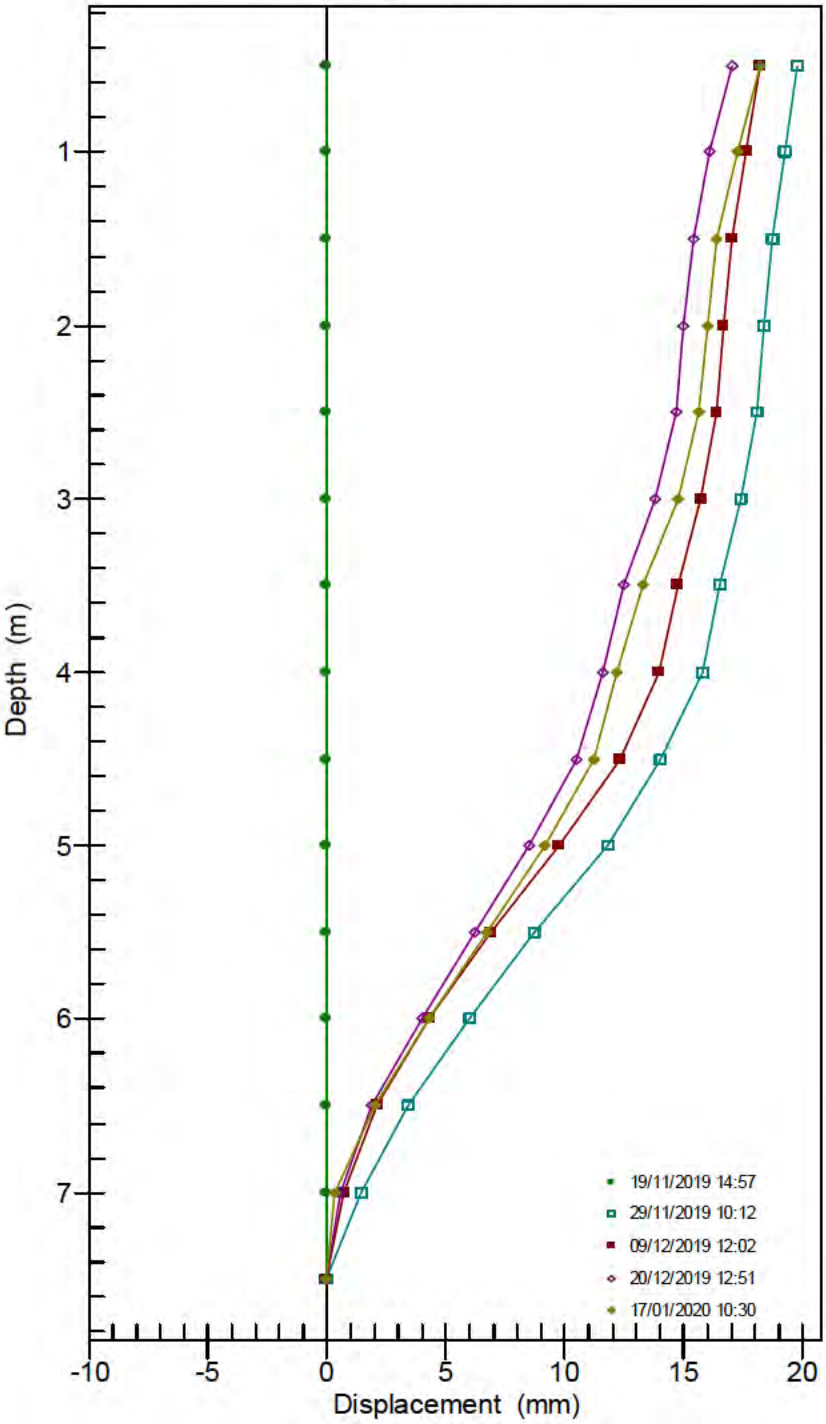


PROJECT:
SITE: 7234e
INSTALLATION: BH01
COMPANY:
CLIENT:

NOTE:

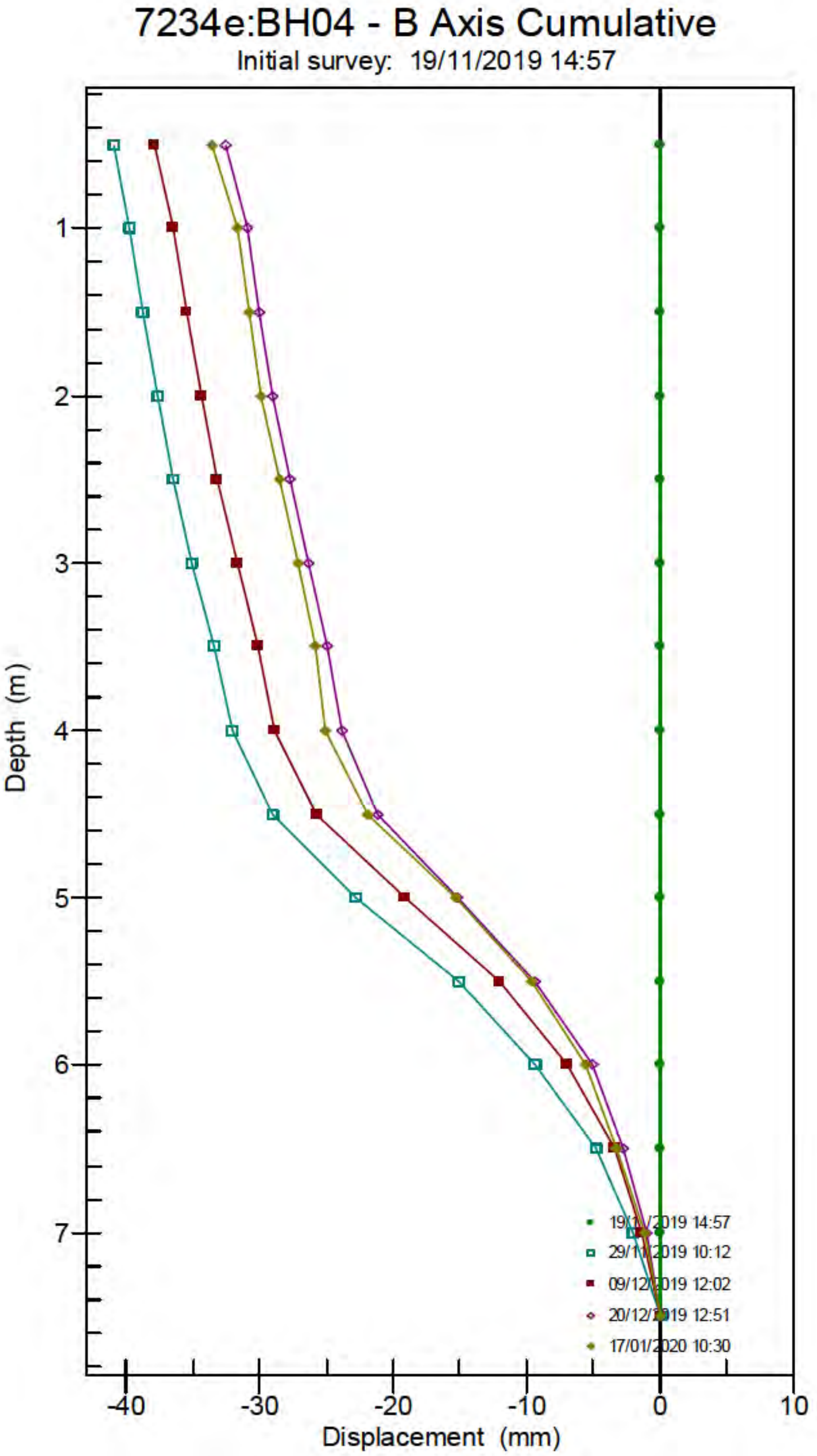
7234e:BH04 - A Axis Cumulative

Initial survey: 19/11/2019 14:57



PROJECT:
SITE: 7234e
INSTALLATION: BH04
COMPANY:
CLIENT:

NOTE:

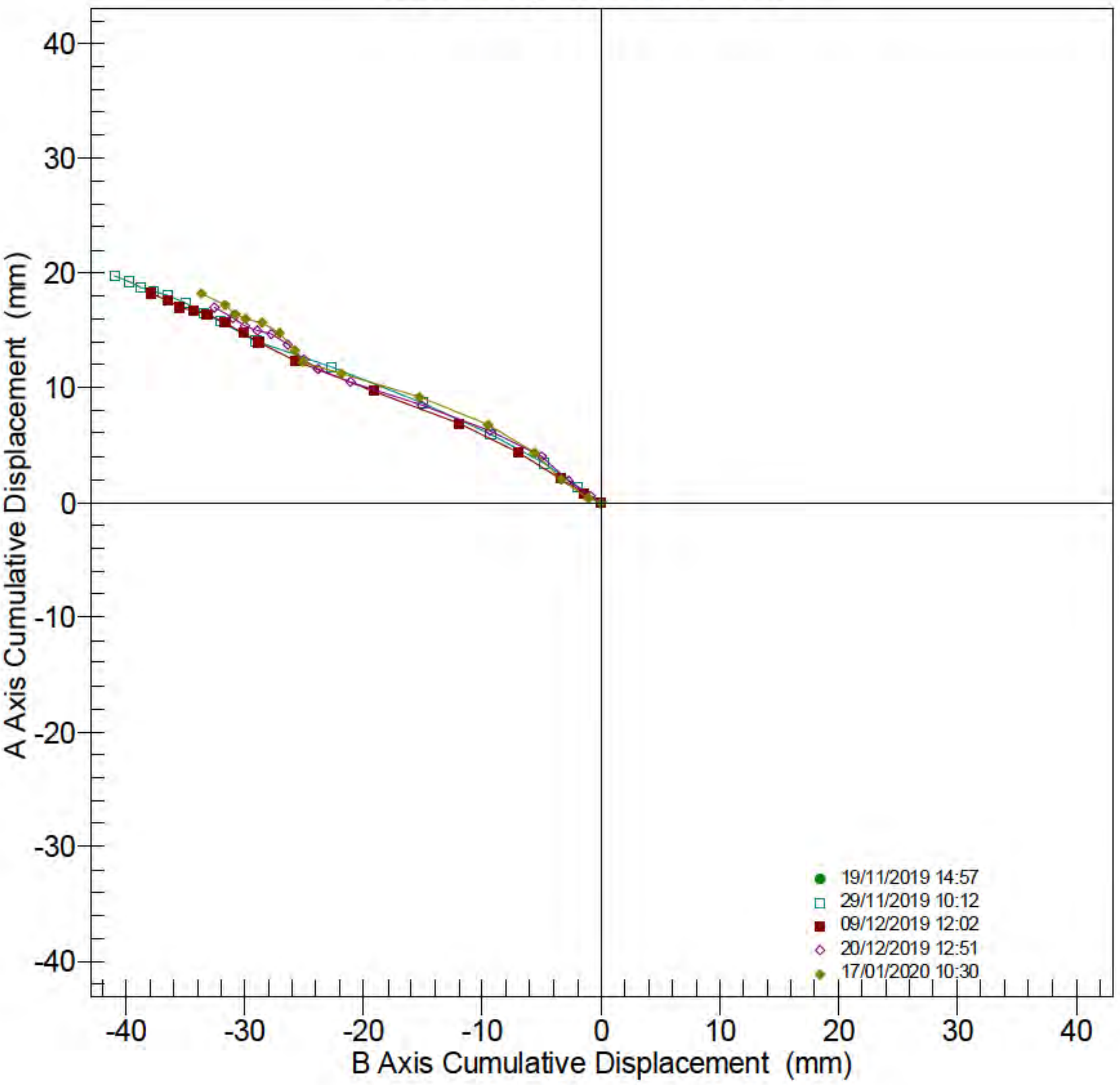


PROJECT:
SITE: 7234e
INSTALLATION: BH04
COMPANY:
CLIENT:

NOTE:

7234e:BH04 - A Axis vs B Axis

Initial survey: 19/11/2019 14:57

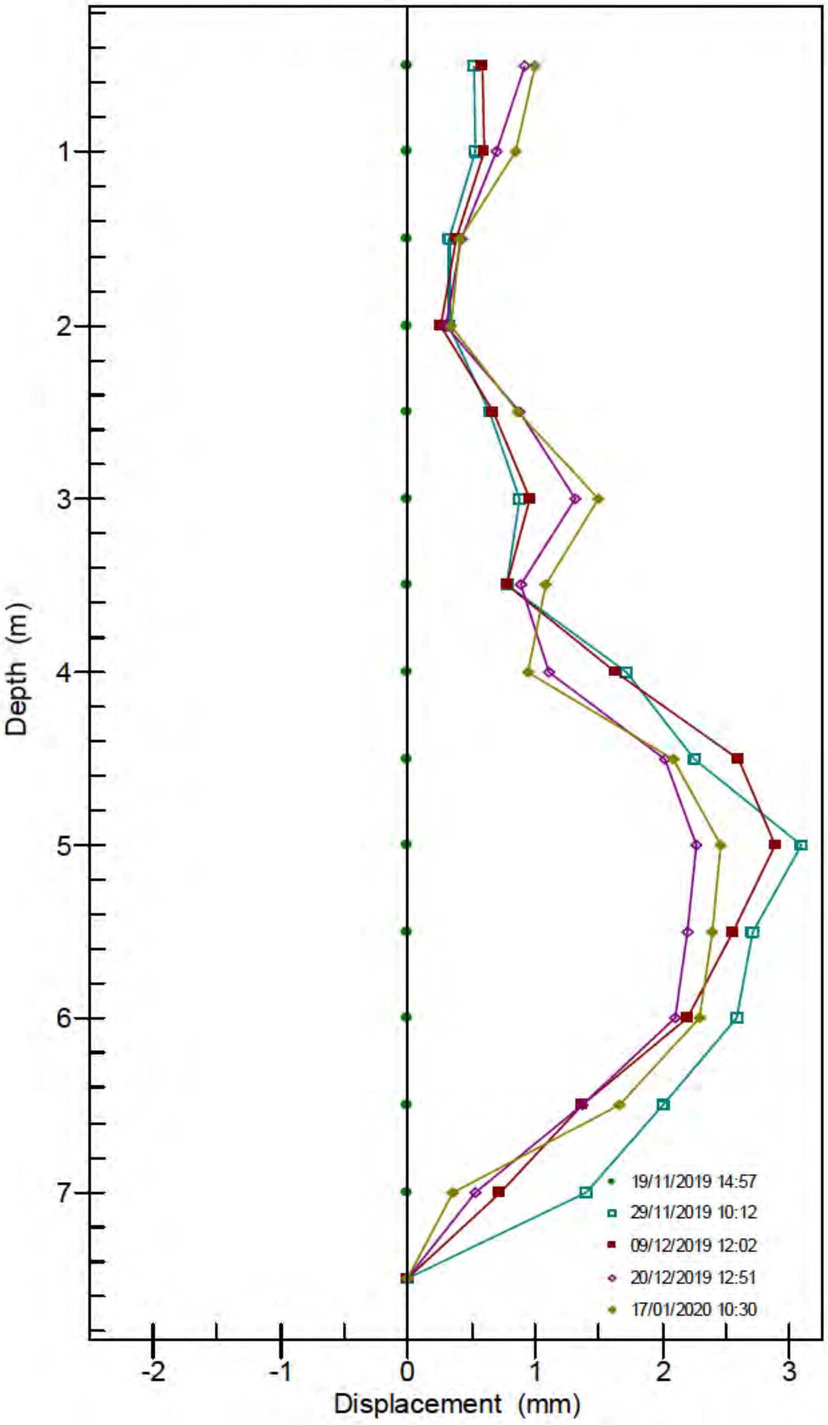


PROJECT:
SITE: 7234e
INSTALLATION: BH04
COMPANY:
CLIENT:

NOTE:

7234e:BH04 - A Axis Incremental

Initial survey: 19/11/2019 14:57

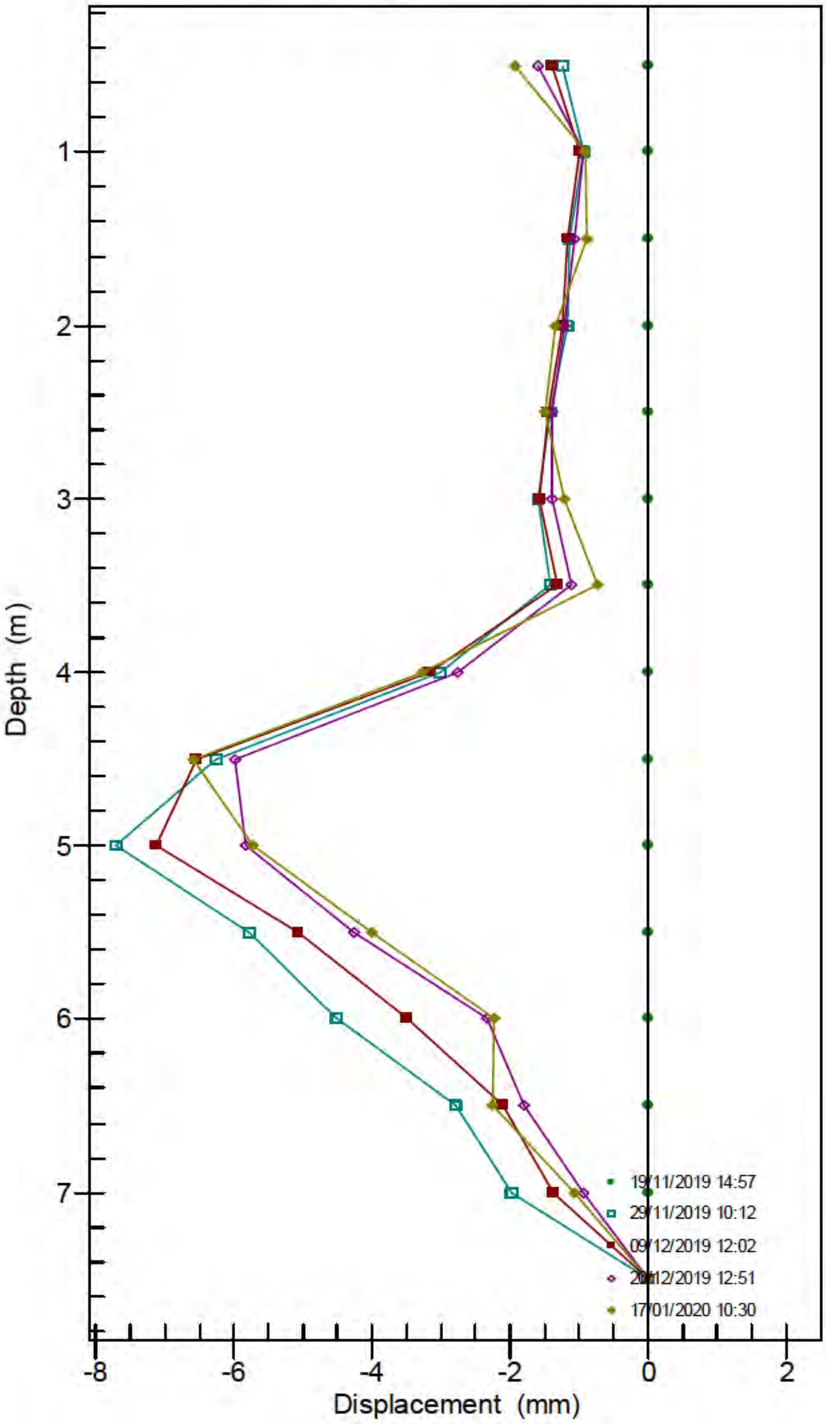


PROJECT:
SITE: 7234e
INSTALLATION: BH04
COMPANY:
CLIENT:

NOTE:

7234e:BH04 - B Axis Incremental

Initial survey: 19/11/2019 14:57

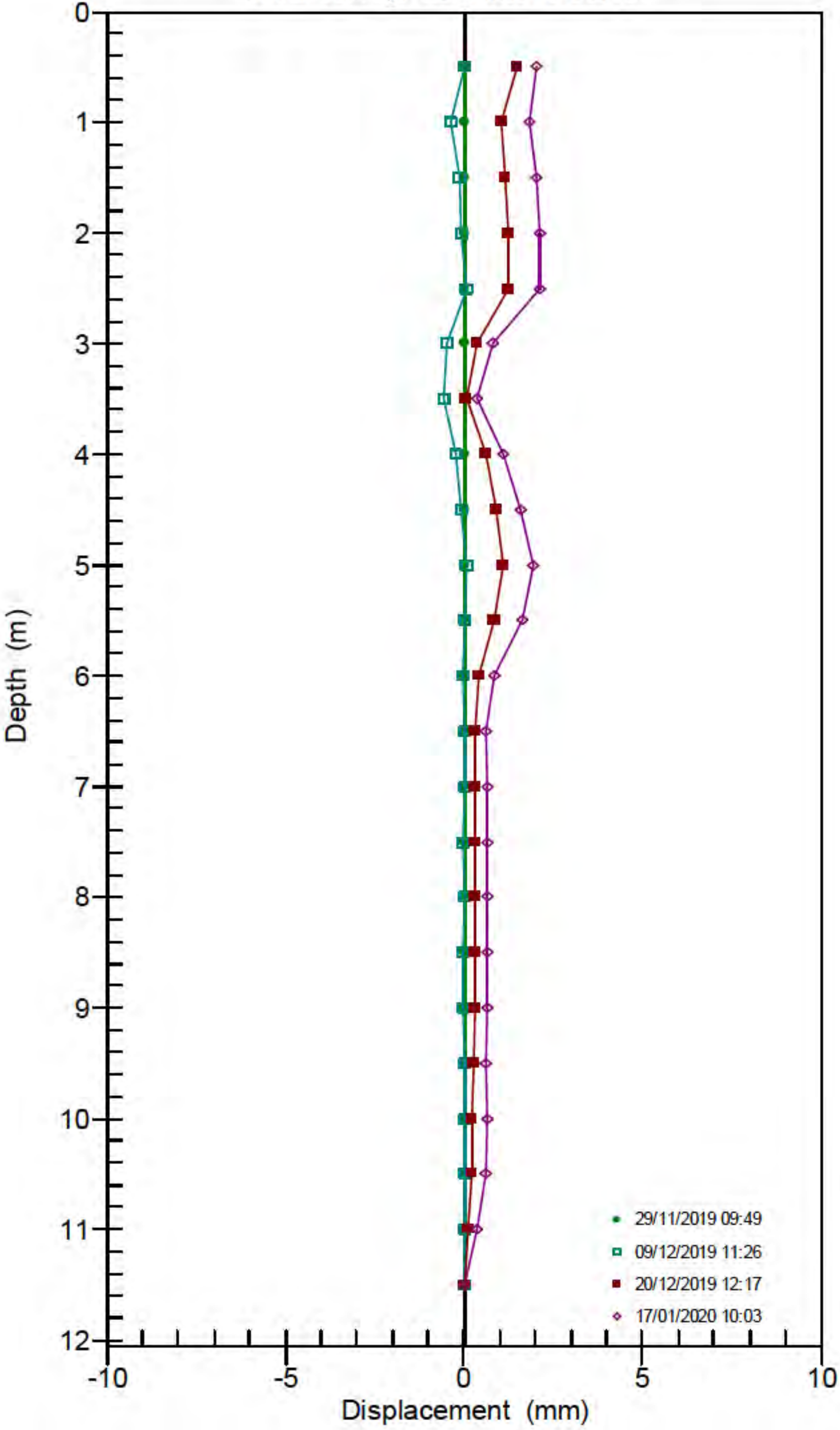


PROJECT:
SITE: 7234e
INSTALLATION: BH04
COMPANY:
CLIENT:

NOTE:

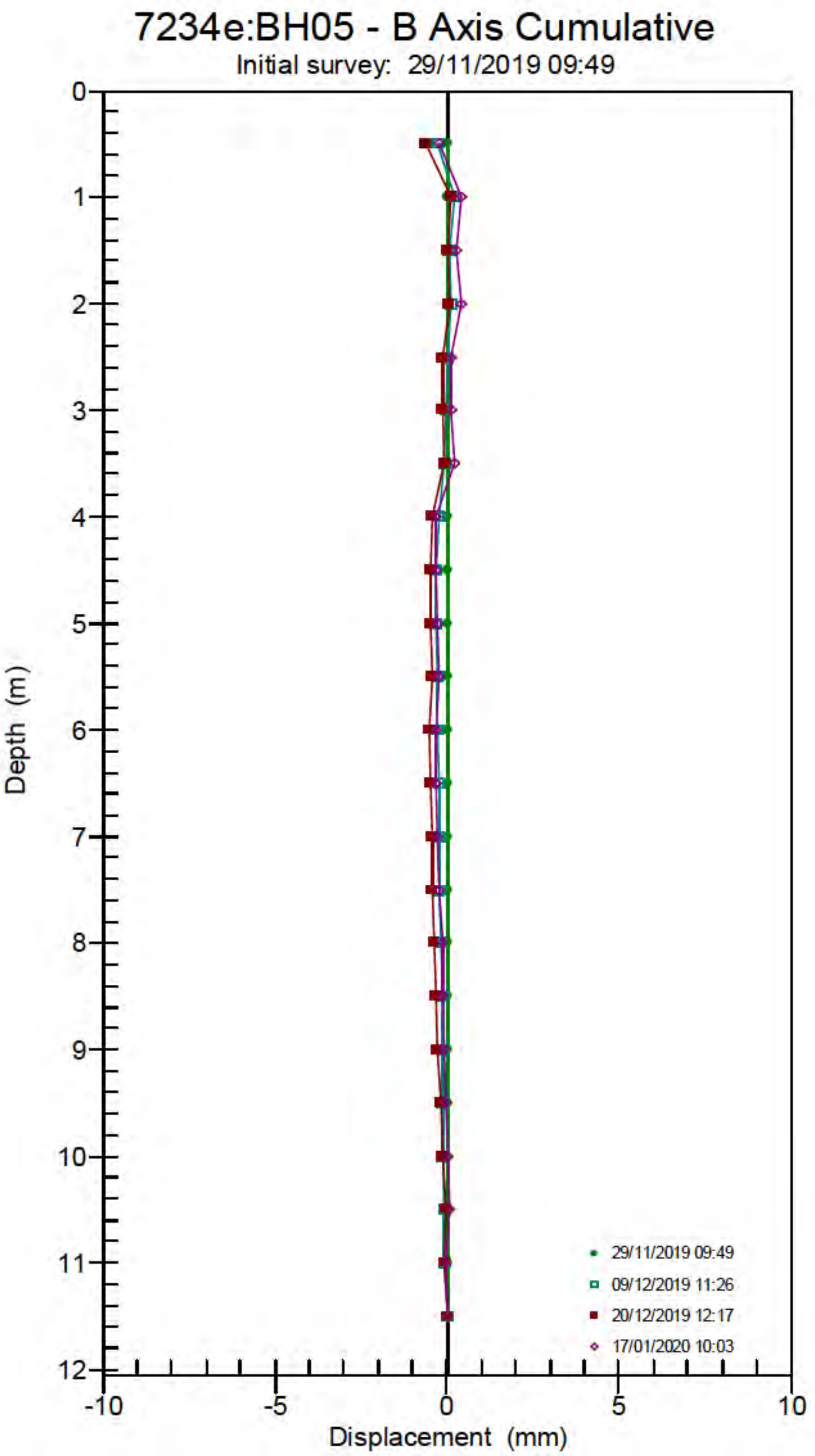
7234e:BH05 - A Axis Cumulative

Initial survey: 29/11/2019 09:49



PROJECT:
SITE: 7234e
INSTALLATION: BH05
COMPANY:
CLIENT:

NOTE:

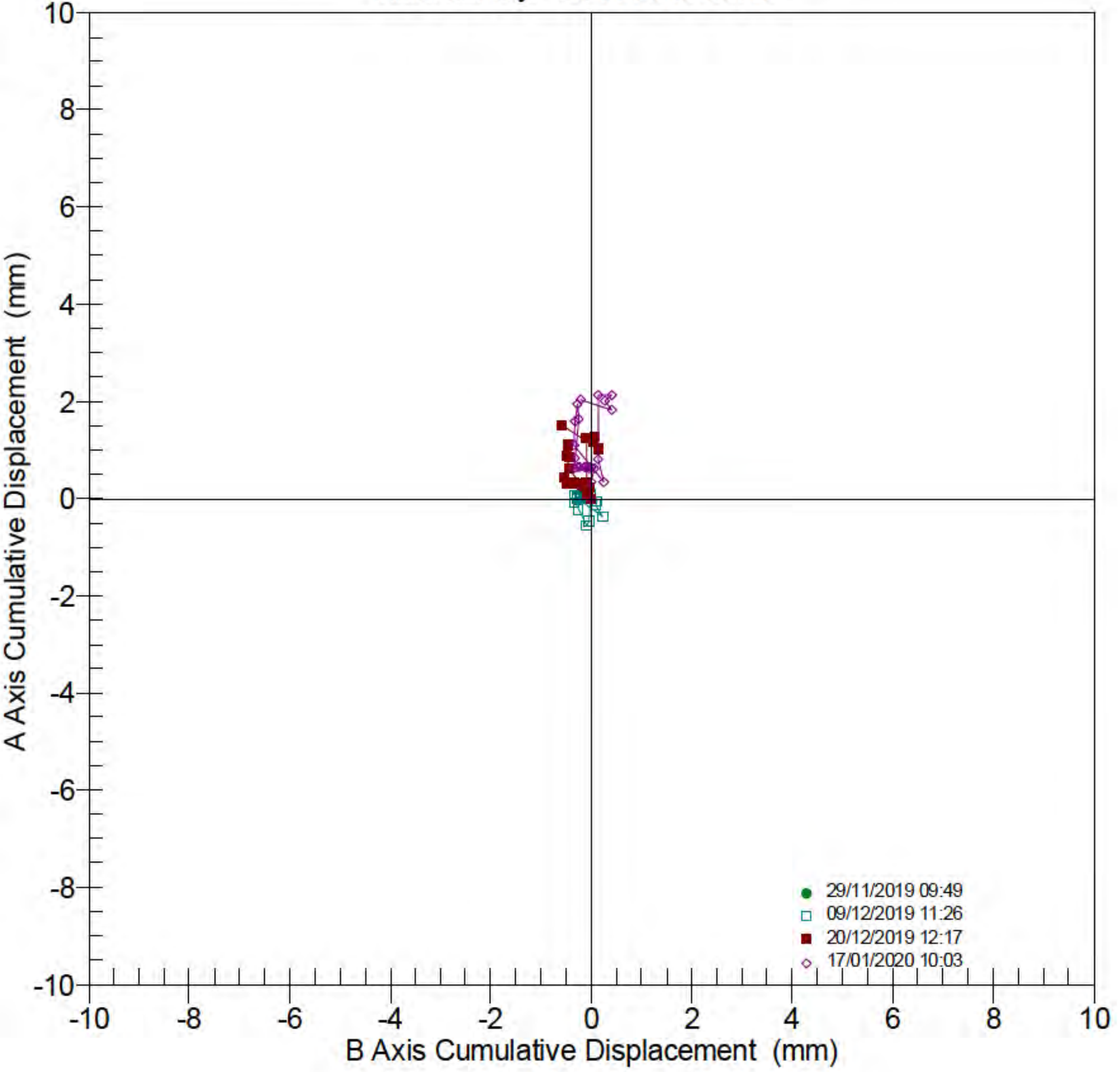


PROJECT:
SITE: 7234e
INSTALLATION: BH05
COMPANY:
CLIENT:

NOTE:

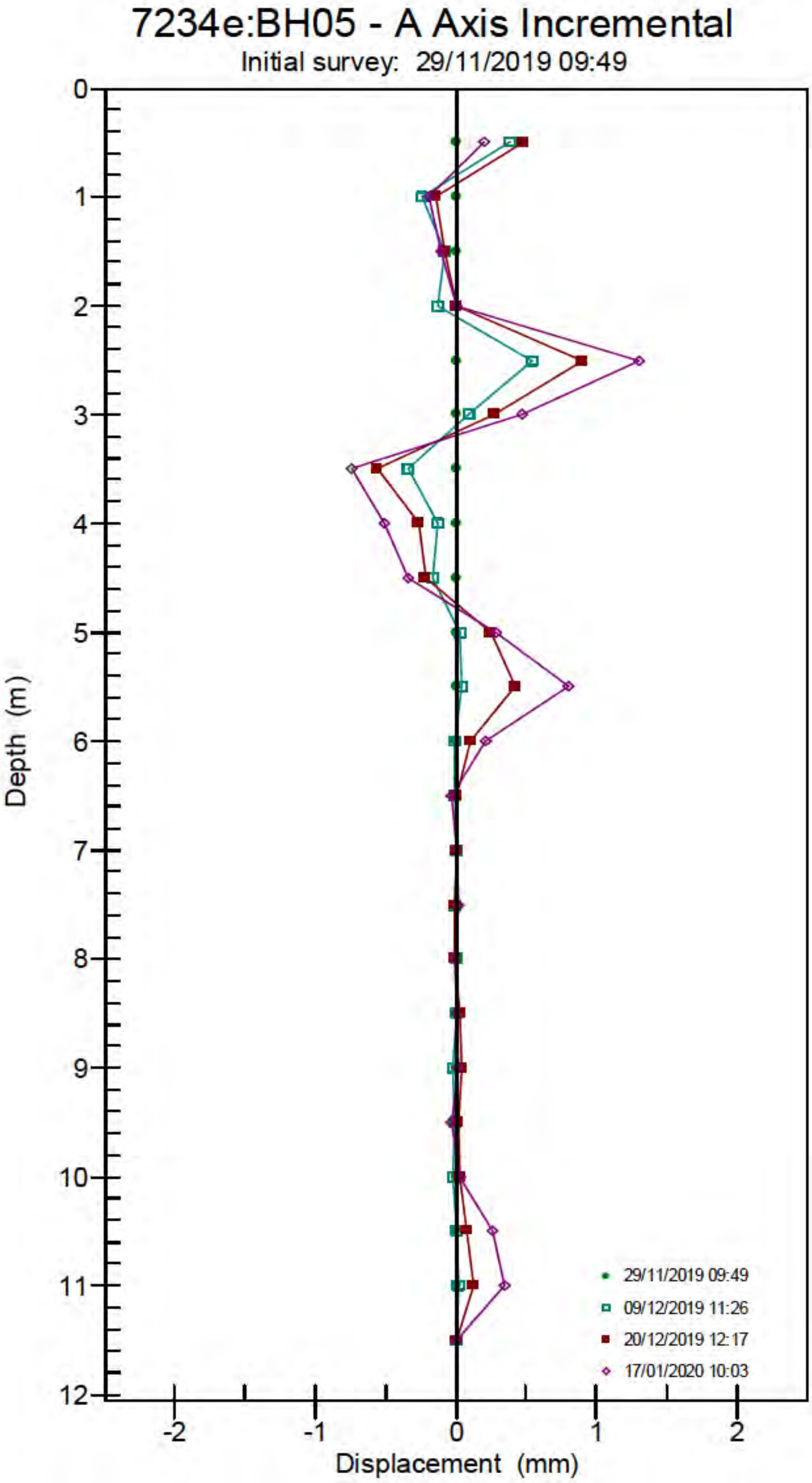
7234e:BH05 - A Axis vs B Axis

Initial survey: 29/11/2019 09:49



PROJECT:
SITE: 7234e
INSTALLATION: BH05
COMPANY:
CLIENT:

NOTE:

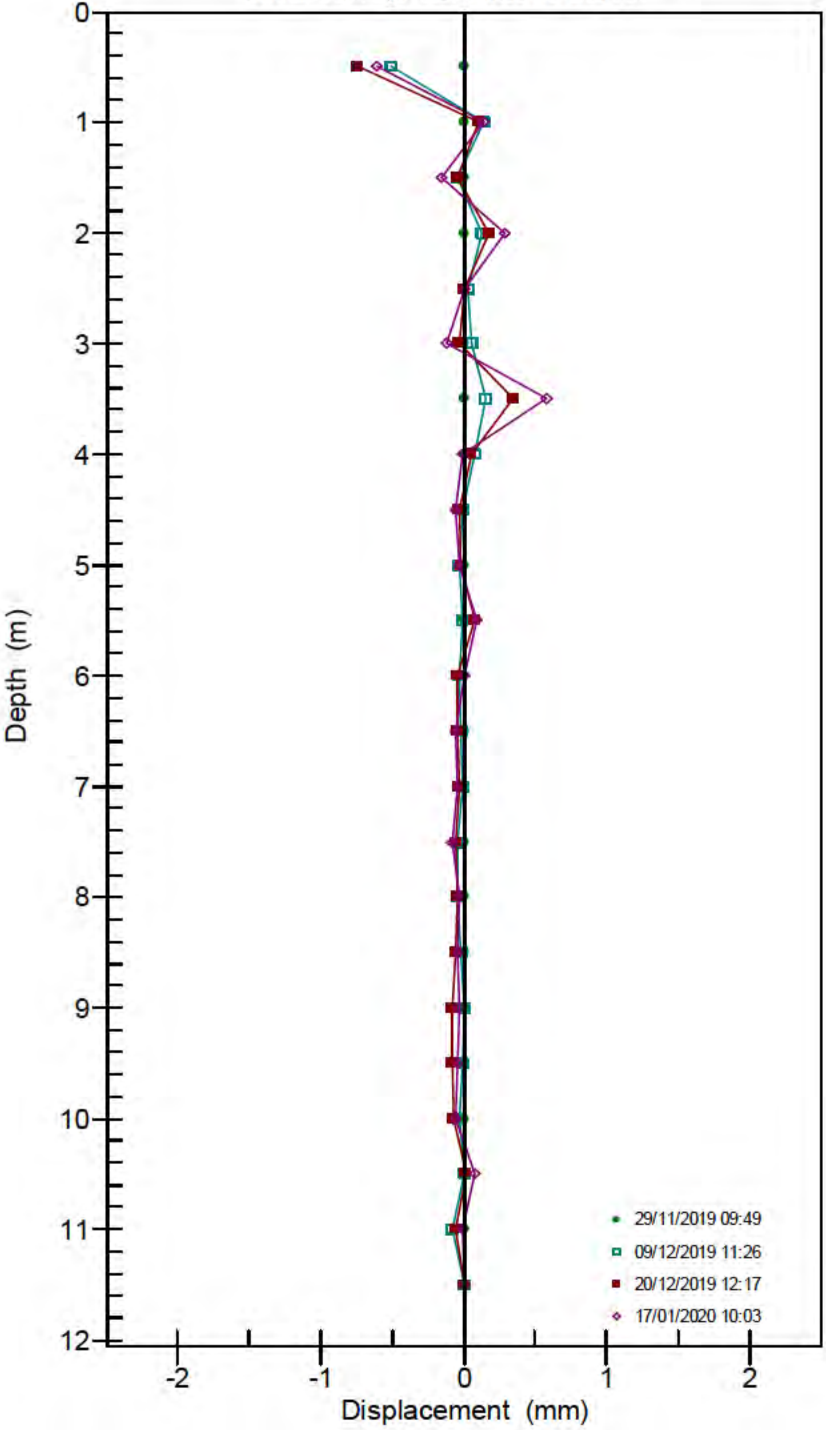


PROJECT:
SITE: 7234e
INSTALLATION: BH05
COMPANY:
CLIENT:

NOTE:

7234e:BH05 - B Axis Incremental

Initial survey: 29/11/2019 09:49



PROJECT:
SITE: 7234e
INSTALLATION: BH05
COMPANY:
CLIENT:

NOTE:

APPENDIX J GEOTECHNICAL LABORATORY TEST RESULTS

2788

Laboratory Report

GEO Site & Testing Services Ltd

Contract Number: 46217

Client Ref: **7234e.02**

Client PO: **8500**

Report Date: **12-11-2019**

Client **Earth Science Partnership**
33 Cardiff Road
Taff's Well
Cardiff
CF15 7RB

Contract Title: **Godre'r Graig**

For the attention of: **Matthew Eynon**

Date Received: **22-10-2019**

Date Completed: **12-11-2019**

Test Description	Qty
Moisture Content BS 1377:1990 - Part 2 : 3.2 - * UKAS	1
4 Point Liquid & Plastic Limit BS 1377:1990 - Part 2 : 4.3 & 5.3 - * UKAS	1
PSD Wet Sieve method BS 1377:1990 - Part 2 : 9.2 - * UKAS	14
PSD: Sedimentation by pipette carried out with Wet Sieve (Wet Sieve must also be selected) BS 1377:1990 - Part 2 : 9.4 - * UKAS	3
Large Shear Box 300mm Peak with 3 confining pressures includes remoulding BS 1377:1990 - Part 7 : 5 and Specification for Highway Works Vol.1 Clause 636 Part 2 - @ Non Accredited Test	6
Disposal of samples for job	1

Notes: **Observations and Interpretations are outside the UKAS Accreditation**
*** - denotes test included in laboratory scope of accreditation**
 # - denotes test carried out by approved contractor
@ - denotes non accredited tests

This certificate is issued in accordance with the accreditation requirements of the United Kingdom Accreditation Service. The results reported herein relate only to the material supplied to the laboratory. This certificate shall not be reproduced except in full, without the prior written approval of the laboratory.

Approved Signatories:
Emma Sharp (Office Manager) - Paul Evans (Quality/Technical Manager) - Richard John (Advanced Testing Manager)
Sean Penn (Administrative/Accounts Assistant) - Shaun Jones (Laboratory manager) - Wayne Honey (Administrative/Quality Assistant)

GSTL

NATURAL MOISTURE, LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX
(BS 1377 : Part 2 : 1990 Method 5)

Contract Number	**46217**
Site Name	**Godre'r Graig**
Date Tested	**01/11/2019**
	DESCRIPTIONS

Sample/Hole Reference	Sample Number	Sample Type	Depth (m)			Descriptions
TP104			2.50	-		Grey fine sandy silty CLAY.
				-		
				-		
				-		
				-		
				-		
				-		
				-		
				-		
				-		
				-		
				-		
				-		
				-		
				-		
				-		
				-		
				-		
				-		
				-		
				-		
				-		
				-		
				-		

Operators	Checked	12/11/2019	Wayne Honey (Administrative/Quality Assistant)
Dean Smith	Approved	12/11/2019	Paul Evans (Quality/Technical Manager)

UKAS TESTING
2788

GSTL

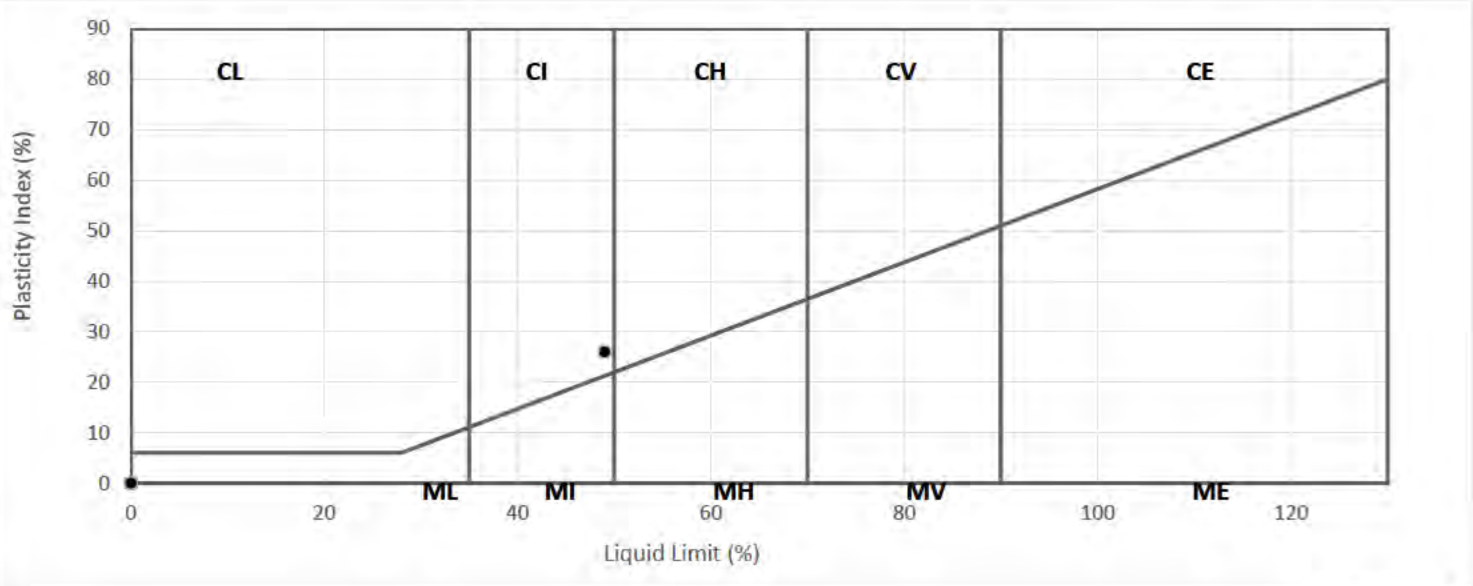
NATURAL MOISTURE, LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX
(BS 1377 : Part 2 : 1990 Method 5)

Contract Number	**46217**
Project Location	**Godre'r Graig**
Date Tested	**01/11/2019**

Sample/Hole Reference	Sample Number	Sample Type	Depth (m)			Moisture Content %	Liquid Limit %	Plastic Limit %	Plasticity index %	Passing 0.425mm %	Remarks
TP104			2.50	-		32	49	23	26	100	CI Intermediate Plasticity
				-							
				-							
				-							
				-							
				-							
				-							
				-							
				-							
				-							
				-							
				-							
				-							
				-							
				-							
				-							
				-							
				-							
				-							
				-							
				-							
				-							
				-							
				-							

Symbols: NP : Non Plastic # : Liquid Limit and Plastic Limit Wet Sieved

PLASTICITY CHART FOR CASAGRANDE CLASSIFICATION
BS 5930:1999+A2:2010



Operators	Checked	12/11/2019	Wayne Honey (Administrative/Quality Assistant)
Dean Smith	Approved	12/11/2019	Paul Evans (Quality/Technical Manager)

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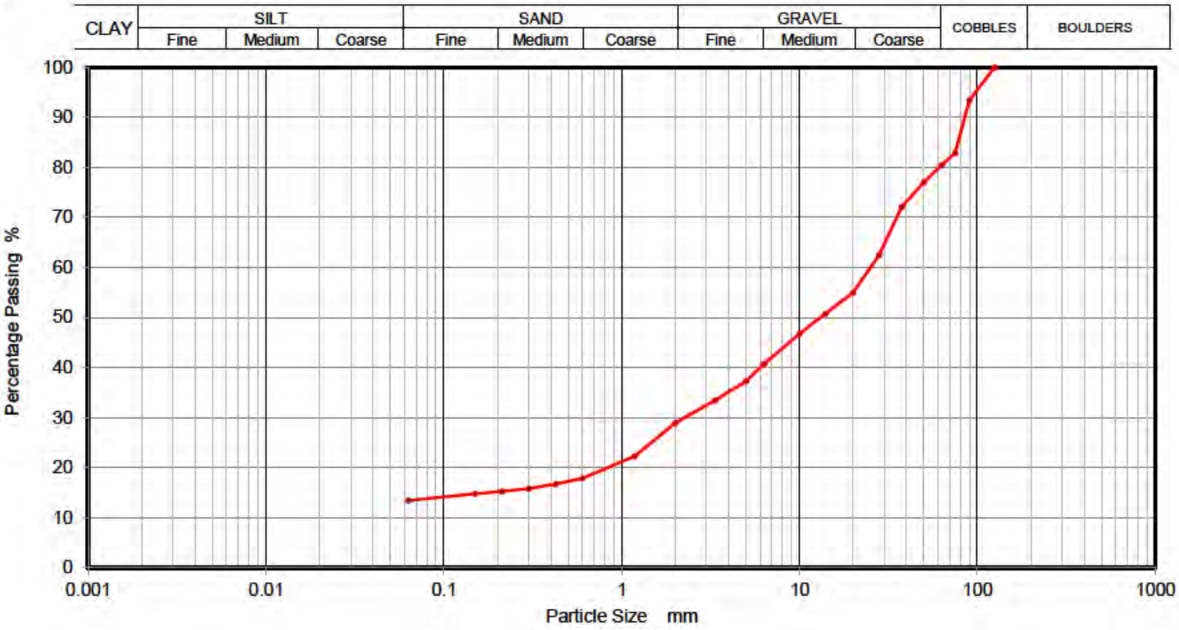
GSTL

PARTICLE SIZE DISTRIBUTION
BS 1377 Part 2:1990
Wet Sieve, Clause 9.2

		Contract Number	46217
		Borehole/Pit No.	TP101
Site Name	Godre'r Graig	Sample No.	
Soil Description	Brown clayey/silty fine to coarse sandy fine to coarse GRAVEL (with cobbles)	Depth Top	0.60
		Depth Base	
Date Tested	26/11/2019	Sample Type	B



Sieving		Sedimentation	
Particle Size mm	% Passing	Particle Size mm	% Passing
125	100		
90	93		
75	83		
63	80		
50	77		
37.5	72		
28	62		
20	55		
14	51		
10	47		
6.3	41		
5	37		
3.35	33		
2	29		
1.18	22		
0.6	18		
0.425	17		
0.3	16		
0.212	15		
0.15	15		
0.063	13		

Sample Proportions	% dry mass
Cobbles	20
Gravel	51
Sand	16
Silt and Clay	13

Remarks

Preparation and testing in accordance with BS1377 unless noted below

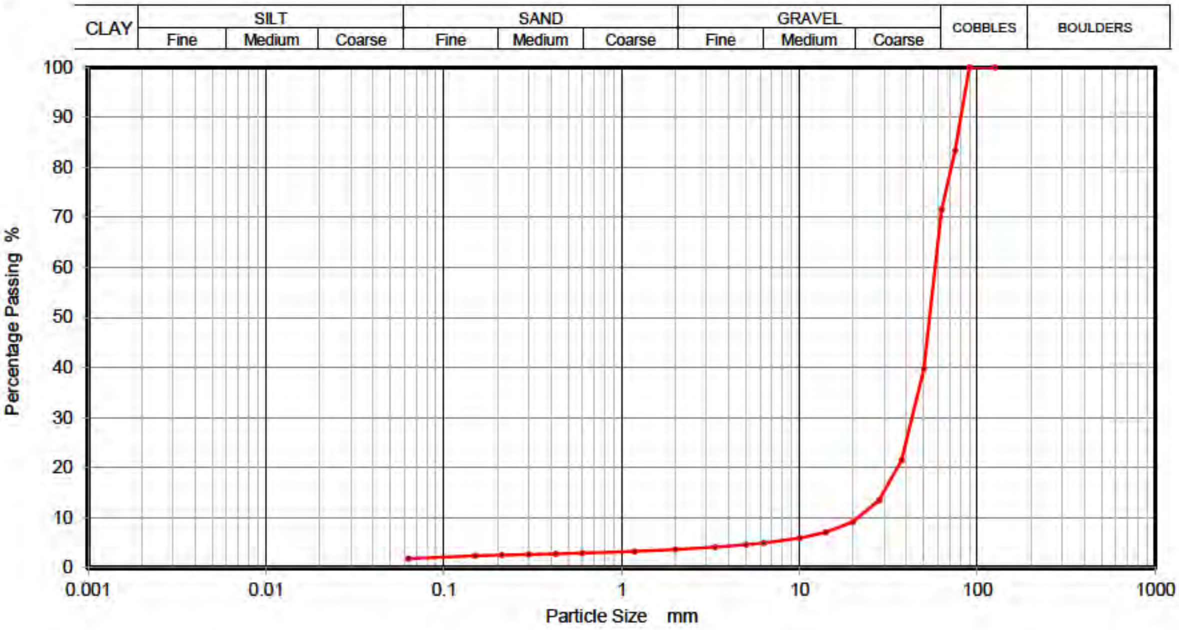
Operators	Checked	27/11/2019	Wayne Honey	W. Honey
RO/MH	Approved	28/11/2019	Paul Evans	P Evans

UKAS TESTING 2788

GSTL

PARTICLE SIZE DISTRIBUTION
BS 1377 Part 2:1990
Wet Sieve, Clause 9.2

		Contract Number	46217
		Borehole/Pit No.	TP101
Site Name	**Godre'r Graig**	Sample No.	
Soil Description	Brown slightly clayey/silty slightly fine to coarse sandy fine to coarse GRAVEL (with cobbles)	Depth Top	1.00
		Depth Base	
Date Tested	25/11/2019	Sample Type	B



Sieving		Sedimentation	
Particle Size mm	% Passing	Particle Size mm	% Passing
125	100		
90	100		
75	83		
63	72		
50	40		
37.5	22		
28	13		
20	9		
14	7		
10	6		
6.3	5		
5	5		
3.35	4		
2	4		
1.18	3		
0.6	3		
0.425	3		
0.3	3		
0.212	3		
0.15	2		
0.063	2		

Sample Proportions	% dry mass
Cobbles	28
Gravel	68
Sand	2
Silt and Clay	2

Remarks

Preparation and testing in accordance with BS1377 unless noted below

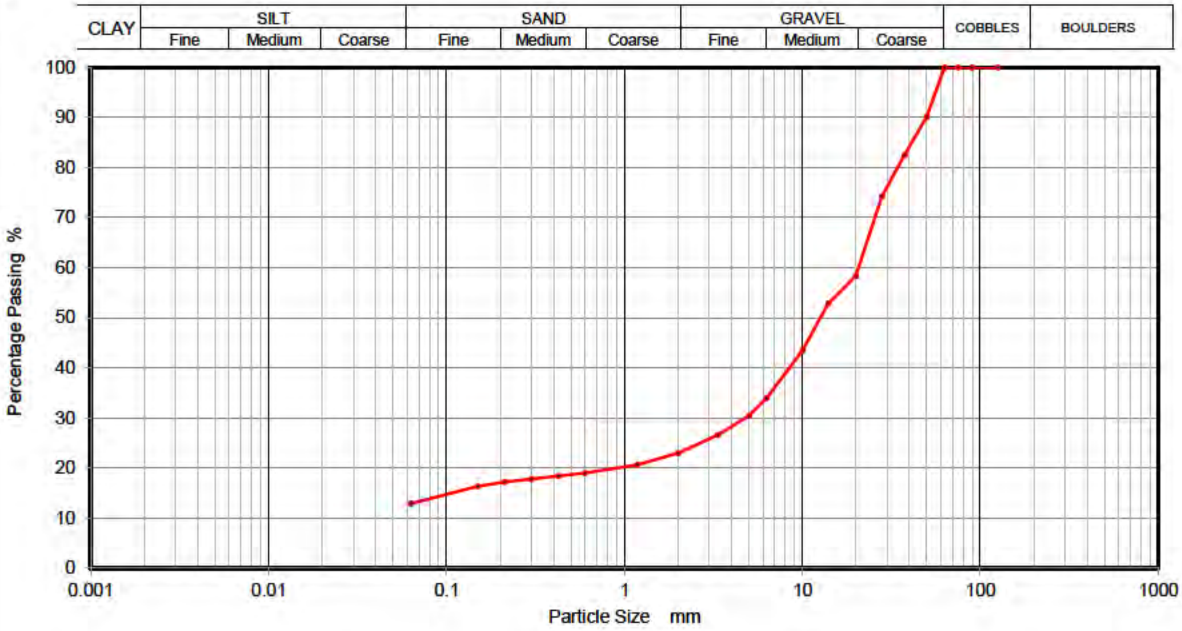
Operators	Checked	27/11/2019	Wayne Honey	W. Honey
RO/MH	Approved	28/11/2019	Paul Evans	DP Evans

UKAS TESTING 2788

GSTL

PARTICLE SIZE DISTRIBUTION
BS 1377 Part 2:1990
Wet Sieve, Clause 9.2

Contract Number	46217		
Borehole/Pit No.	TP101		
Site Name	Godre'r Graig	Sample No.	
Soil Description	Brown fine to coarse sandy clayey/silty fine to coarse GRAVEL	Depth Top	2.90
		Depth Base	
Date Tested	25/11/2019	Sample Type	B



Sieving		Sedimentation	
Particle Size mm	% Passing	Particle Size mm	% Passing
125	100		
90	100		
75	100		
63	100		
50	90		
37.5	82		
28	74		
20	58		
14	53		
10	43		
6.3	34		
5	30		
3.35	27		
2	23		
1.18	21		
0.6	19		
0.425	18		
0.3	18		
0.212	17		
0.15	16		
0.063	13		

Sample Proportions	% dry mass
Cobbles	0
Gravel	77
Sand	10
Silt and Clay	13

Remarks

Preparation and testing in accordance with BS1377 unless noted below

Operators	Checked	27/11/2019	Wayne Honey	W. Honey
RO/MH	Approved	28/11/2019	Paul Evans	D P Evans

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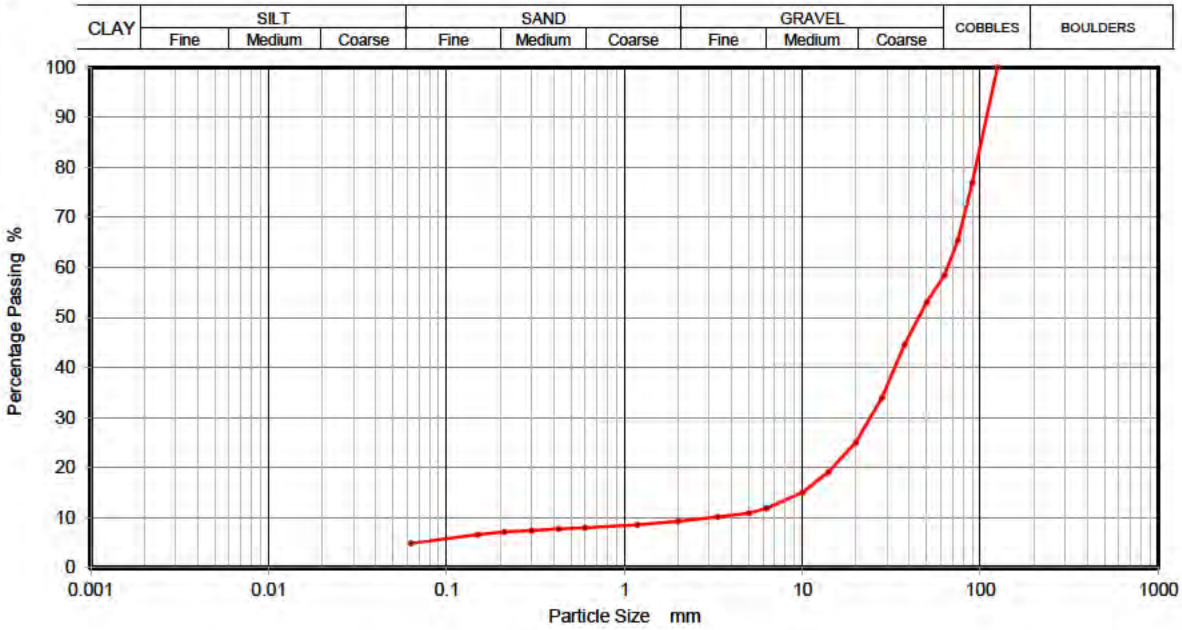
GSTL	**PARTICLE SIZE DISTRIBUTION** **BS 1377 Part 2:1990** **Wet Sieve, Clause 9.2**	Contract Number	**46217**
		Borehole/Pit No.	**TP102**
Site Name	**Godre'r Graig**	Sample No.	
Soil Description	Brown slightly fine to coarse sandy slightly clayey/silty fine to coarse GRAVEL (with cobbles)	Depth Top	**1.00**
		Depth Base	
Date Tested	25/11/2019	Sample Type	**B**



Sieving		Sedimentation	
Particle Size mm	% Passing	Particle Size mm	% Passing
125	100		
90	77		
75	65		
63	58		
50	53		
37.5	45		
28	34		
20	25		
14	19		
10	15		
6.3	12		
5	11		
3.35	10		
2	9		
1.18	9		
0.6	8		
0.425	8		
0.3	7		
0.212	7		
0.15	7		
0.063	5		

Sample Proportions	% dry mass
Cobbles	42
Gravel	49
Sand	4
Silt and Clay	5

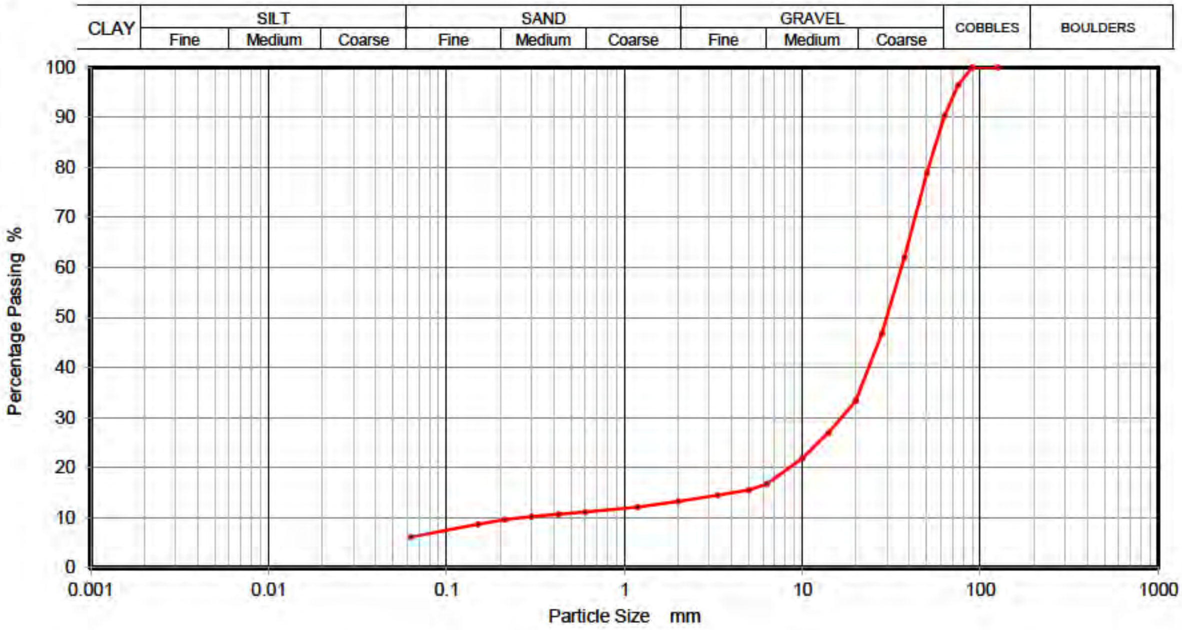
Remarks

Preparation and testing in accordance with BS1377 unless noted below

Operators	Checked	27/11/2019	Wayne Honey	W. Honey
RO/MH	Approved	28/11/2019	Paul Evans	P Evans

UKAS TESTING 2788

GSTL	**PARTICLE SIZE DISTRIBUTION** **BS 1377 Part 2:1990** **Wet Sieve, Clause 9.2**	Contract Number	**46217**
		Borehole/Pit No.	**TP102**
Site Name	**Godre'r Graig**	Sample No.	
Soil Description	Brown slightly clayey/silty slightly fine to coarse sandy fine to coarse GRAVEL (with cobbles)	Depth Top	**2.00**
		Depth Base	
Date Tested	25/11/2019	Sample Type	**B**



Sieving		**Sedimentation**	
Particle Size mm	% Passing	Particle Size mm	% Passing
125	100		
90	100		
75	96		
63	90		
50	79		
37.5	62		
28	47		
20	33		
14	27		
10	22		
6.3	17		
5	16		
3.35	15		
2	13		
1.18	12		
0.6	11		
0.425	11		
0.3	10		
0.212	10		
0.15	9		
0.063	6		

Sample Proportions	% dry mass
Cobbles	10
Gravel	77
Sand	7
Silt and Clay	6

Remarks

Preparation and testing in accordance with BS1377 unless noted below

Operators	Checked	27/11/2019	Wayne Honey	W. Honey
RO/MH	Approved	28/11/2019	Paul Evans	P Evans

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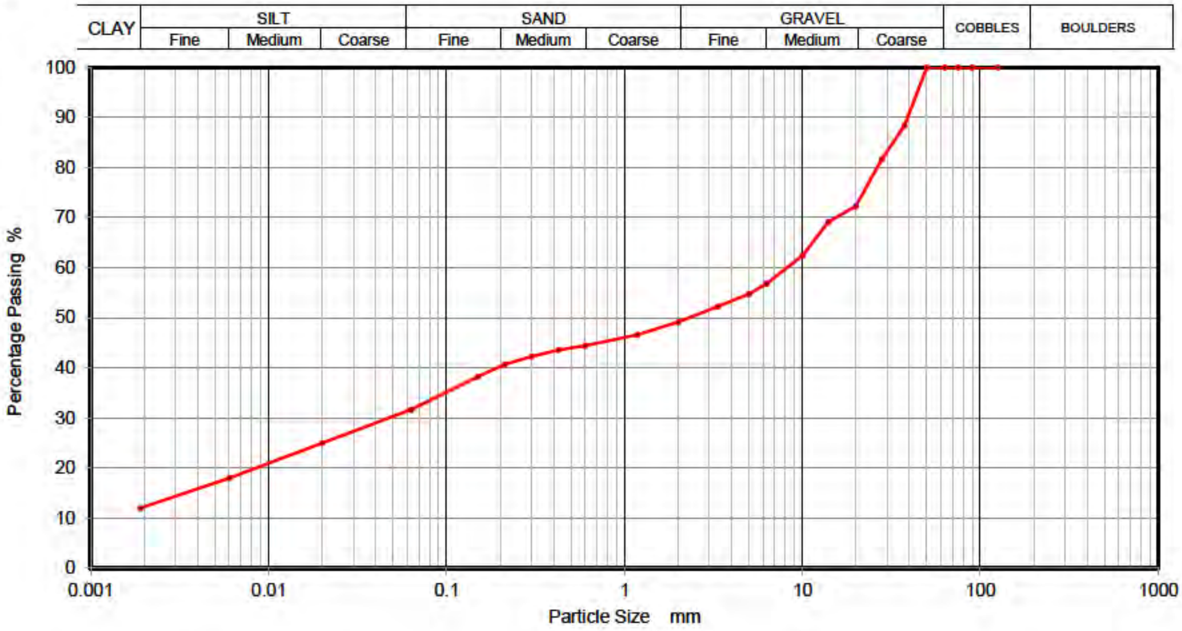
GSTL	**PARTICLE SIZE DISTRIBUTION** **BS 1377 Part 2:1990** **Wet Sieve & Pipette Analysis, Clause 9.2 & 9.4**	Contract Number	**46217**
		Borehole/Pit No.	**TP102**
Site Name	**Godre'r Graig**	Sample No.	
Soil Description	Brown clayey fine to coarse sandy silty fine to coarse GRAVEL	Depth Top	**2.60**
		Depth Base	
Date Tested	26/11/2019	Sample Type	**B**



Sieving		Sedimentation	
Particle Size mm	% Passing	Particle Size mm	% Passing
125	100	0.0200	25
90	100	0.0060	18
75	100	0.0020	12
63	100		
50	100		
37.5	88		
28	82		
20	72		
14	69		
10	62		
6.3	57		
5	55		
3.35	52		
2	49		
1.18	47		
0.6	44		
0.425	44		
0.3	42		
0.212	41		
0.15	38		
0.063	32		

Sample Proportions	% dry mass
Cobbles	0
Gravel	51
Sand	17
Silt	20
Clay	12

Remarks

Preparation and testing in accordance with BS1377 unless noted below

Operators	Checked	27/11/2019	Wayne Honey	W. Honey
RO/MH	Approved	28/11/2019	Paul Evans	P Evans

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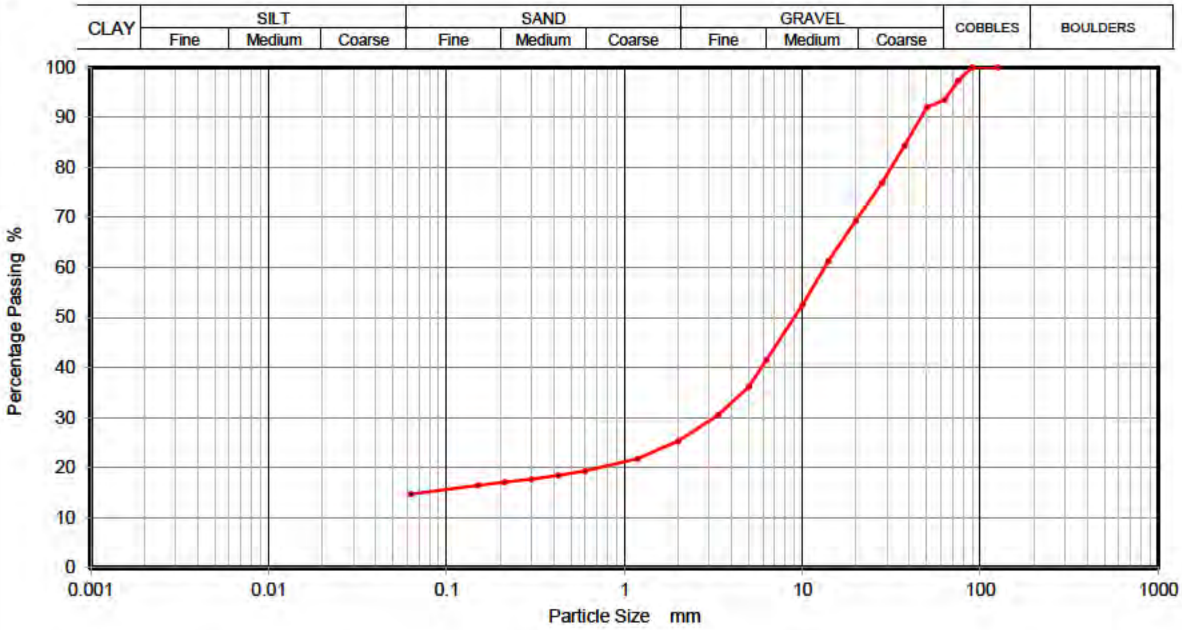
GSTL

PARTICLE SIZE DISTRIBUTION
BS 1377 Part 2:1990
Wet Sieve, Clause 9.2

		Contract Number	46217
		Borehole/Pit No.	TP102
Site Name	Godre'r Graig	Sample No.	
Soil Description	Brown fine to coarse sandy clayey/silty fine to coarse GRAVEL (with cobbles)	Depth Top	2.90
		Depth Base	
Date Tested	26/11/2019	Sample Type	B



Sieving		Sedimentation	
Particle Size mm	% Passing	Particle Size mm	% Passing
125	100		
90	100		
75	97		
63	93		
50	92		
37.5	84		
28	77		
20	69		
14	61		
10	53		
6.3	42		
5	36		
3.35	30		
2	25		
1.18	22		
0.6	19		
0.425	18		
0.3	18		
0.212	17		
0.15	16		
0.063	15		

Sample Proportions	% dry mass
Cobbles	7
Gravel	68
Sand	10
Silt and Clay	15

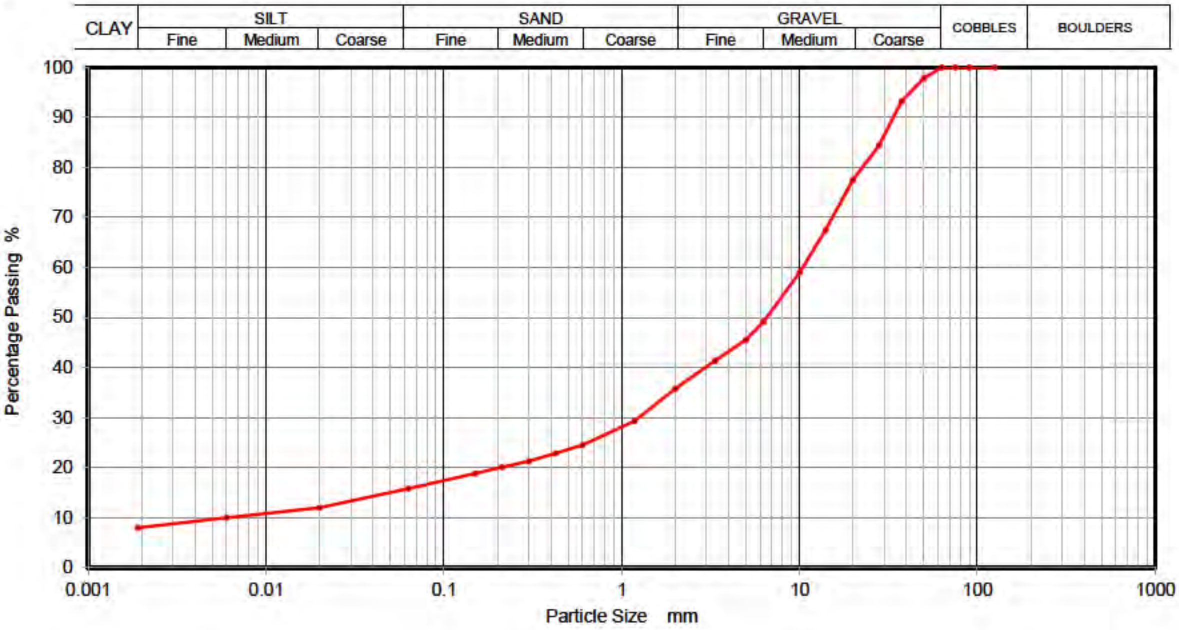
Remarks

Preparation and testing in accordance with BS1377 unless noted below

Operators	Checked	27/11/2019	Wayne Honey	W. Honey
RO/MH	Approved	28/11/2019	Paul Evans	P Evans

UKAS TESTING 2788

GSTL	PARTICLE SIZE DISTRIBUTION BS 1377 Part 2:1990 Wet Sieve & Pipette Analysis, Clause 9.2 & 9.4	Contract Number	46217
		Borehole/Pit No.	TP102
Site Name	Godre'r Graig	Sample No.	
Soil Description	Brown slightly clayey slightly silty fine to coarse sandy fine to coarse GRAVEL	Depth Top	3.80
		Depth Base	
Date Tested	26/11/2019	Sample Type	B



Sieving		Sedimentation	
Particle Size mm	% Passing	Particle Size mm	% Passing
125	100	0.0200	12
90	100	0.0060	10
75	100	0.0020	8
63	100		
50	98		
37.5	93		
28	84		
20	77		
14	67		
10	59		
6.3	49		
5	46		
3.35	41		
2	36		
1.18	29		
0.6	25		
0.425	23		
0.3	21		
0.212	20		
0.15	19		
0.063	16		

Sample Proportions	% dry mass
Cobbles	0
Gravel	64
Sand	20
Silt	8
Clay	8

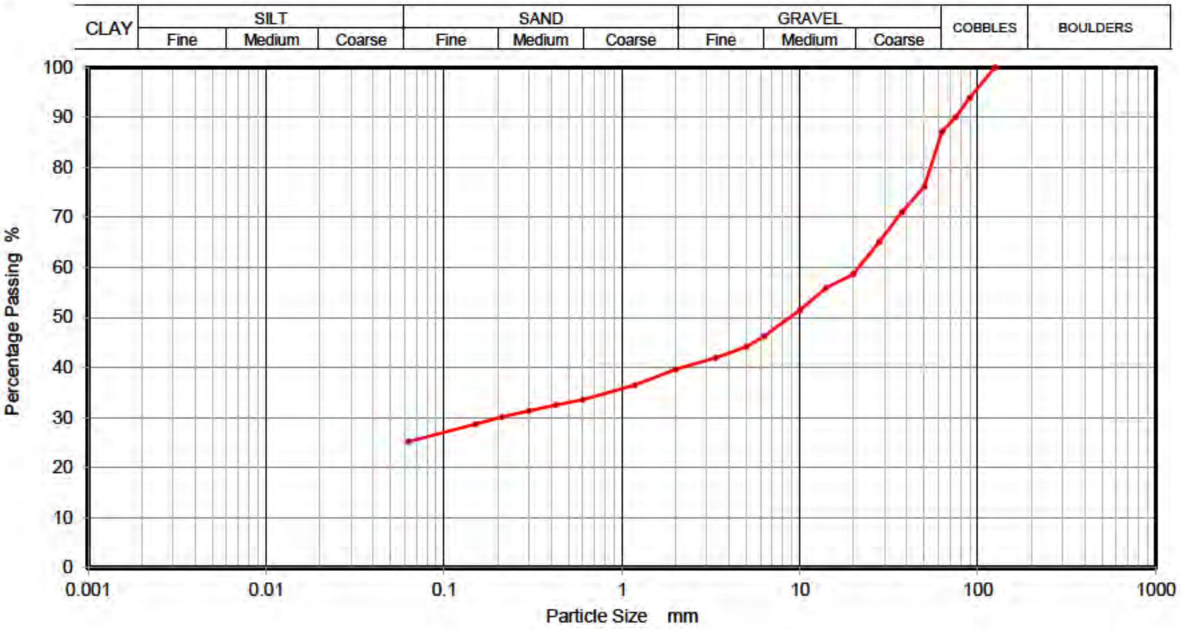
Remarks

Preparation and testing in accordance with BS1377 unless noted below

Operators	Checked	27/11/2019	Wayne Honey	W. Honey
RO/MH	Approved	28/11/2019	Paul Evans	D P Evans

UKAS
TESTING
2788

GSTL	**PARTICLE SIZE DISTRIBUTION** **BS 1377 Part 2:1990** **Wet Sieve, Clause 9.2**	Contract Number	**46217**
		Borehole/Pit No.	**TP103**
Site Name	**Godre'r Graig**	Sample No.	
Soil Description	Brown fine to coarse sandy clayey/silty fine to coarse GRAVEL (with cobbles)	Depth Top	**0.30**
		Depth Base	
Date Tested	26/11/2019	Sample Type	**B**



Sieving		**Sedimentation**	
Particle Size mm	% Passing	Particle Size mm	% Passing
125	100		
90	94		
75	90		
63	87		
50	76		
37.5	71		
28	65		
20	59		
14	56		
10	51		
6.3	46		
5	44		
3.35	42		
2	40		
1.18	37		
0.6	34		
0.425	33		
0.3	31		
0.212	30		
0.15	29		
0.063	25		

Sample Proportions	% dry mass
Cobbles	13
Gravel	47
Sand	15
Silt and Clay	25

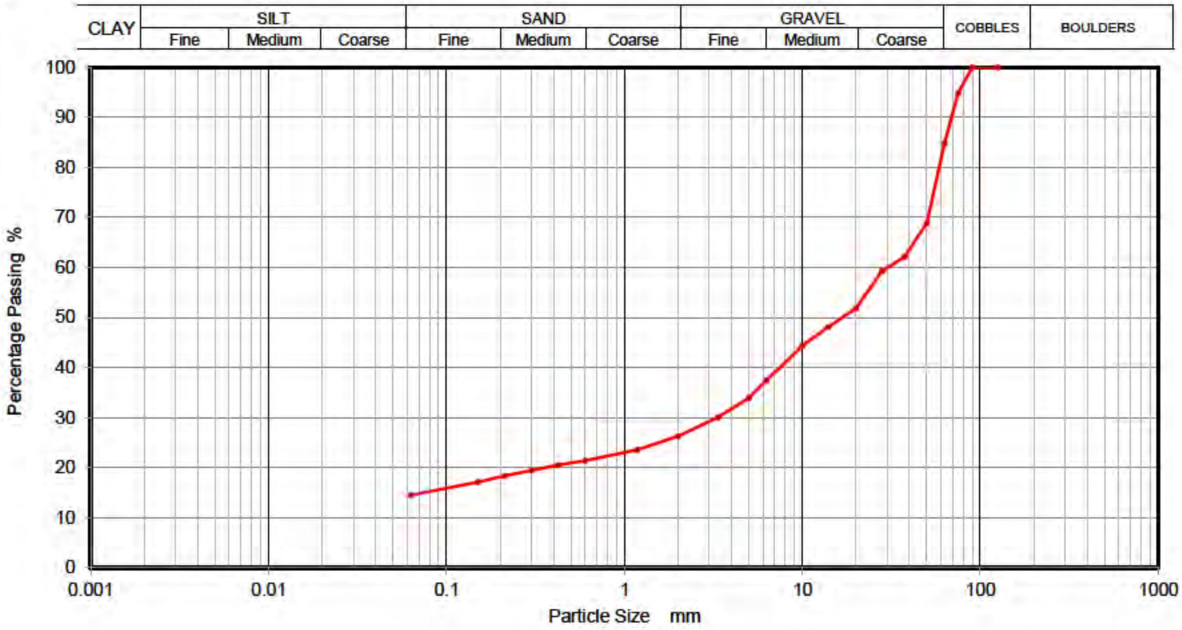
Remarks

Preparation and testing in accordance with BS1377 unless noted below

Operators	Checked	27/11/2019	Wayne Honey	W. Honey
RO/MH	Approved	28/11/2019	Paul Evans	P Evans

UKAS TESTING 2788

GSTL	PARTICLE SIZE DISTRIBUTION BS 1377 Part 2:1990 Wet Sieve, Clause 9.2	Contract Number	46217
		Borehole/Pit No.	TP103
Site Name	**Godre'r Graig**	Sample No.	
Soil Description	Brown fine to coarse sandy clayey/silty fine to coarse GRAVEL (with cobbles)	Depth Top	0.60
		Depth Base	
Date Tested	25/11/2019	Sample Type	B



Sieving		Sedimentation	
Particle Size mm	% Passing	Particle Size mm	% Passing
125	100		
90	100		
75	95		
63	85		
50	69		
37.5	62		
28	59		
20	52		
14	48		
10	44		
6.3	37		
5	34		
3.35	30		
2	26		
1.18	24		
0.6	21		
0.425	21		
0.3	19		
0.212	18		
0.15	17		
0.063	15		

Sample Proportions	% dry mass
Cobbles	15
Gravel	59
Sand	11
Silt and Clay	15

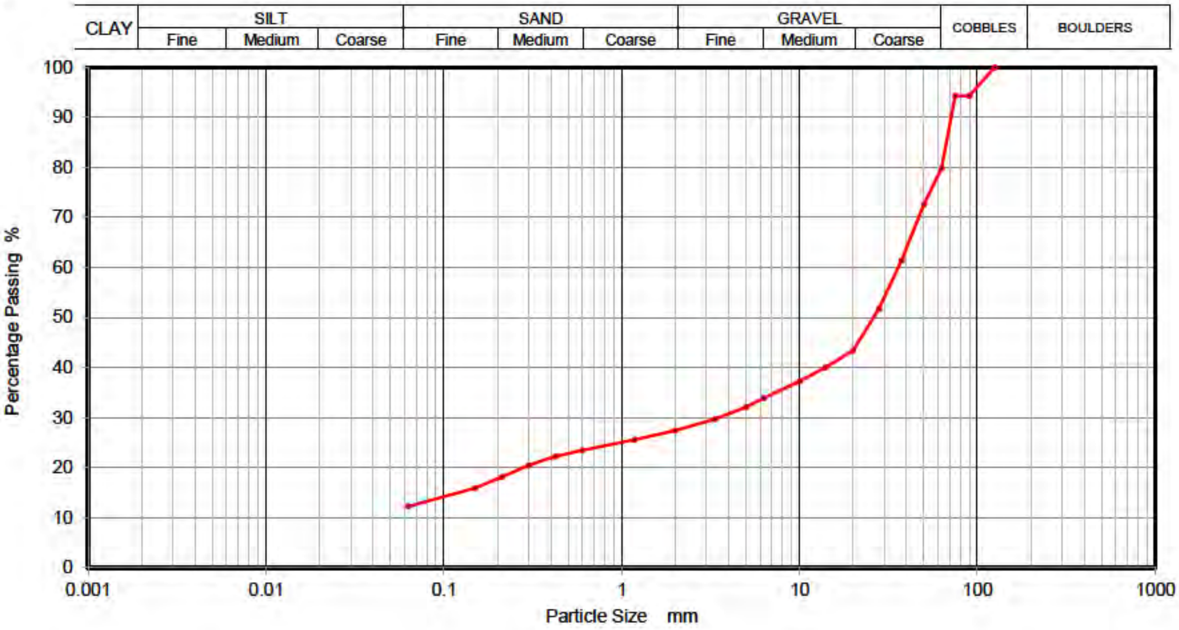
Remarks

Preparation and testing in accordance with BS1377 unless noted below

Operators	Checked	27/11/2019	Wayne Honey	W. Honey
RO/MH	Approved	28/11/2019	Paul Evans	P Evans

UKAS TESTING 2788

GSTL	**PARTICLE SIZE DISTRIBUTION** **BS 1377 Part 2:1990** **Wet Sieve, Clause 9.2**	Contract Number	**46217**
		Borehole/Pit No.	**TP103**
Site Name	**Godre'r Graig**	Sample No.	
Soil Description	Brown clayey/silty fine to coarse sandy fine to coarse GRAVEL (with cobbles)	Depth Top	**1.50**
		Depth Base	
Date Tested	25/11/2019	Sample Type	**B**



Sieving		Sedimentation	
Particle Size mm	% Passing	Particle Size mm	% Passing
125	100		
90	94		
75	94		
63	80		
50	73		
37.5	61		
28	52		
20	43		
14	40		
10	37		
6.3	34		
5	32		
3.35	30		
2	27		
1.18	26		
0.6	23		
0.425	22		
0.3	21		
0.212	18		
0.15	16		
0.063	12		

Sample Proportions	% dry mass
Cobbles	20
Gravel	53
Sand	15
Silt and Clay	12

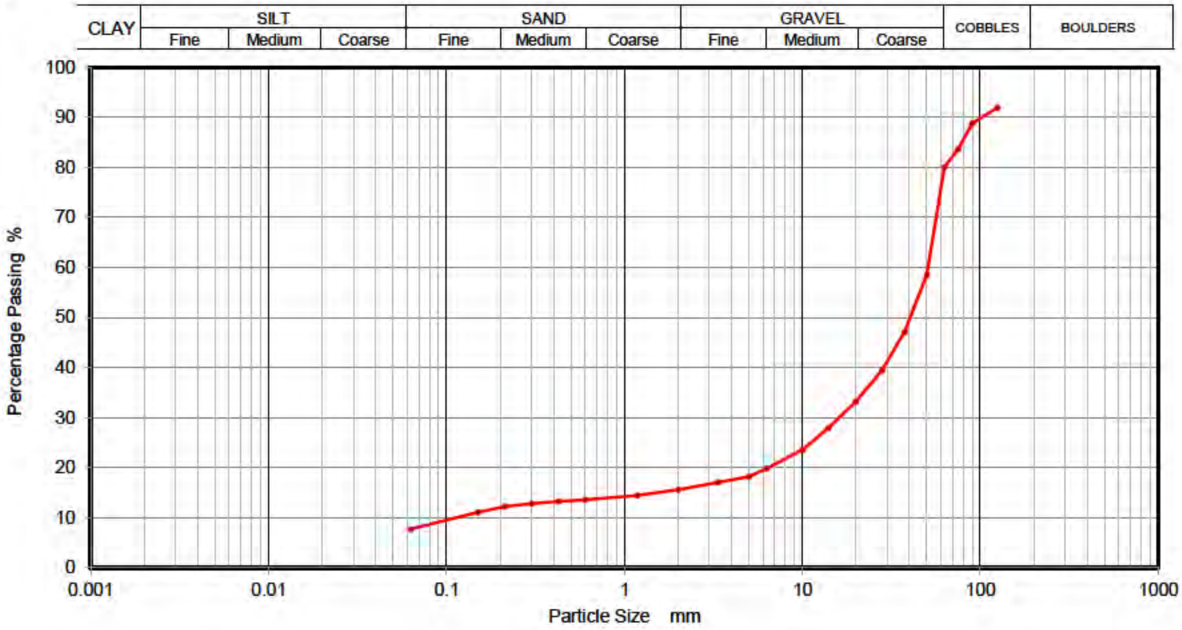
Remarks

Preparation and testing in accordance with BS1377 unless noted below

Operators	Checked	27/11/2019	Wayne Honey	W. Honey
RO/MH	Approved	28/11/2019	Paul Evans	P Evans

UKAS TESTING 2788

GSTL	**PARTICLE SIZE DISTRIBUTION** **BS 1377 Part 2:1990** **Wet Sieve, Clause 9.2**	Contract Number	**46217**
		Borehole/Pit No.	**TP104**
Site Name	**Godre'r Graig**	Sample No.	
Soil Description	Brown slightly clayey/silty slightly fine to coarse sandy fine to coarse GRAVEL (with cobbles)	Depth Top	**1.00**
		Depth Base	
Date Tested	25/11/2019	Sample Type	**B**



Sieving		**Sedimentation**	
Particle Size mm	% Passing	Particle Size mm	% Passing
125	92		
90	89		
75	84		
63	80		
50	59		
37.5	47		
28	39		
20	33		
14	28		
10	24		
6.3	20		
5	18		
3.35	17		
2	16		
1.18	14		
0.6	14		
0.425	13		
0.3	13		
0.212	12		
0.15	11		
0.063	8		

Sample Proportions	% dry mass
Cobbles	20
Gravel	64
Sand	8
Silt and Clay	8

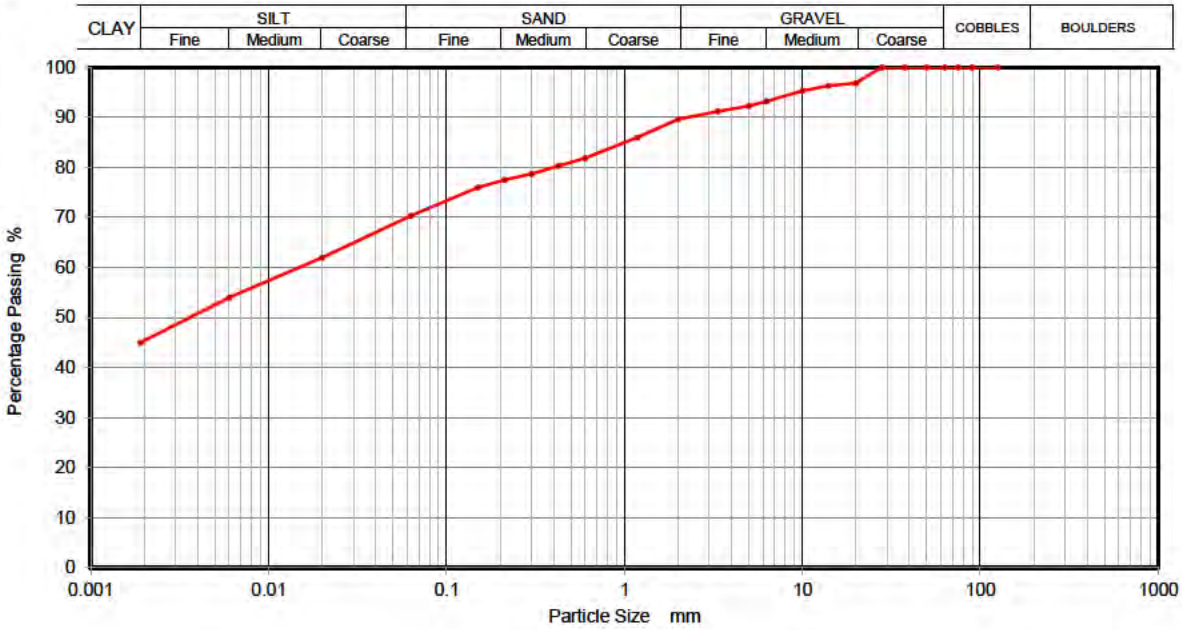
Remarks

Preparation and testing in accordance with BS1377 unless noted below

Operators	Checked	27/11/2019	Wayne Honey	W. Honey
RO/MH	Approved	28/11/2019	Paul Evans	P Evans

UKAS TESTING 2788

GSTL	PARTICLE SIZE DISTRIBUTION BS 1377 Part 2:1990 Wet Sieve & Pipette Analysis, Clause 9.2 & 9.4	Contract Number	46217
		Borehole/Pit No.	TP104
Site Name	**Godre'r Graig**	Sample No.	
Soil Description	Brown fine to coarse gravelly fine to coarse sandy silty CLAY	Depth Top	3.30
		Depth Base	
Date Tested	26/11/2019	Sample Type	B



Sieving		Sedimentation	
Particle Size mm	% Passing	Particle Size mm	% Passing
125	100	0.0200	62
90	100	0.0060	54
75	100	0.0020	45
63	100		
50	100		
37.5	100		
28	100		
20	97		
14	96		
10	95		
6.3	93		
5	92		
3.35	91		
2	90		
1.18	86		
0.6	82		
0.425	80		
0.3	79		
0.212	77		
0.15	76		
0.063	70		

Sample Proportions	% dry mass
Cobbles	0
Gravel	10
Sand	20
Silt	25
Clay	45

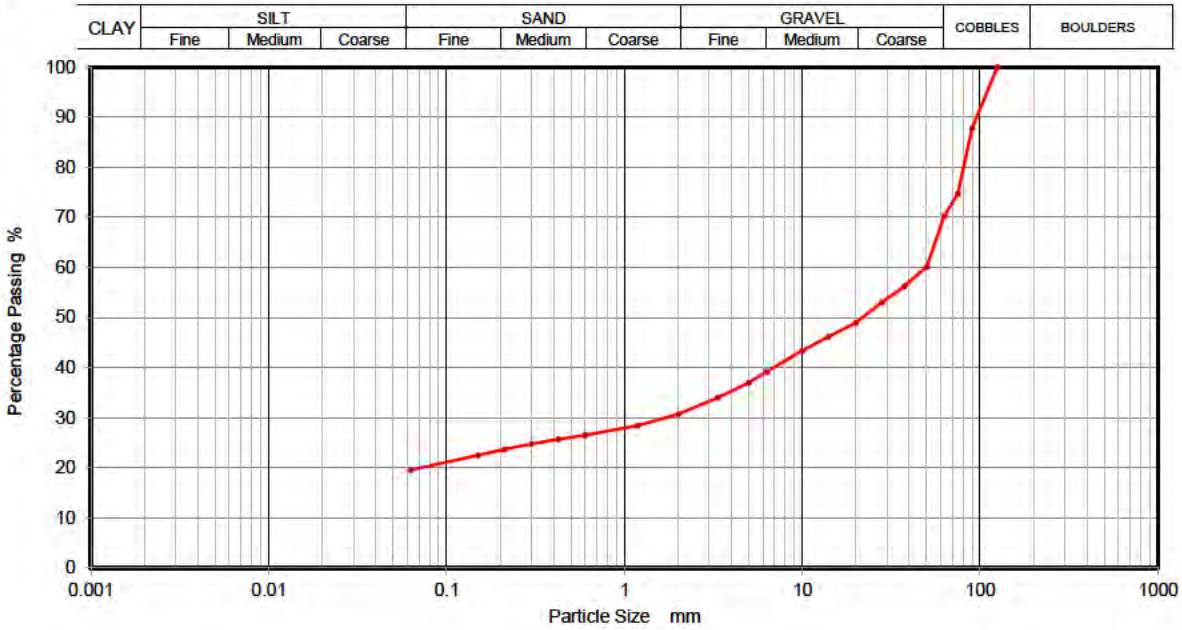
Remarks

Preparation and testing in accordance with BS1377 unless noted below

Operators	Checked	27/11/2019	Wayne Honey	W. Honey
RO/MH	Approved	28/11/2019	Paul Evans	P Evans

UKAS TESTING 2788

GSTL	**PARTICLE SIZE DISTRIBUTION** **BS 1377 Part 2:1990** **Wet Sieve, Clause 9.2**	Contract Number	**46217**
		Borehole/Pit No.	**TP104**
Site Name	**Godre'r Graig**	Sample No.	
Soil Description	Brown fine to coarse sandy clayey/silty fine to coarse GRAVEL (with cobbles)	Depth Top	**4.50**
		Depth Base	
Date Tested	25/11/2019	Sample Type	**B**



Sieving		**Sedimentation**	
Particle Size mm	% Passing	Particle Size mm	% Passing
125	100		
90	88		
75	75		
63	70		
50	60		
37.5	56		
28	53		
20	49		
14	46		
10	43		
6.3	39		
5	37		
3.35	34		
2	31		
1.18	28		
0.6	27		
0.425	26		
0.3	25		
0.212	24		
0.15	22		
0.063	20		

Sample Proportions	% dry mass
Cobbles	30
Gravel	39
Sand	11
Silt and Clay	20

Remarks

Preparation and testing in accordance with BS1377 unless noted below

Operators	Checked	27/11/2019	Wayne Honey	W. Honey
RO/MH	Approved	28/11/2019	Paul Evans	D P Evans

UKAS TESTING 2788

Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.
BS1377:Part 7:5 :1990.

Borehole Number: TP101 Depth from (m): 0.60
Sample Number : N/A

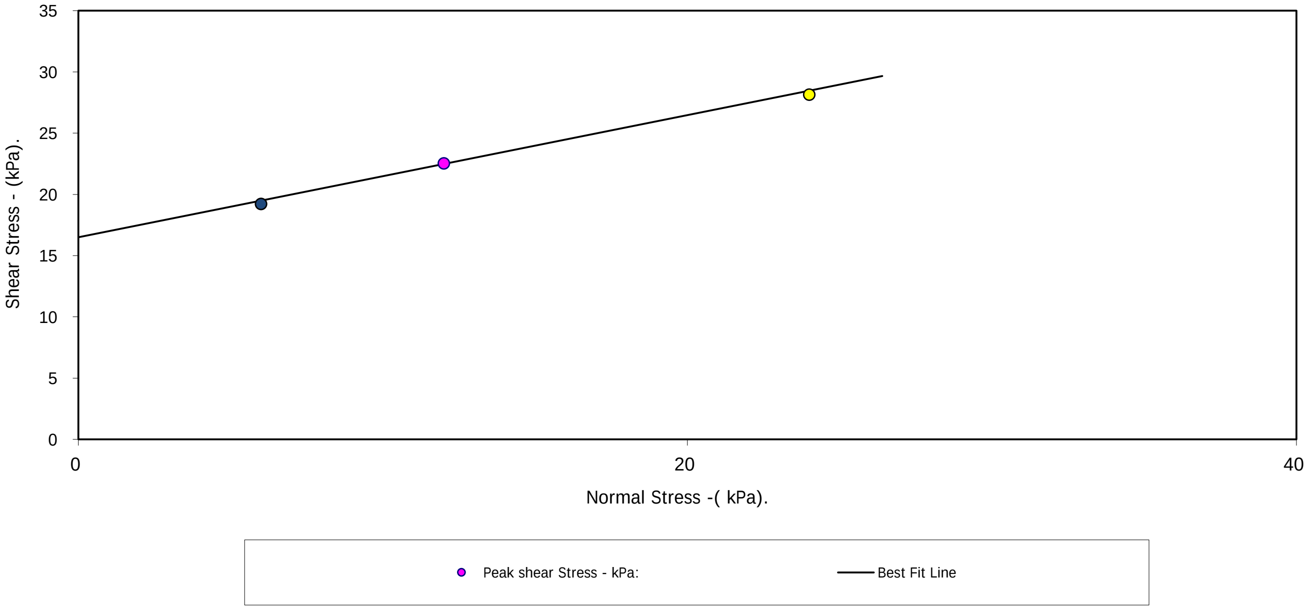
Sample Type:	B
Particle Density - Mg/m3:	2.65 (Assumed)
Specimen Tested:	Remoulded (Light Tamping) Material above 20mm removed.

Sample Description:
Brown fine to medium gravelly silty CLAY

STAGE	1	2	3
Initial Conditions			
Height - mm:	145.00	145.00	145.00
Length - mm:	300.00	300.00	300.00
Moisture Content - %:	15	15	15
Bulk Density - Mg/m3:	2.17	2.17	2.17
Dry Density - Mg/m3:	1.89	1.89	1.89
Voids Ratio:	0.4014	0.4014	0.4014
Normal Pressure- kPa	6	12	24
Consolidation			
Consolidated Height - mm:	143.97	143.14	142.30
Shear			
Rate of Strain (mm/min)	3.000	3.000	3.000
Strain at peak shear stress (%)	14.63	15.39	19.21
Peak shear Stress - kPa:	19	23	28

PEAK	
Angle of Shearing Resistance:(~~θ~~)	26.5
Effective Cohesion - kPa:	17

FAILURE CONDITIONS



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Client Ref Number:
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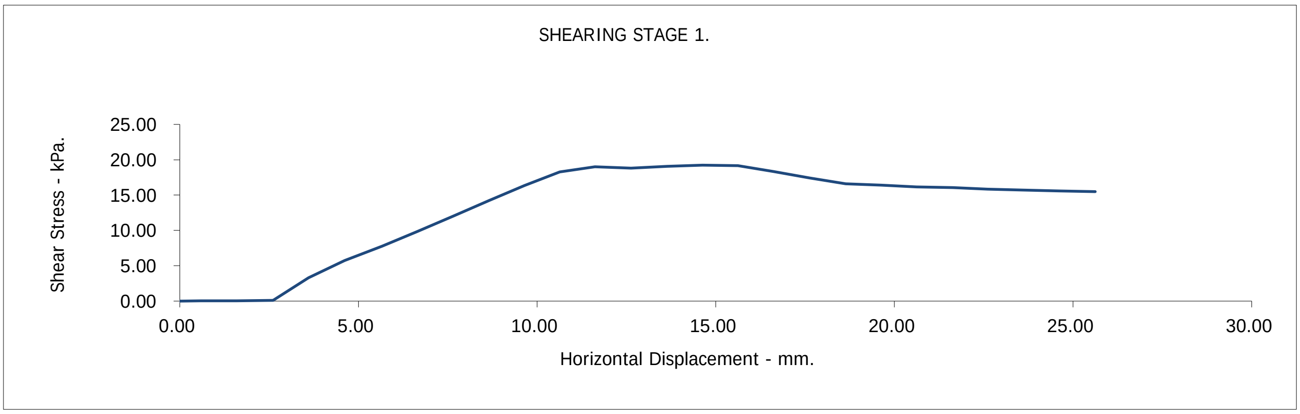
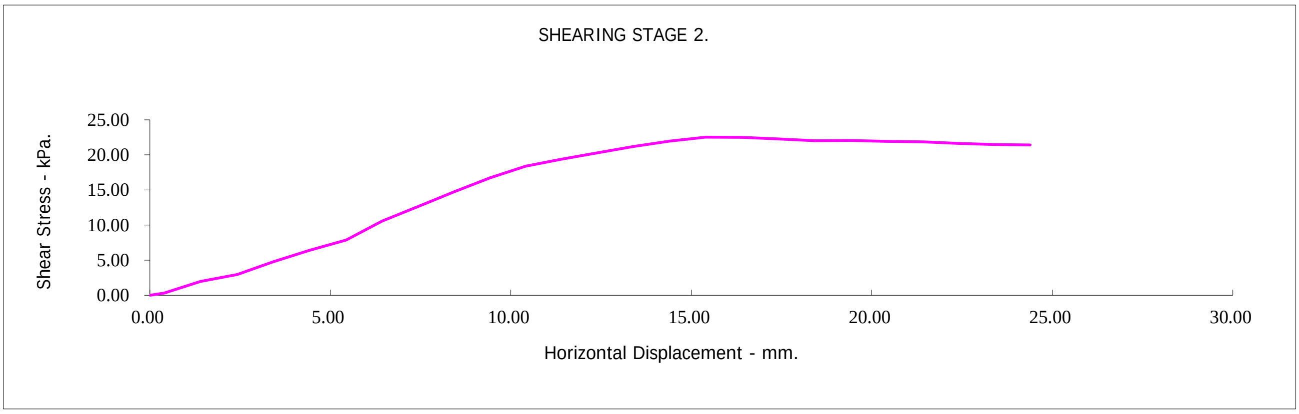
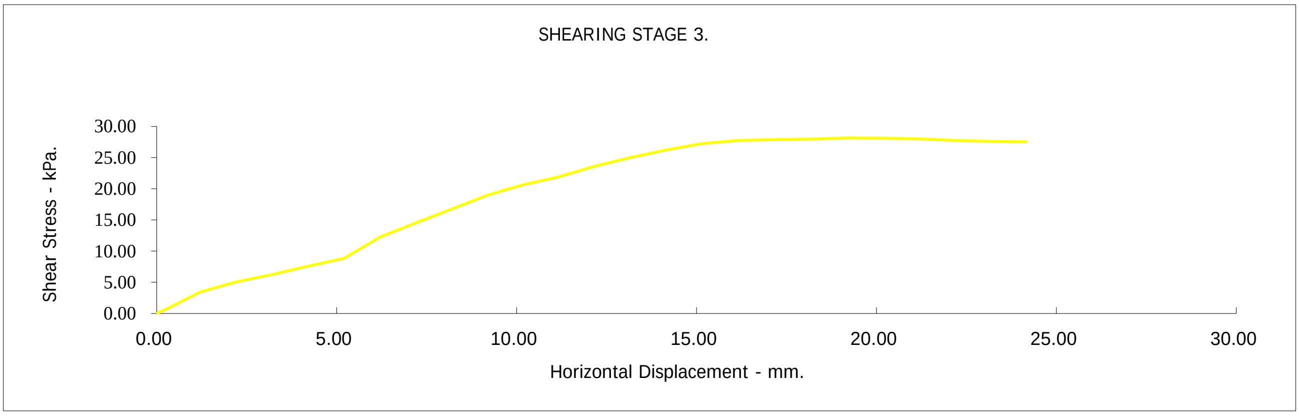
Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

BS1377:Part 7:5 :1990.

Borehole/Sample Number: TP101 Depth (m): 0.60







Godre'r Graig

Contract No.:
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Client Ref Number:
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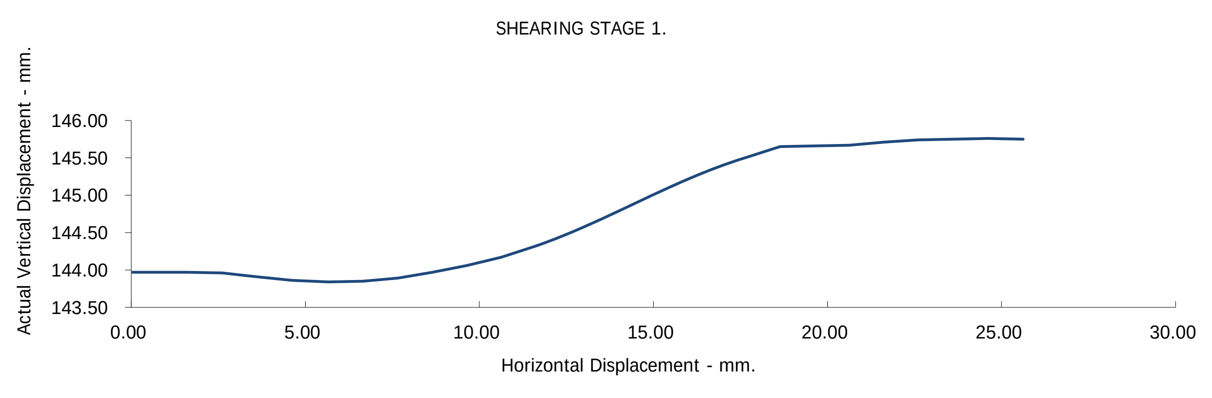
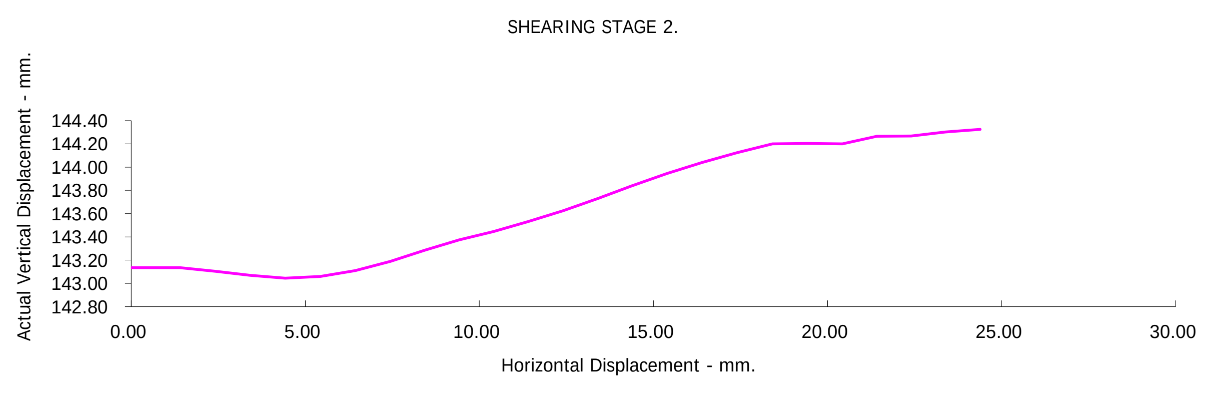
Figure.

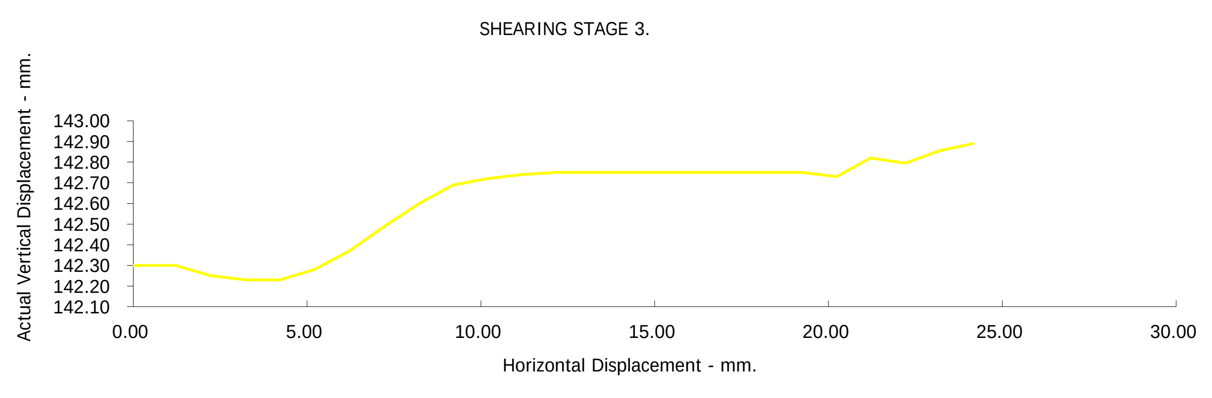
Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

BS1377:Part 7:5 :1990.

Borehole/Sample Number: TP101 Depth (m): 0.60







Godre'r Graig

Contract No.:
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Client Ref Number:
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Figure.

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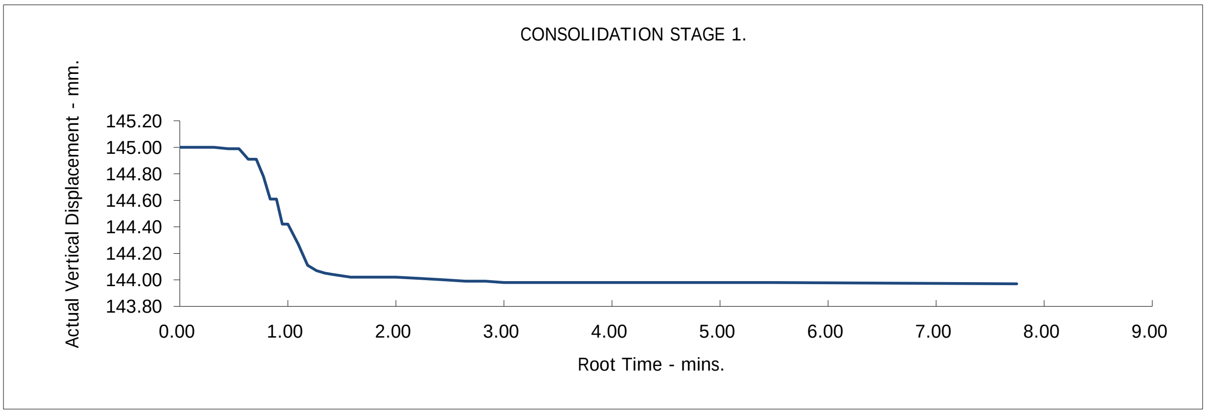
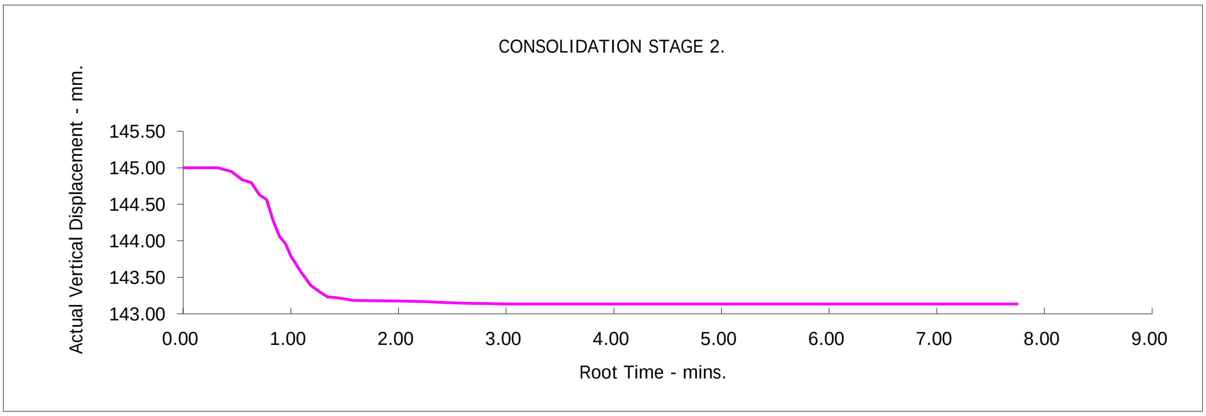
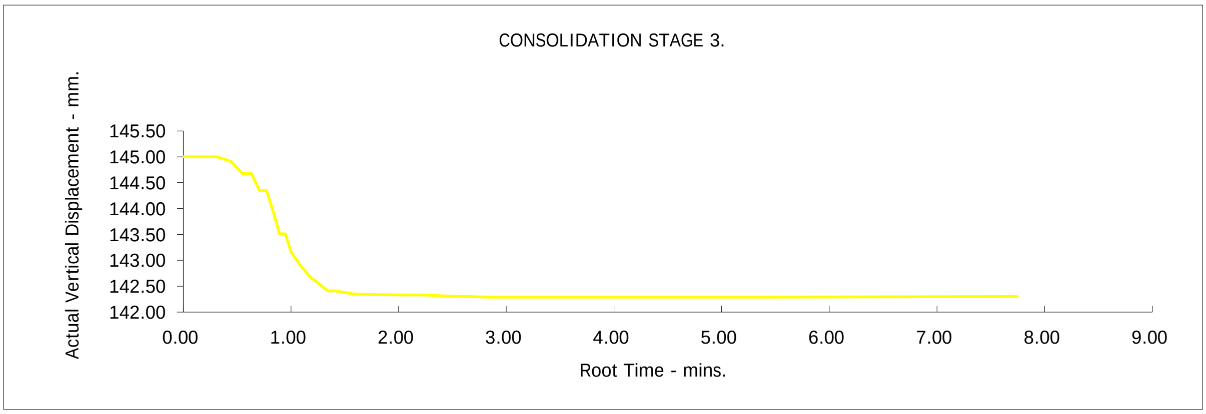
Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

BS1377:Part 7:5 :1990.

Borehole/Sample Number: TP101 Depth (m): 0.60







Godre'r Graig

Contract No.:
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Client Ref Number:
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Figure.

Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

BS1377:Part 7:5 :1990.

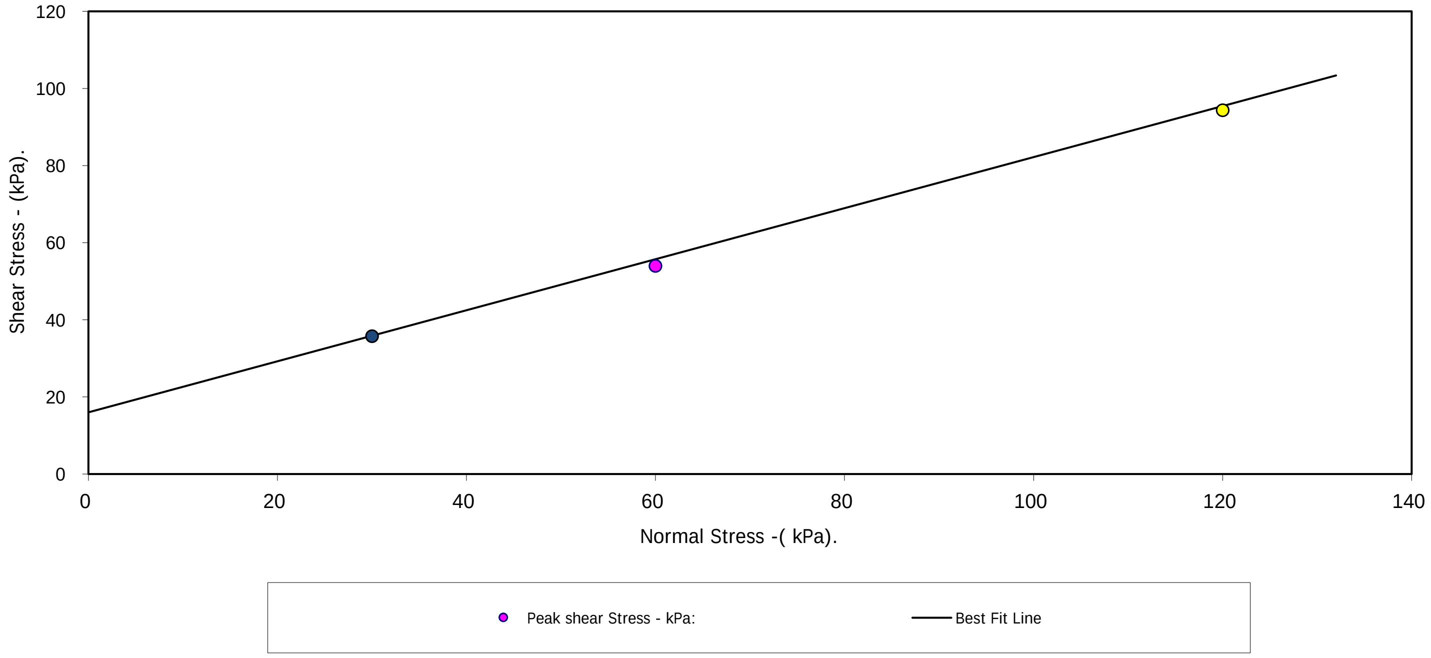
Borehole Number:	TP101	Depth from (m):	2.90
Sample Number :	N/A		

Sample Type:	B
Particle Density - Mg/m3:	2.65 (Assumed)
Specimen Tested:	Remoulded (Light Tamping) Material above 20mm removed.
Sample Description: Brown fine to coarse gravelly silty CLAY	

STAGE	1	2	3
Initial Conditions			
Height - mm:	140.00	140.00	140.00
Length - mm:	300.00	300.00	300.00
Moisture Content - %:	12	12	12
Bulk Density - Mg/m3:	2.19	2.19	2.19
Dry Density - Mg/m3:	1.96	1.96	1.96
Voids Ratio:	0.3488	0.3488	0.3488
Normal Pressure- kPa	30	60	120
Consolidation			
Consolidated Height - mm:	135.50	133.70	132.38
Shear			
Rate of Strain (mm/min)	3.000	3.000	3.000
Strain at peak shear stress (%)	61.01	62.02	62.02
Peak shear Stress - kPa:	36	54	94

PEAK	
Angle of Shearing Resistance:(~~θ~~)	33.5
Effective Cohesion - kPa:	16

FAILURE CONDITIONS



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Client Ref Number:
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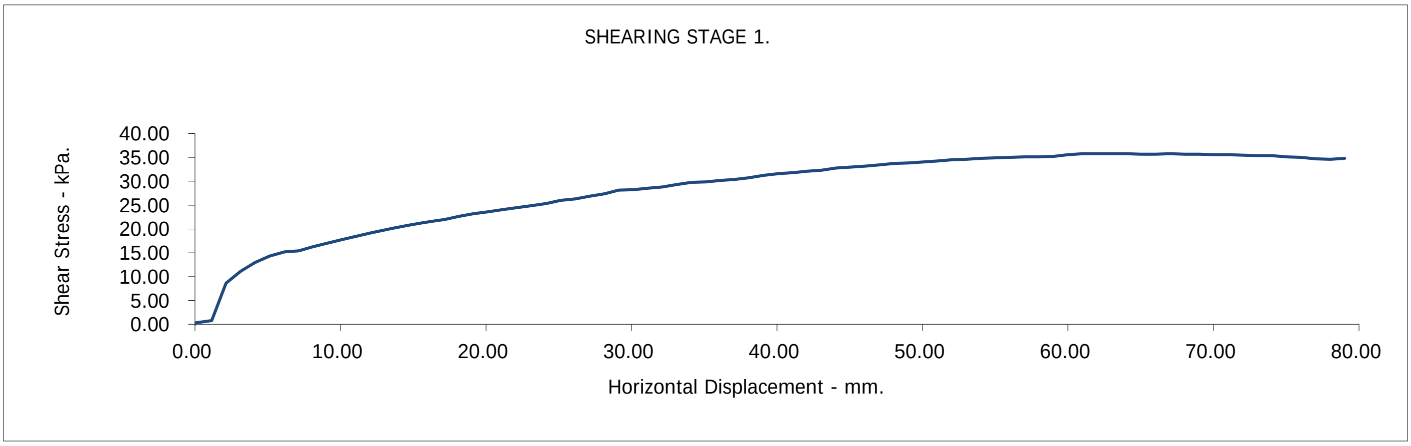
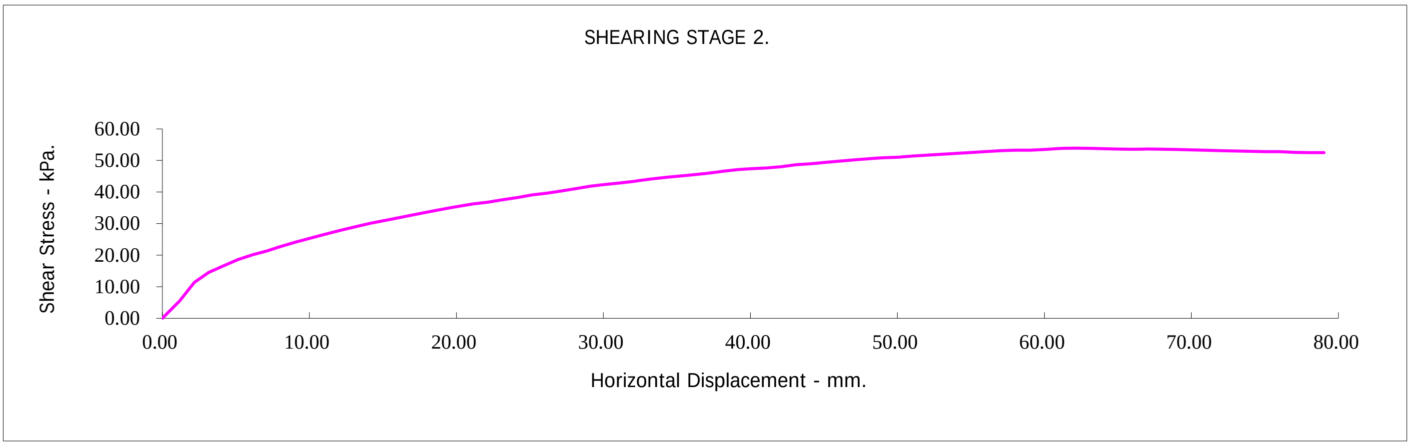
Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

BS1377:Part 7:5 :1990.

Borehole/Sample Number:	TP101	Depth (m):	2.90





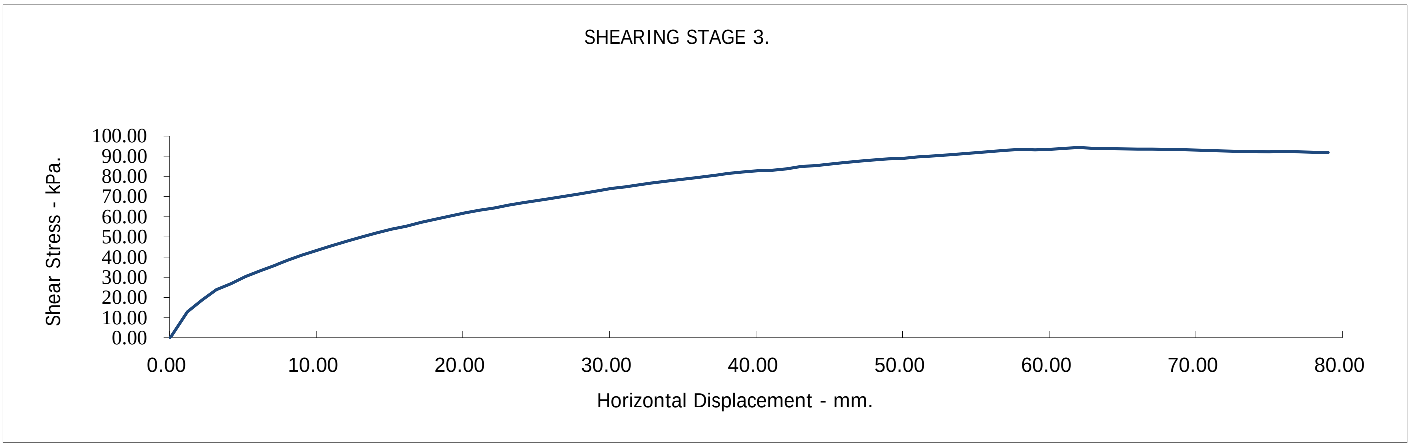


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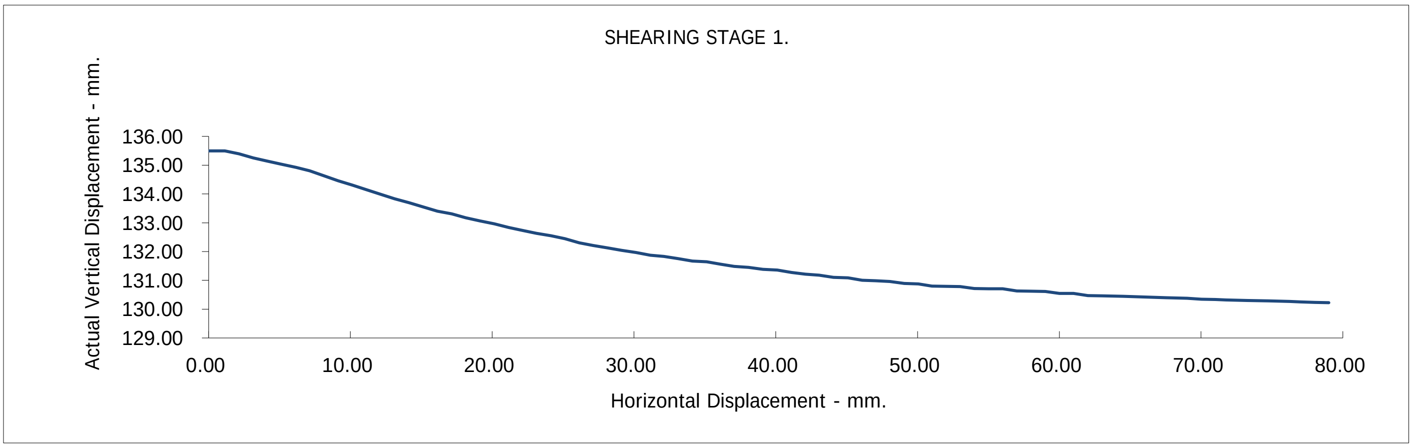
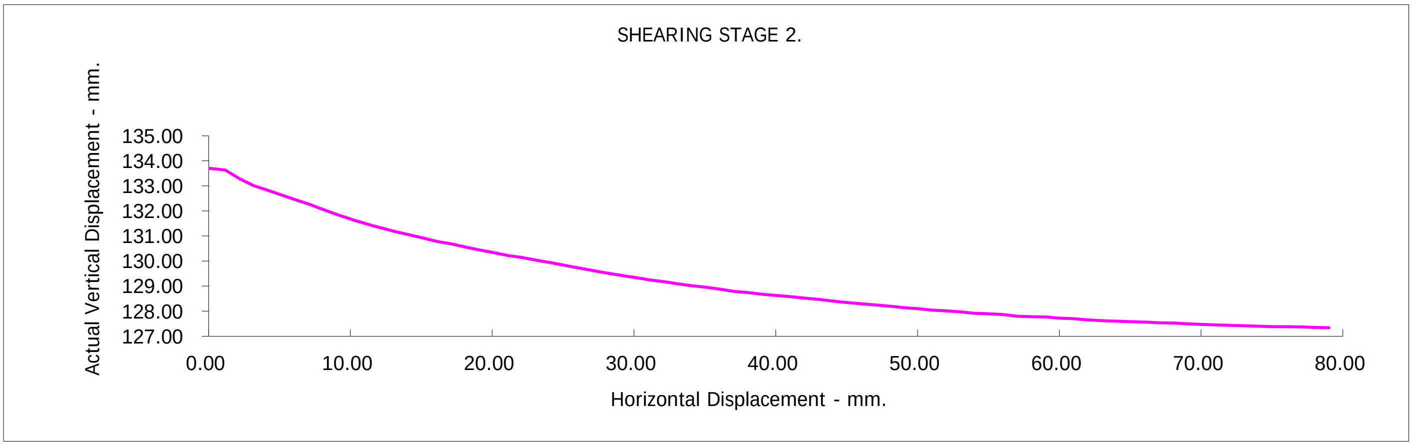
Figure.

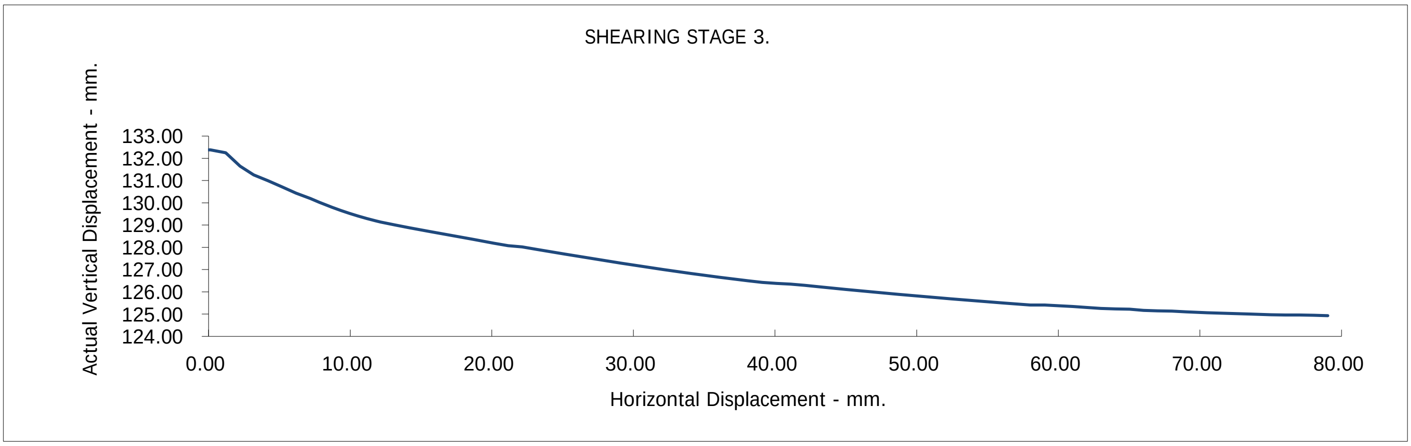
Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

BS1377:Part 7:5 :1990.

Borehole/Sample Number:	TP101	Depth (m):	2.90







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Client Ref Number:
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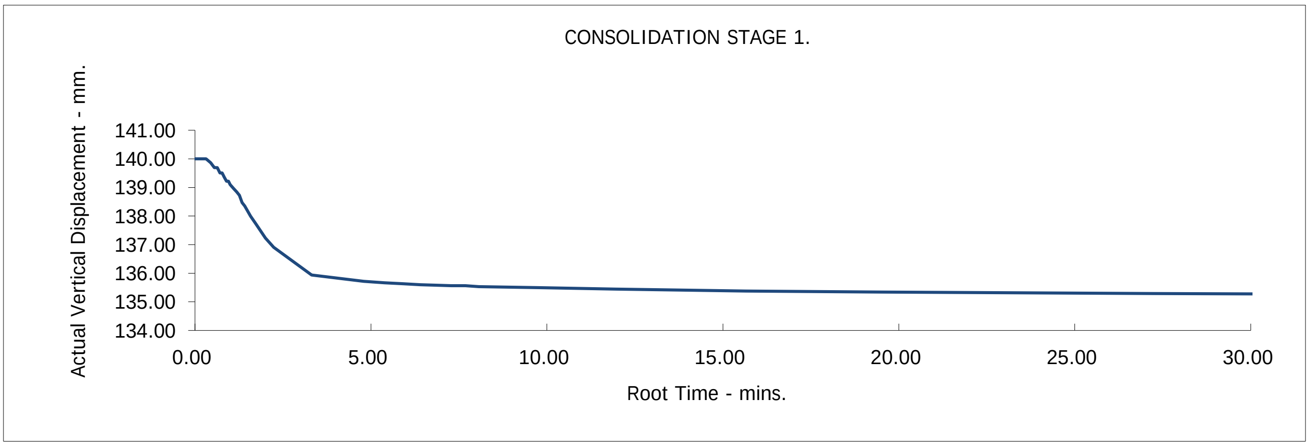
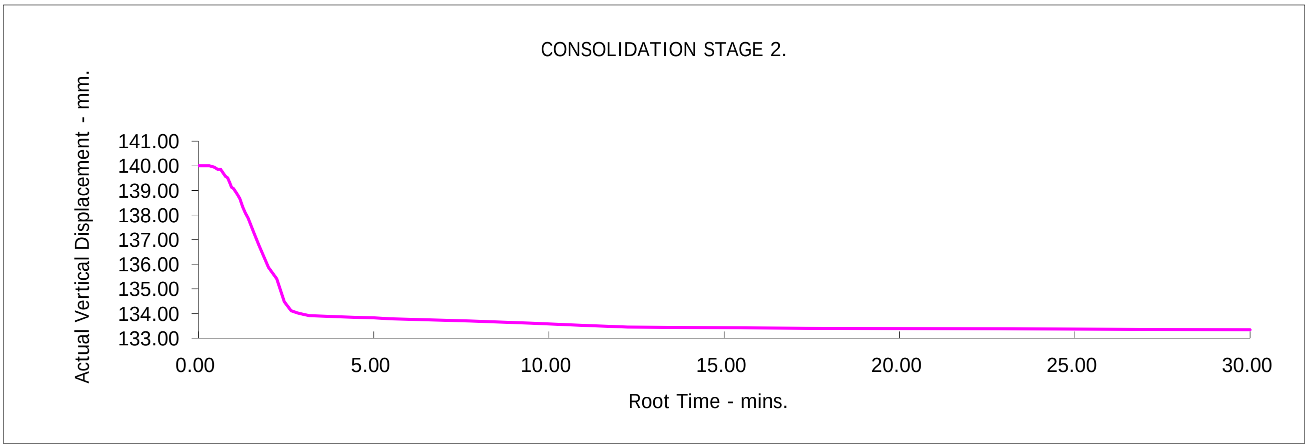
Figure.

Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

BS1377:Part 7:5 :1990.

Borehole/Sample Number:	TP101	Depth (m):	2.90





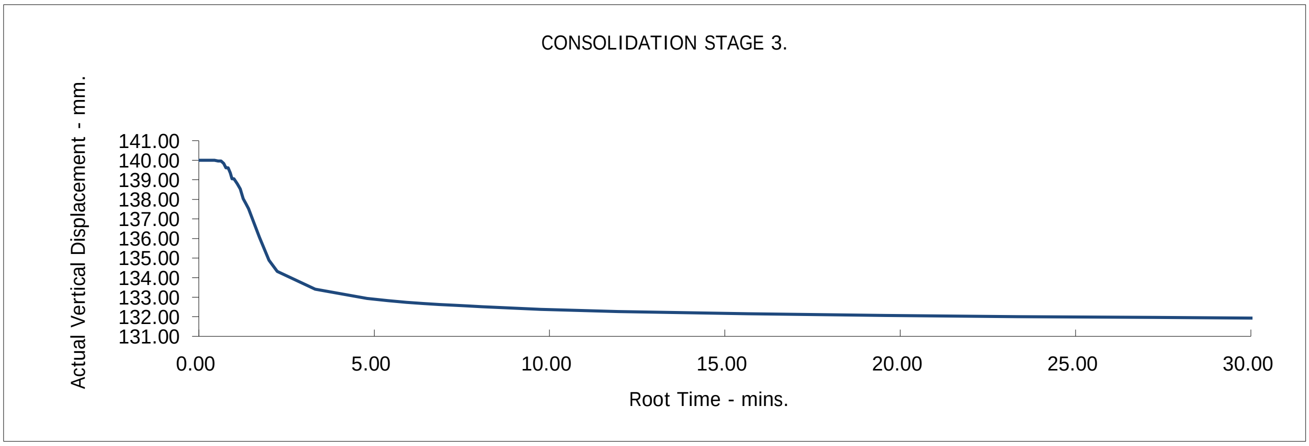


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Figure.

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Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

BS1377:Part 7:5 :1990.

Borehole Number:	TP102	Depth from (m):	1.00
Sample Number :	N/A		

Sample Type:	B
Particle Density - Mg/m3:	2.65 (Assumed)
Specimen Tested:	Remoulded (Light Tamping) Material above 20mm removed.
Sample Description: Brown fine to coarse gravelly silty CLAY	

STAGE	1	2	3
Initial Conditions			
Height - mm:	139.80	139.80	139.80
Length - mm:	300.00	300.00	300.00
Moisture Content - %:	17	17	17
Bulk Density - Mg/m3:	2.23	2.23	2.23
Dry Density - Mg/m3:	1.91	1.91	1.91
Voids Ratio:	0.3869	0.3869	0.3869
Normal Pressure- kPa	10	20	40
Consolidation			
Consolidated Height - mm:	138.41	135.68	133.03
Shear			
Rate of Strain (mm/min)	3.000	3.000	3.000
Strain at peak shear stress (%)	73.54	75.68	75.87
Peak shear Stress - kPa:	25	35	54

PEAK	
Angle of Shearing Resistance:(θ)	44.5
Effective Cohesion - kPa:	15

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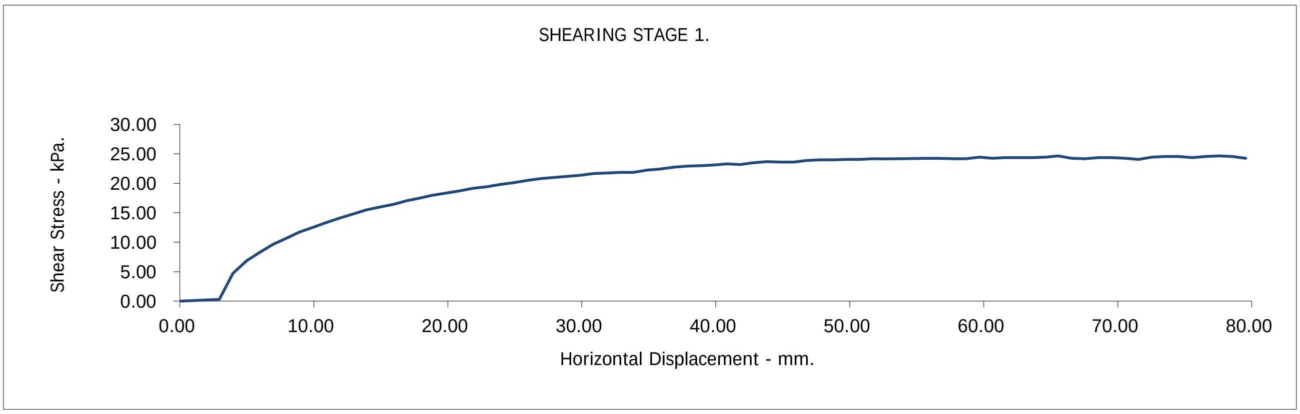
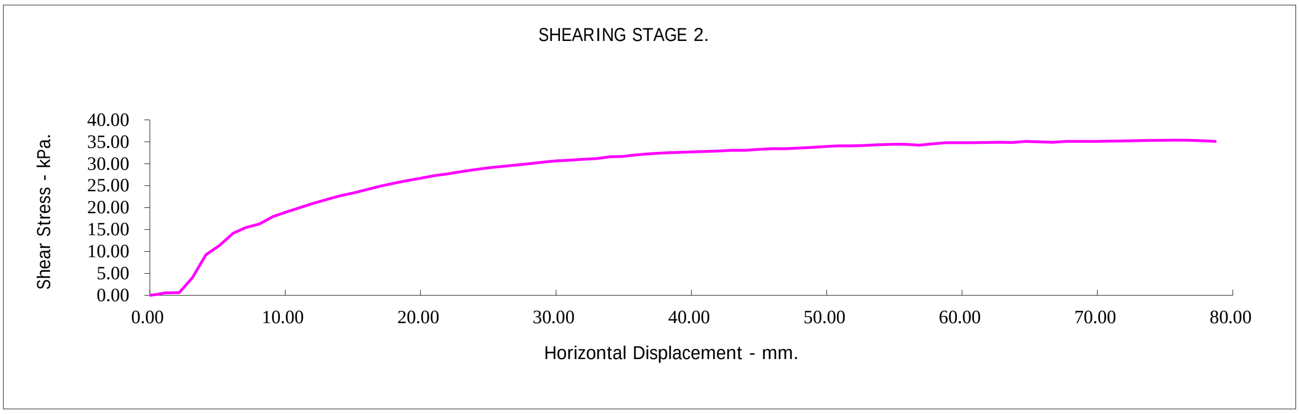
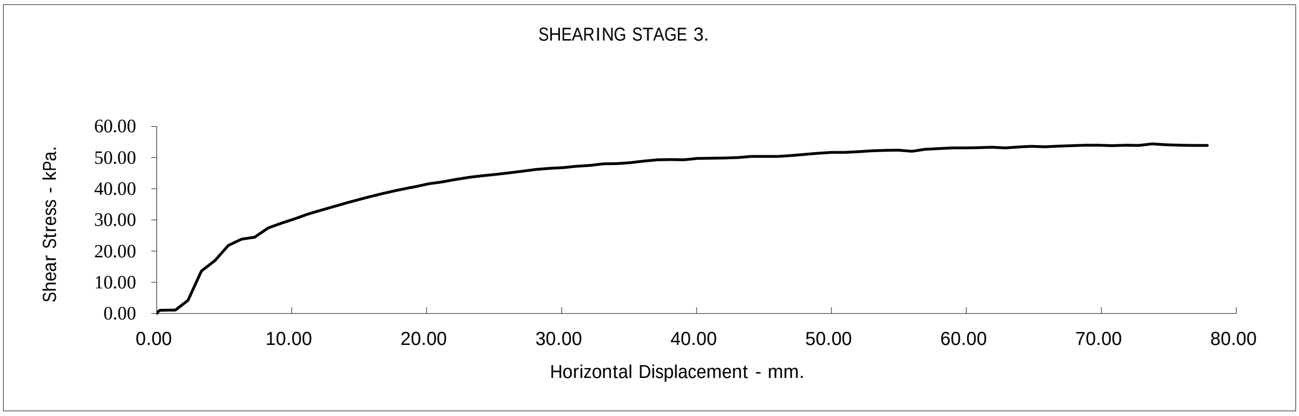
Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

BS1377:Part 7:5 :1990.

Borehole/Sample Number: TP102 Depth (m): 1.00







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Contract No.:
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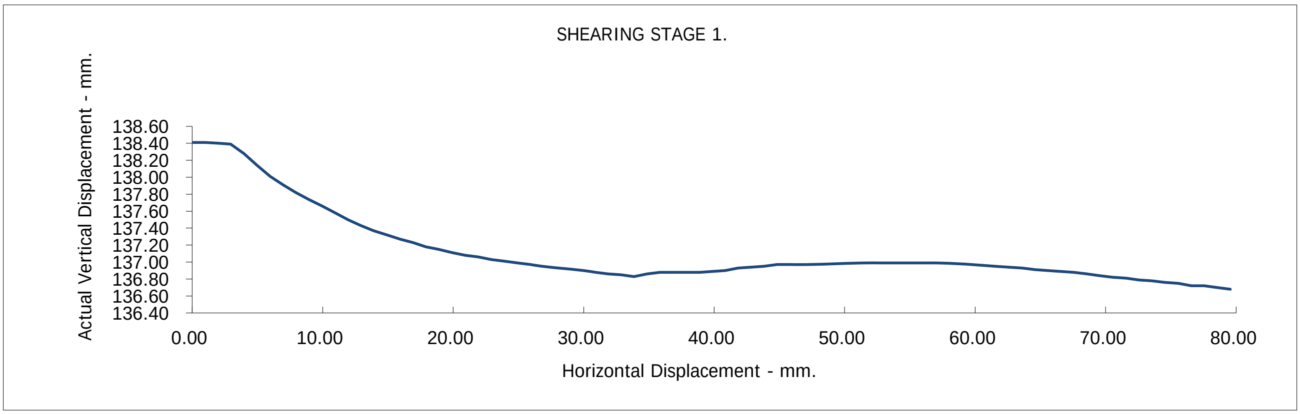
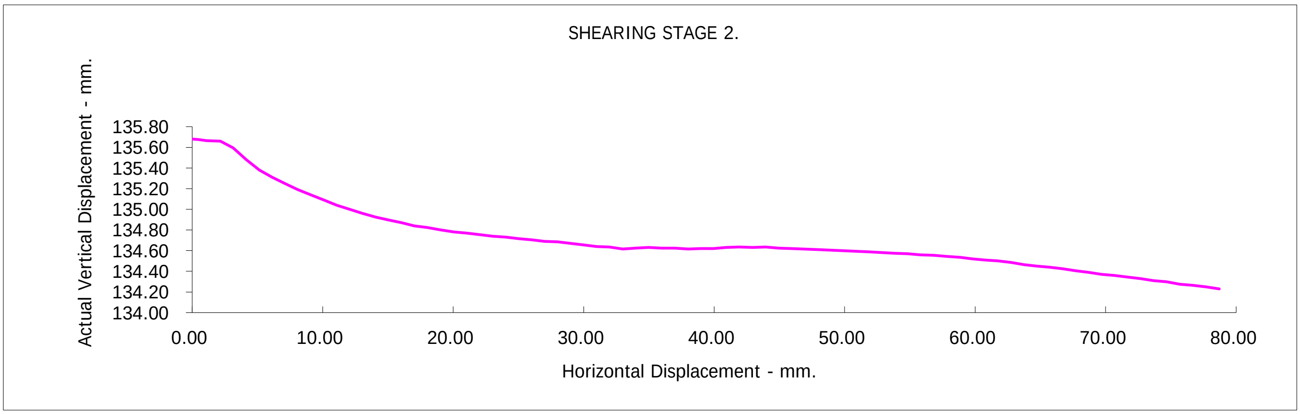
Figure.

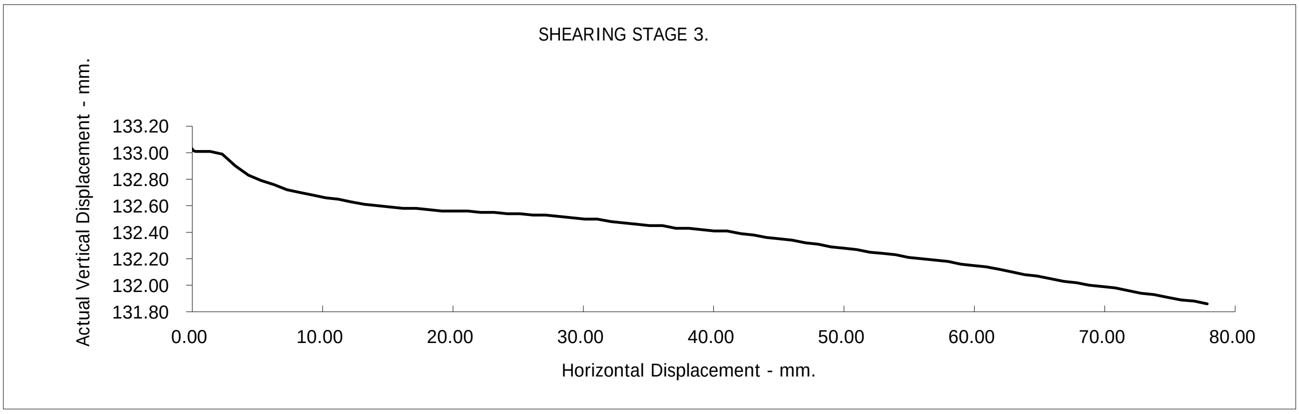
Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

BS1377:Part 7:5 :1990.

Borehole/Sample Number: TP102 Depth (m): 1.00







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Client Ref Number:
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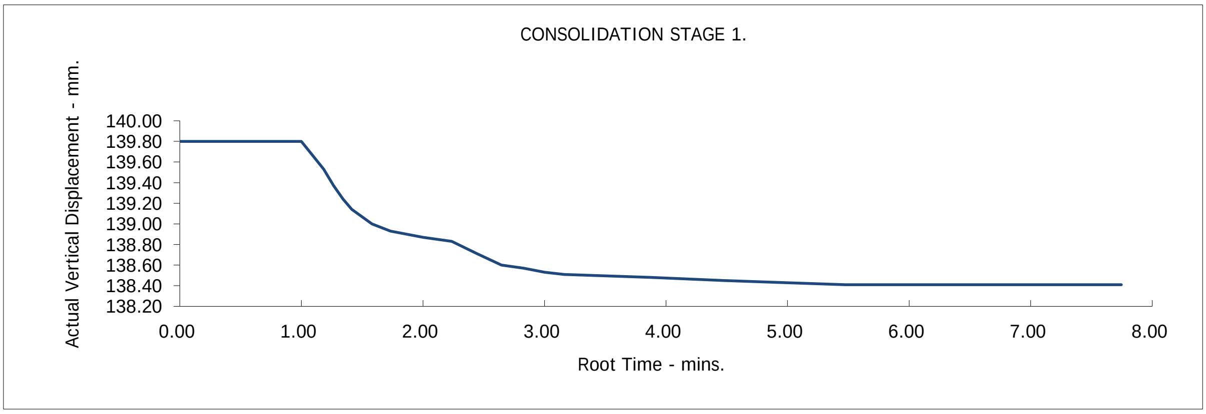
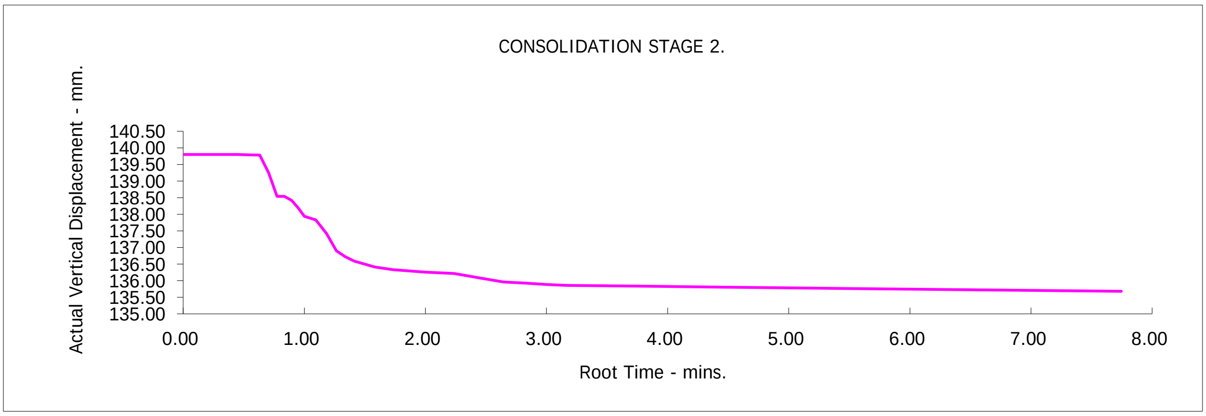
Figure.

Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

BS1377:Part 7:5 :1990.

Borehole/Sample Number:	TP102	Depth (m):	1.00





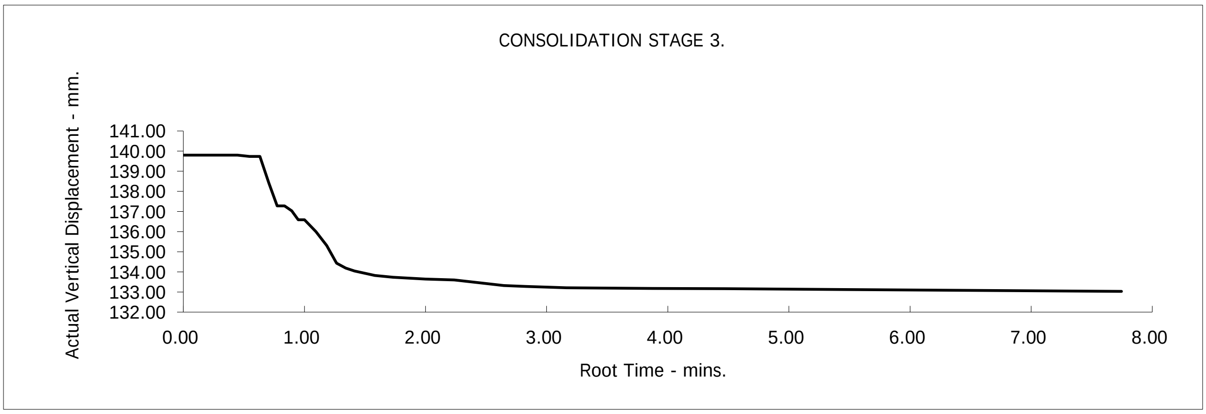


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Figure.

Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

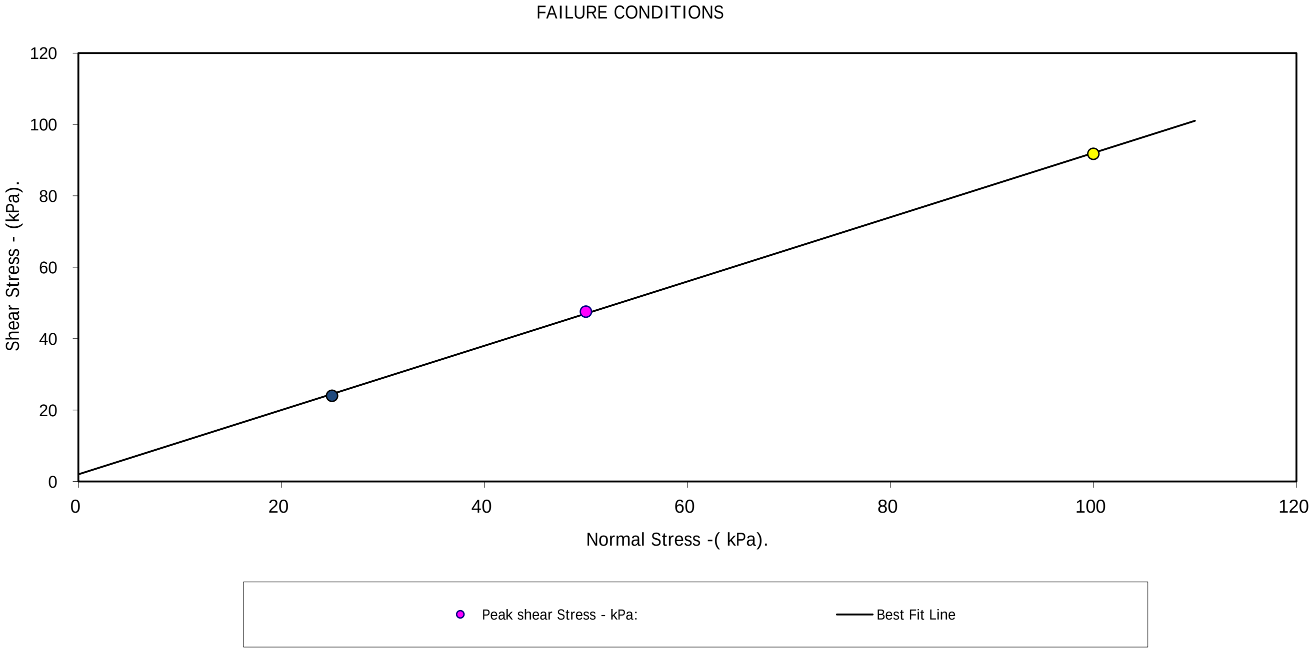
BS1377:Part 7:5 :1990.

Borehole Number:	TP102	Depth from (m):	2.60
Sample Number :	N/A		

Sample Type:	B
Particle Density - Mg/m3:	2.65 (Assumed)
Specimen Tested:	Remoulded (Light Tamping) Material above 20mm removed.
Sample Description: Brown fine to medium gravelly CLAY	

STAGE	1	2	3
Initial Conditions			
Height - mm:	134.00	134.00	134.00
Length - mm:	300.00	300.00	300.00
Moisture Content - %:	34	34	34
Bulk Density - Mg/m3:	1.81	1.81	1.81
Dry Density - Mg/m3:	1.35	1.35	1.35
Voids Ratio:	0.9678	0.9678	0.9678
Normal Pressure- kPa	25	50	100
Consolidation			
Consolidated Height - mm:	132.38	130.32	128.26
Shear			
Rate of Strain (mm/min)	3.000	3.000	3.000
Strain at peak shear stress (%)	31.12	30.76	30.32
Peak shear Stress - kPa:	24	48	92

PEAK	
Angle of Shearing Resistance:(θ)	42.0
Effective Cohesion - kPa:	2



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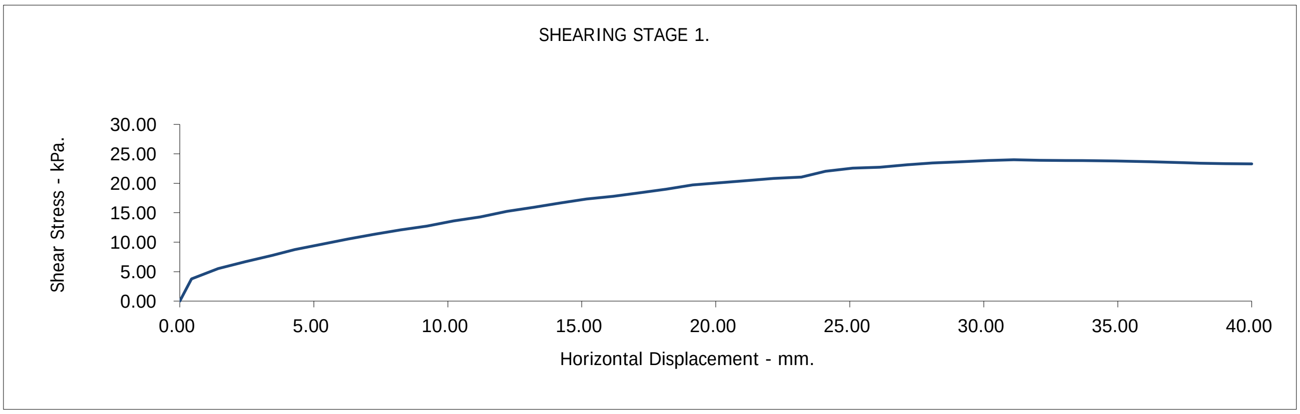
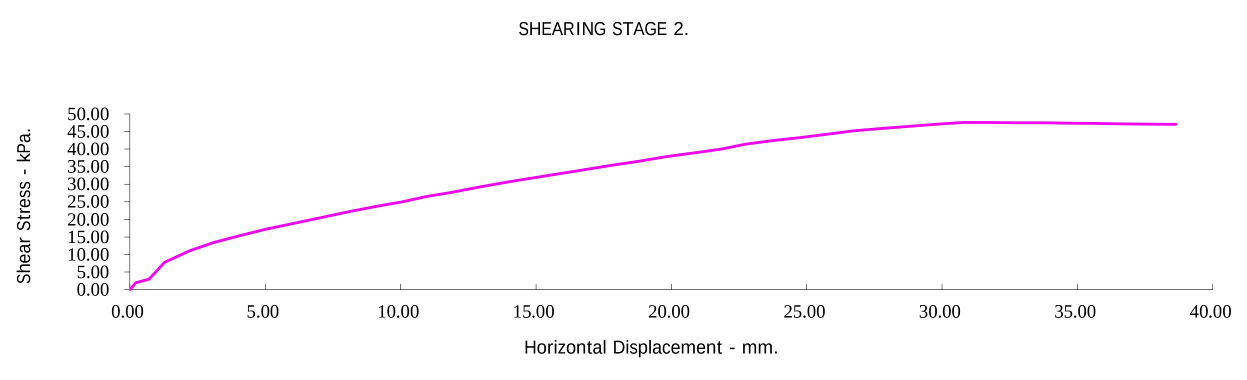
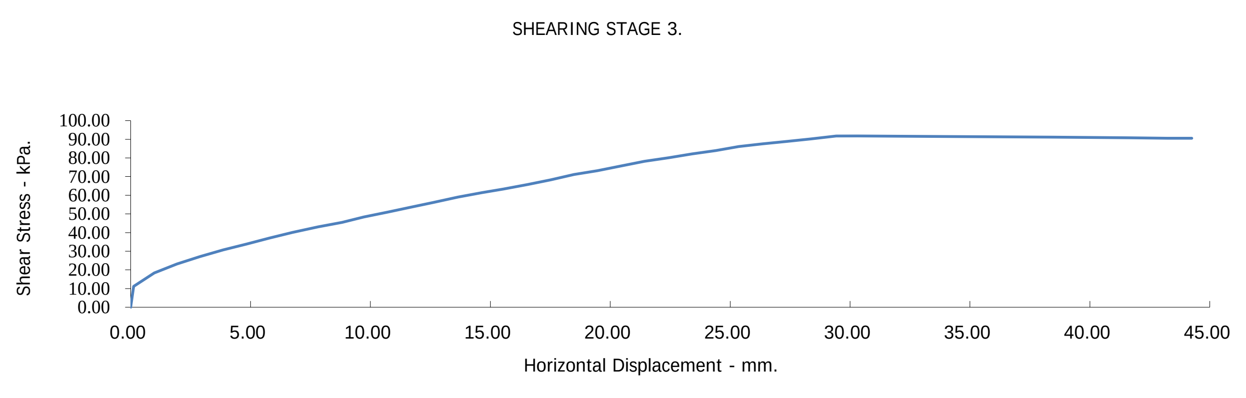
Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

BS1377:Part 7:5 :1990.

Borehole/Sample Number:	TP102	Depth (m):	2.60







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Contract No.:
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Client Ref Number:
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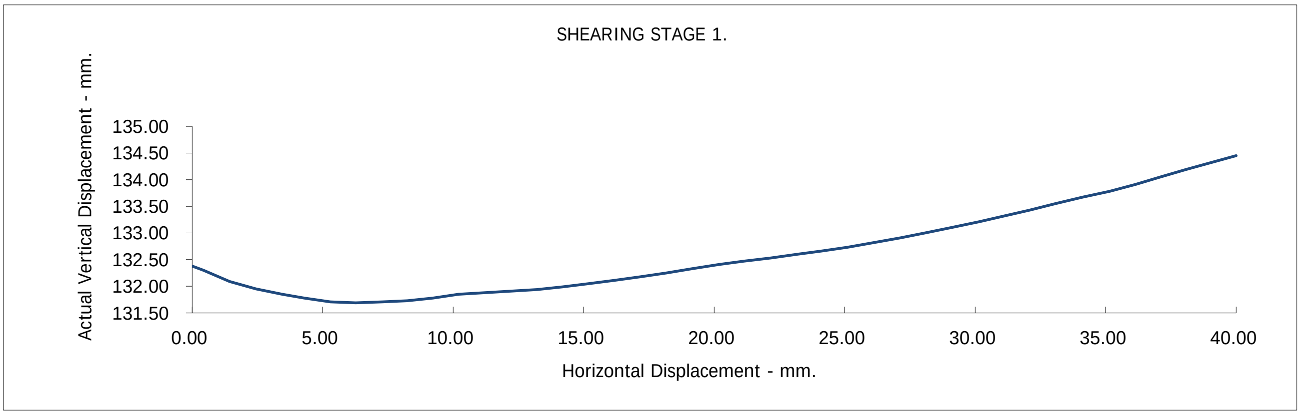
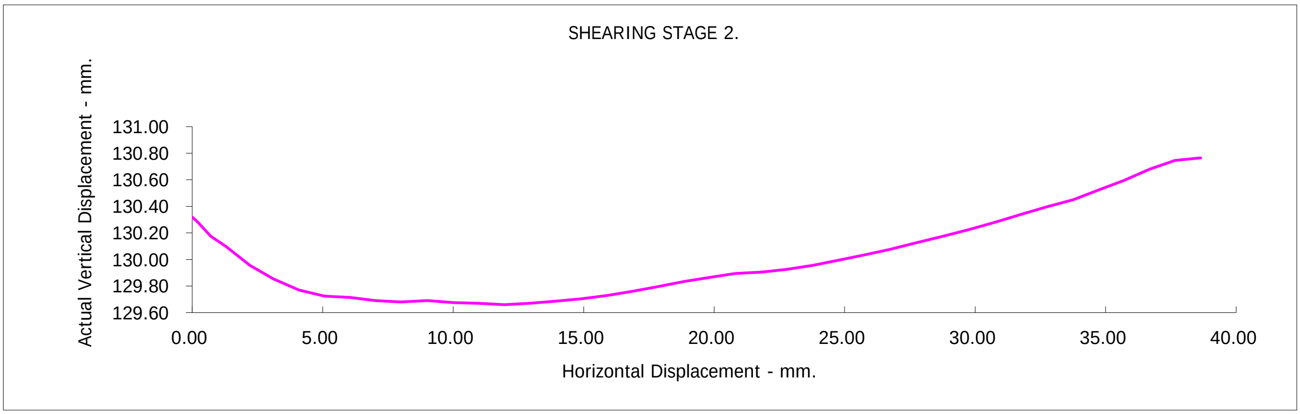
Figure.

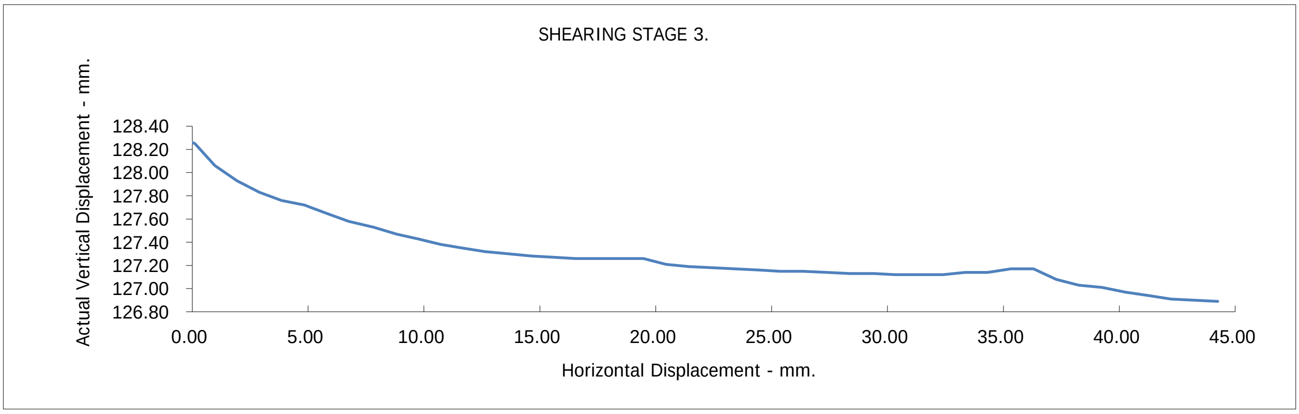
Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

BS1377:Part 7:5 :1990.

Borehole/Sample Number: TP102 Depth (m): 2.60







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Godre'r Graig

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Figure.

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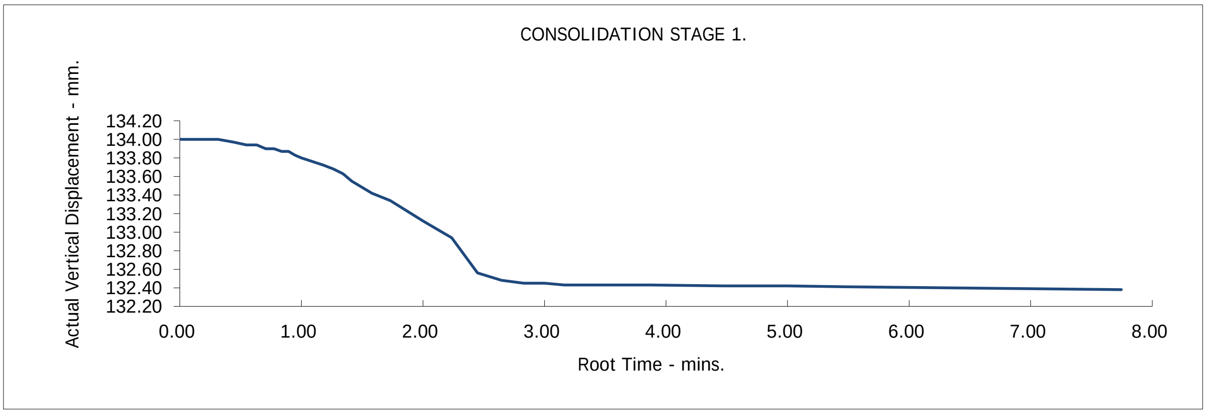
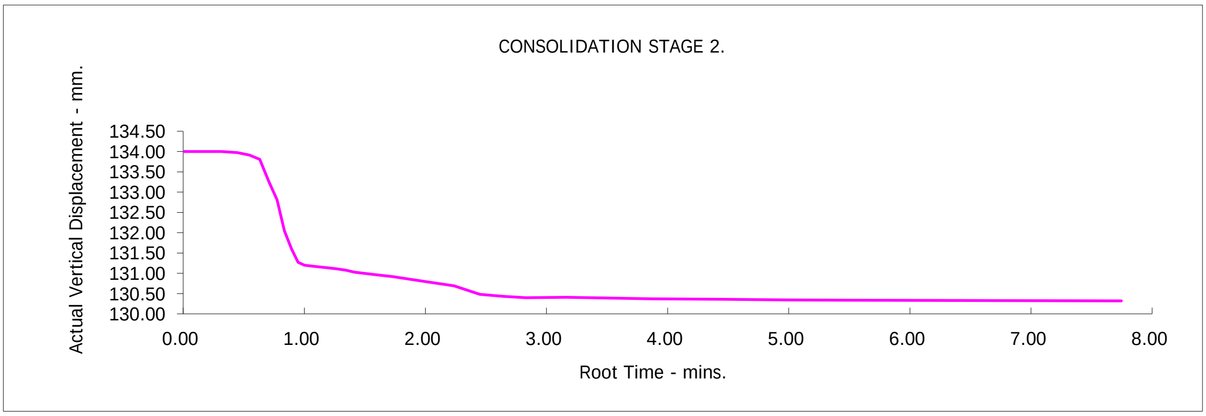
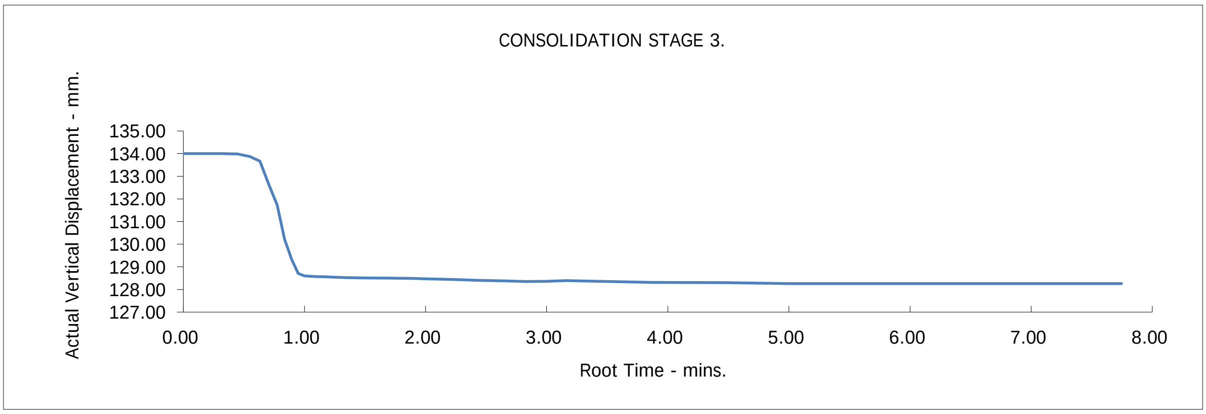
Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

BS1377:Part 7:5 :1990.

Borehole/Sample Number: TP102 Depth (m): 2.60







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Godre'r Graig

Client Ref Number:
7234e.02

Figure.

Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.
BS1377:Part 7:5 :1990.

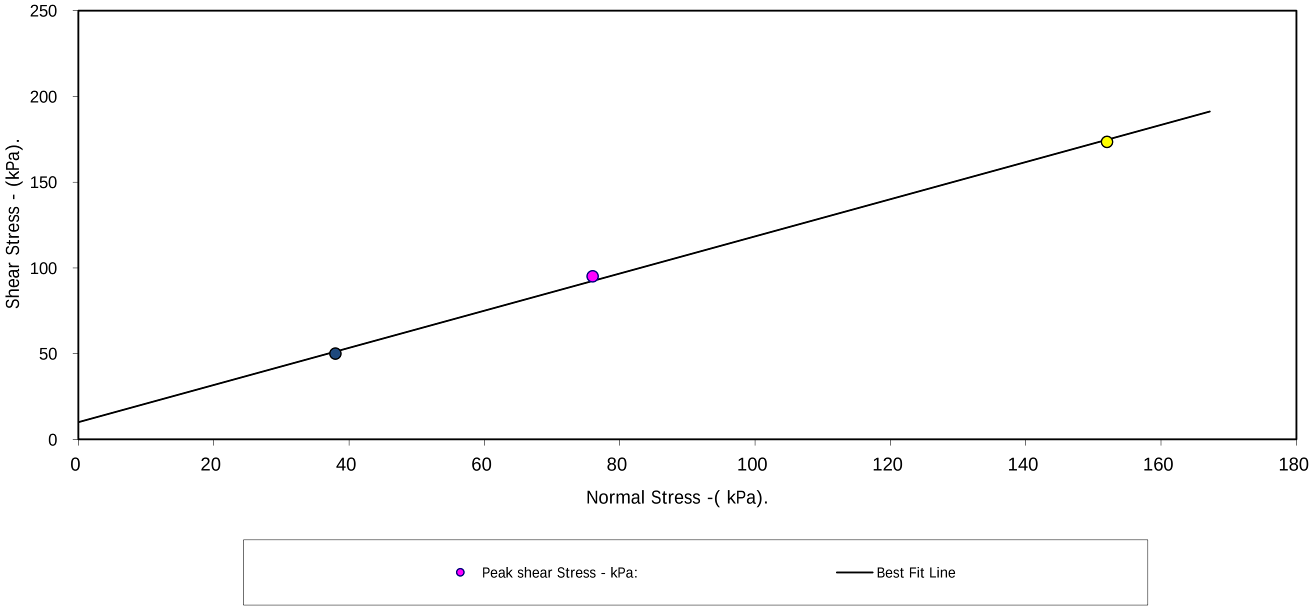
Borehole Number: TP102 Depth from (m): 3.80
Sample Number : N/A

Sample Type:	B
Particle Density - Mg/m3:	2.65 (Assumed)
Specimen Tested:	Remoulded (Light Tamping) Material above 20mm removed.
Sample Description: Brown slightly clayey fine to coarse GRAVEL	

STAGE	1	2	3
Initial Conditions			
Height - mm:	138.50	138.50	138.50
Length - mm:	300.00	300.00	300.00
Moisture Content - %:	16	16	16
Bulk Density - Mg/m3:	2.18	2.18	2.18
Dry Density - Mg/m3:	1.88	1.88	1.88
Voids Ratio:	0.4091	0.4091	0.4091
Normal Pressure- kPa	38	76	152
Consolidation			
Consolidated Height - mm:	133.20	131.40	131.57
Shear			
Rate of Strain (mm/min)	3.000	3.000	3.000
Strain at peak shear stress (%)	53.12	52.66	56.20
Peak shear Stress - kPa:	50	95	174

PEAK	
Angle of Shearing Resistance:(φ)	47.3
Effective Cohesion - kPa:	10

FAILURE CONDITIONS



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Approved Pages 1-4 by: Date

Contract No.:
46217

Godre'r Graig

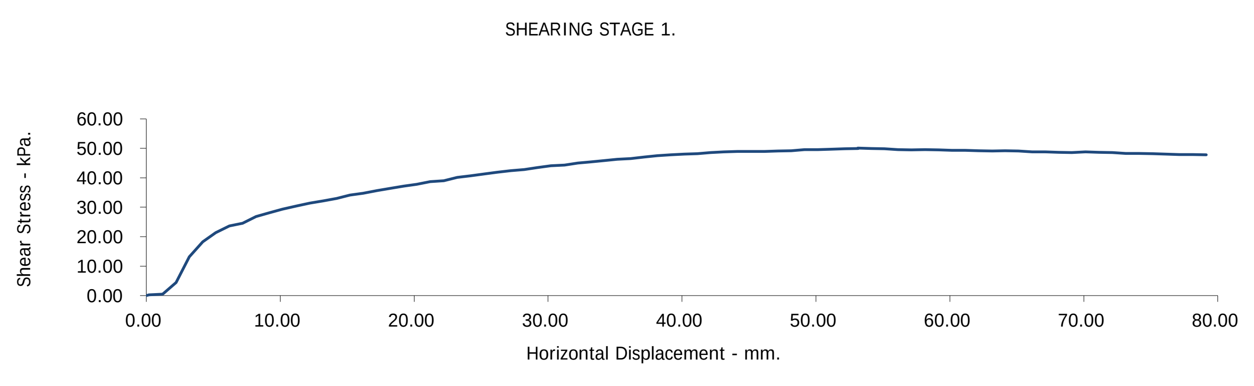
Client Ref Number:
7234e.02

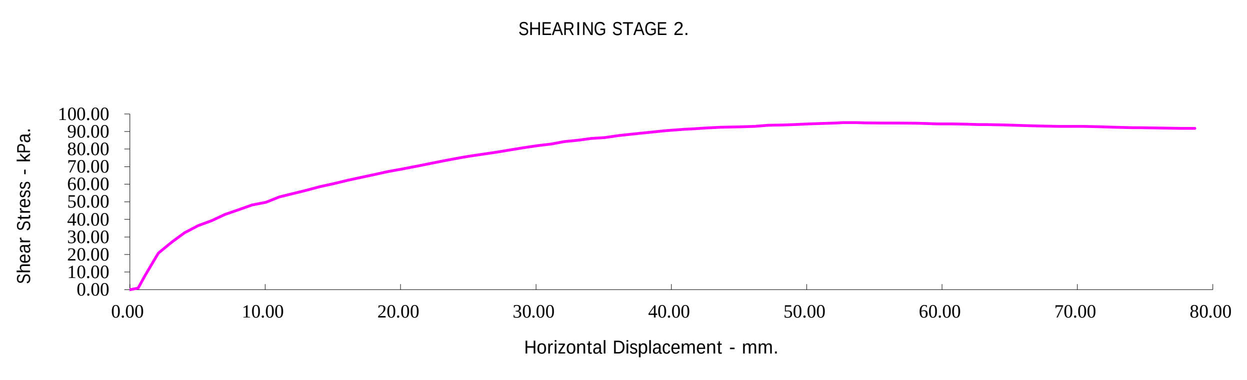
GSTL
GEO SITE & TESTING SERVICES LTD

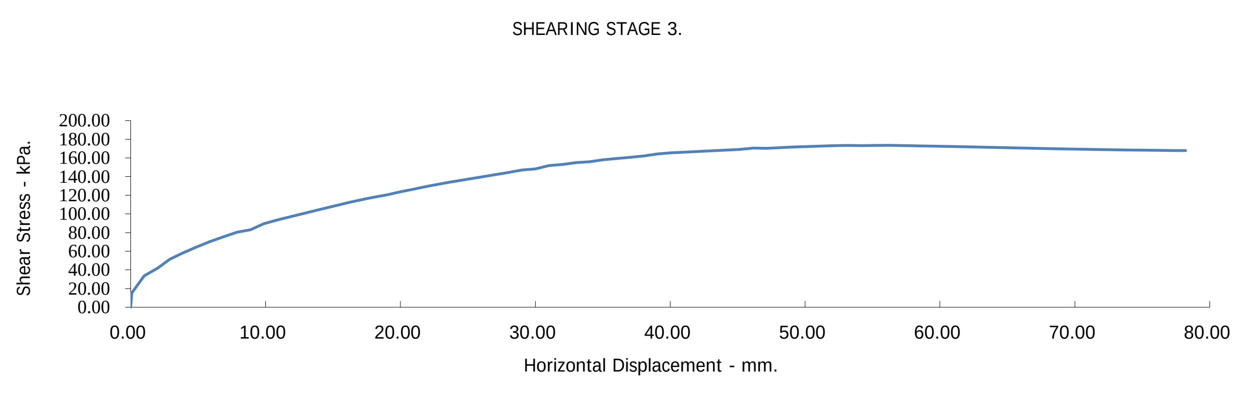
Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

BS1377:Part 7:5 :1990.

Borehole/Sample Number:	TP102	Depth (m):	3.80







Contract No.:
46217

Godre'r Graig

Client Ref Number:
7234e.02

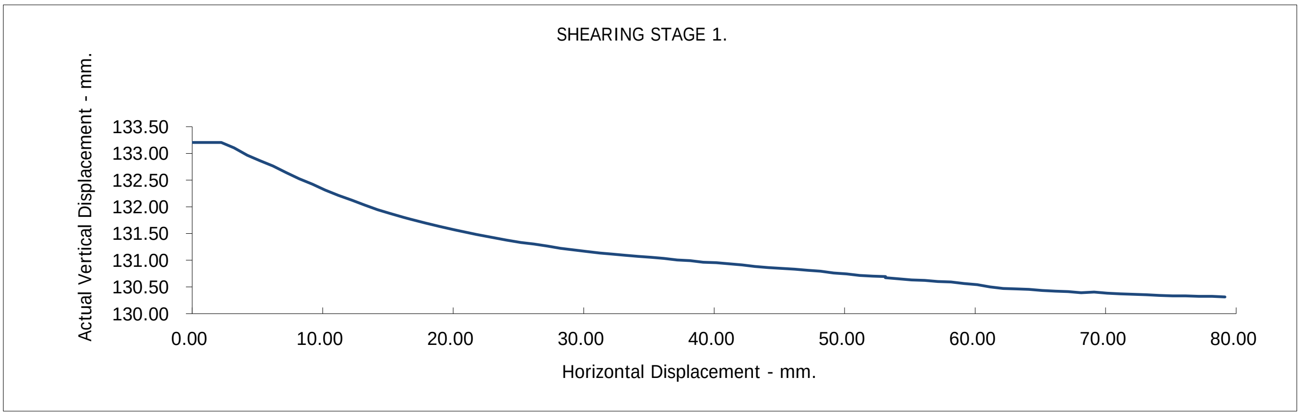
Figure.

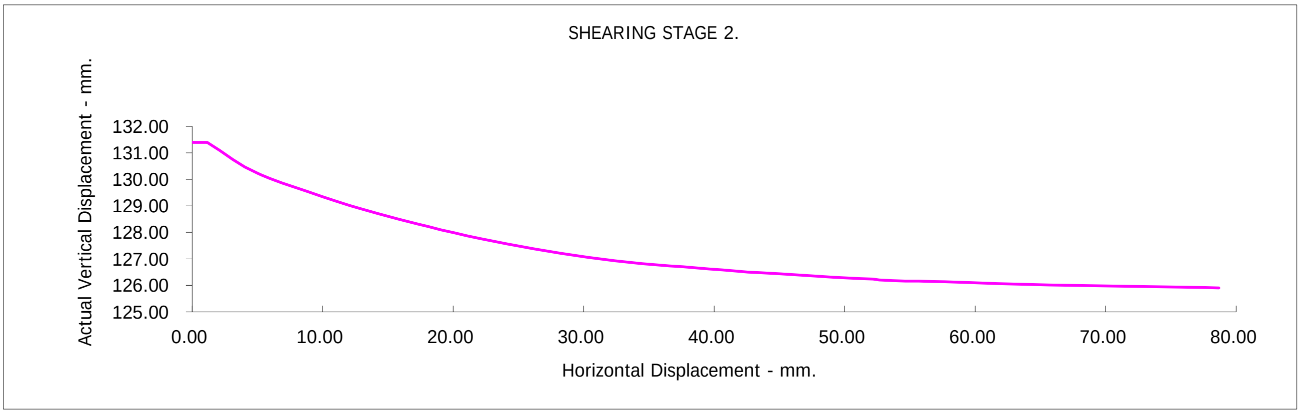
GSTL GEO SITE & TESTING SERVICES LTD

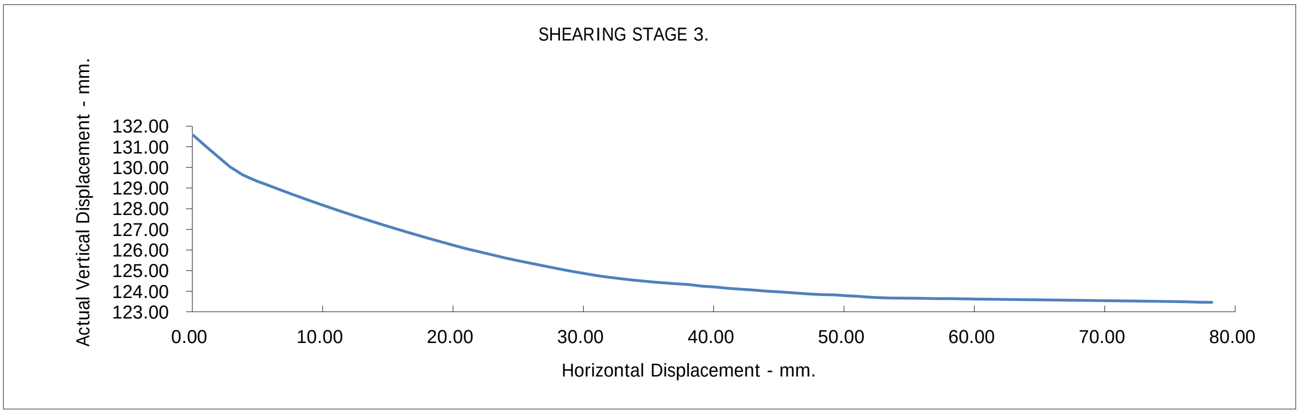
Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

BS1377:Part 7:5 :1990.

Borehole/Sample Number: TP102 Depth (m): 3.80







Contract No.:
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Godre'r Graig

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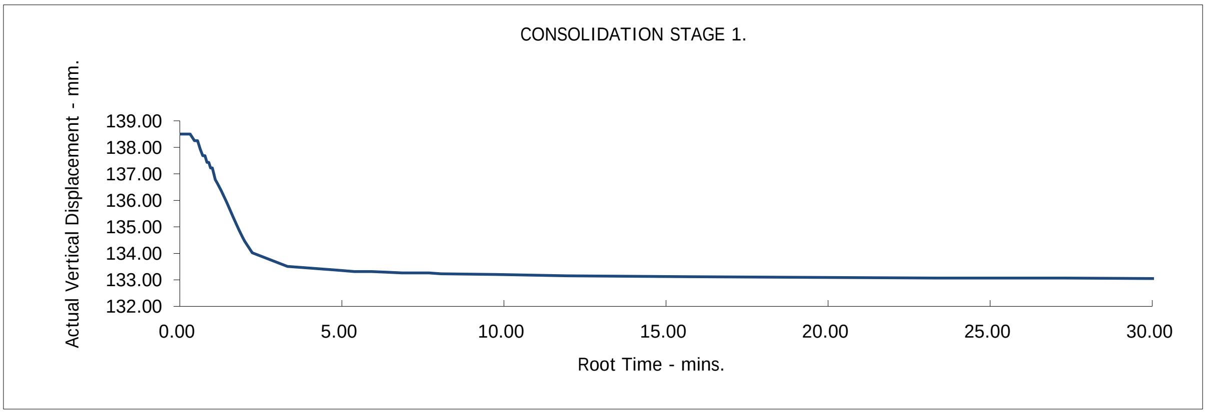
Figure.

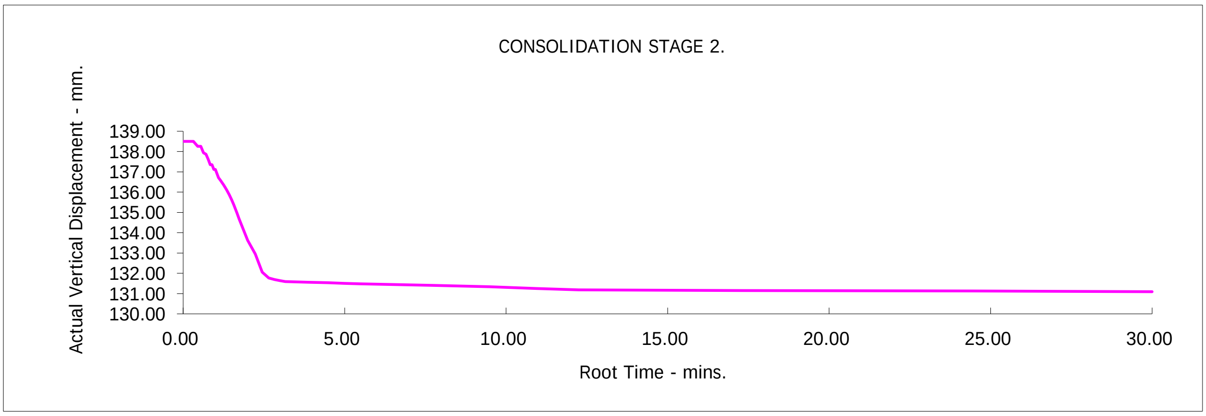
GSTL
GEO SITE & TESTING SERVICES LTD

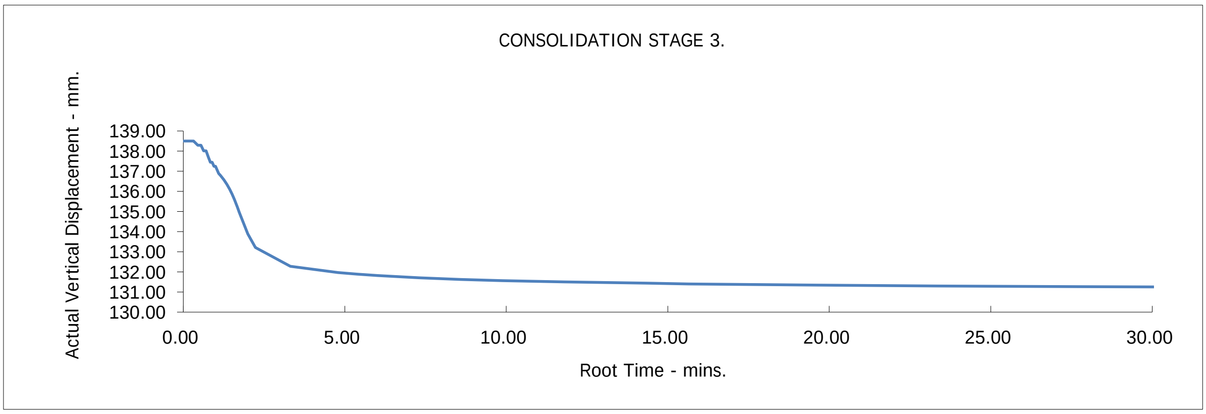
Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

BS1377:Part 7:5 :1990.

Borehole/Sample Number:	TP102	Depth (m):	3.80







Contract No.:
46217

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Client Ref Number:
7234e.02

Figure.

Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

BS1377:Part 7:5 :1990.

Borehole Number: TP104 Depth from (m): 1.00

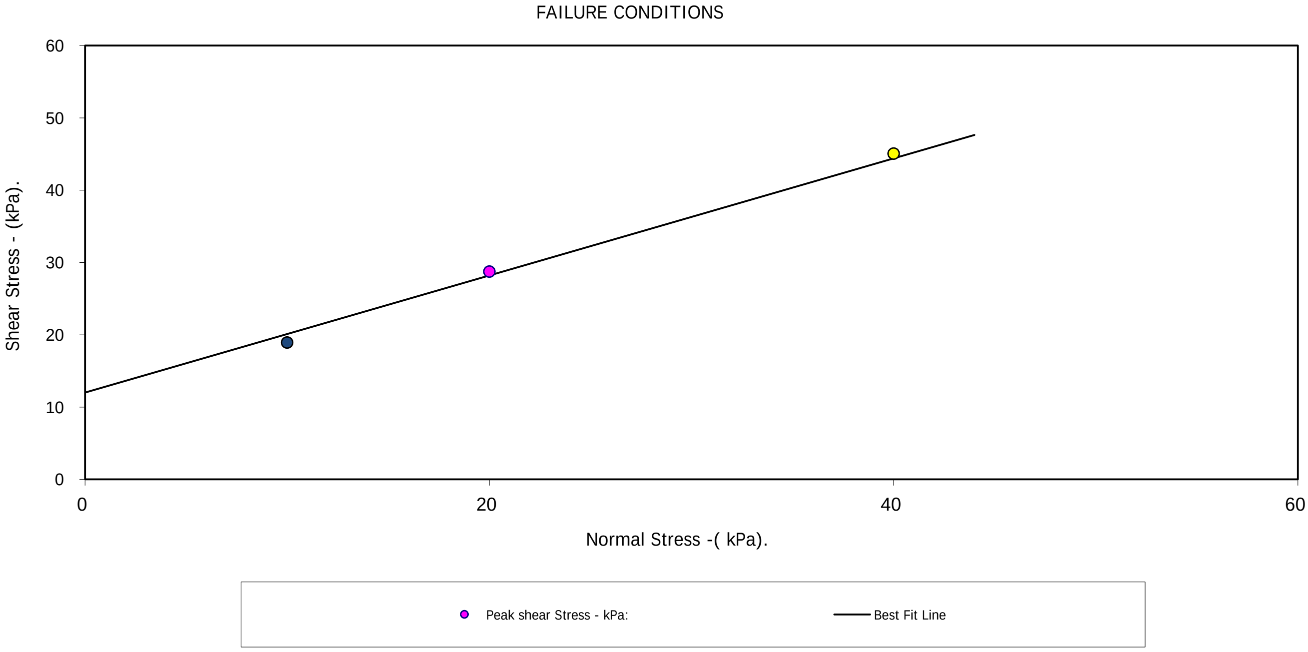
Sample Number : N/A

Sample Type:	B
Particle Density - Mg/m3:	2.65 (Assumed)
Specimen Tested:	Remoulded (Light Tamping) Material above 20mm removed.

Sample Description:
Brown fine to coarse gravelly silty CLAY

STAGE	1	2	3
Initial Conditions			
Height - mm:	133.50	133.50	133.50
Length - mm:	300.00	300.00	300.00
Moisture Content - %:	16	16	16
Bulk Density - Mg/m3:	2.13	2.13	2.13
Dry Density - Mg/m3:	1.83	1.83	1.83
Voids Ratio:	0.4447	0.4447	0.4447
Normal Pressure- kPa	10	20	40
Consolidation			
Consolidated Height - mm:	130.76	129.83	128.90
Shear			
Rate of Strain (mm/min)	3.000	3.000	3.000
Strain at peak shear stress (%)	71.44	70.29	69.14
Peak shear Stress - kPa:	19	29	45

PEAK	
Angle of Shearing Resistance:(θ)	39.0
Effective Cohesion - kPa:	12



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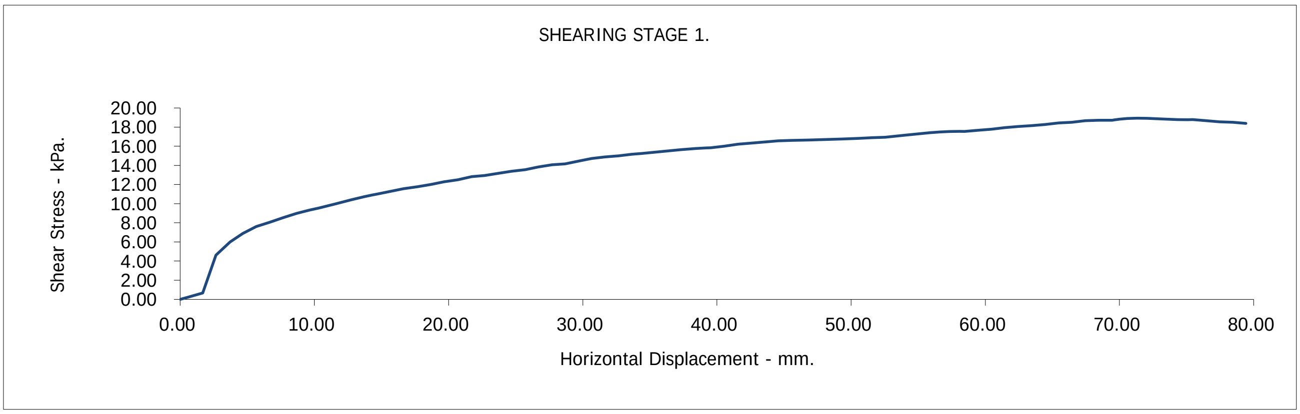
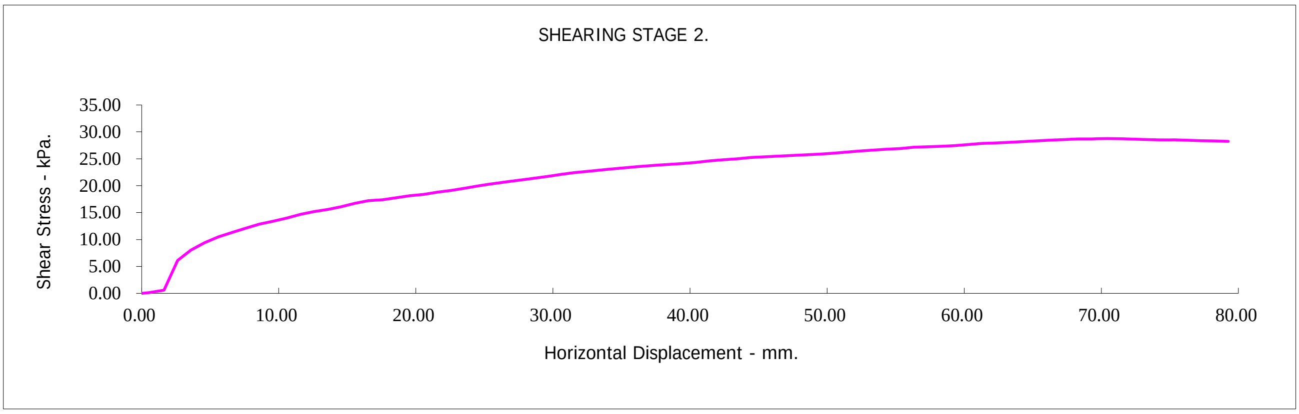
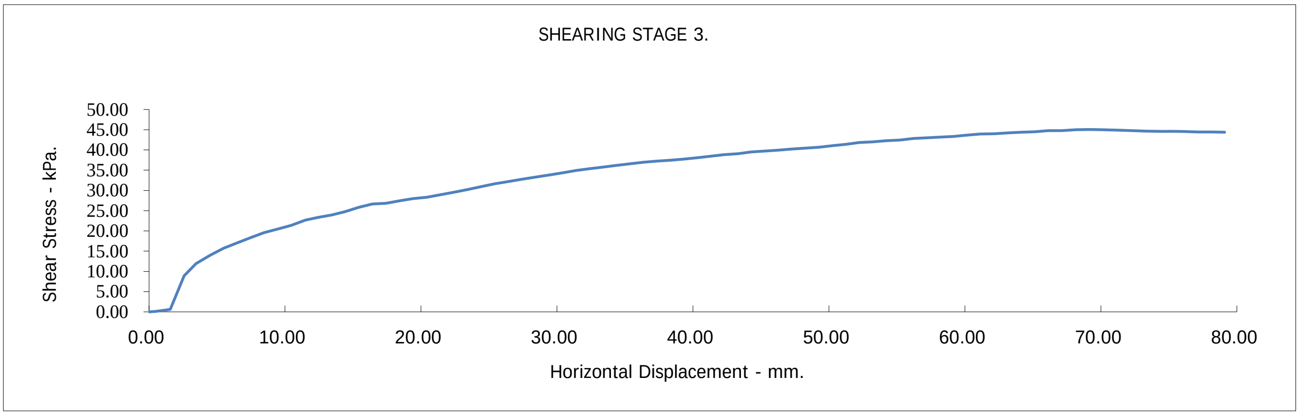
BS1377:Part 7:5 :1990.

Borehole/Sample Number:	TP104	Depth (m):	1.00







Godre'r Graig

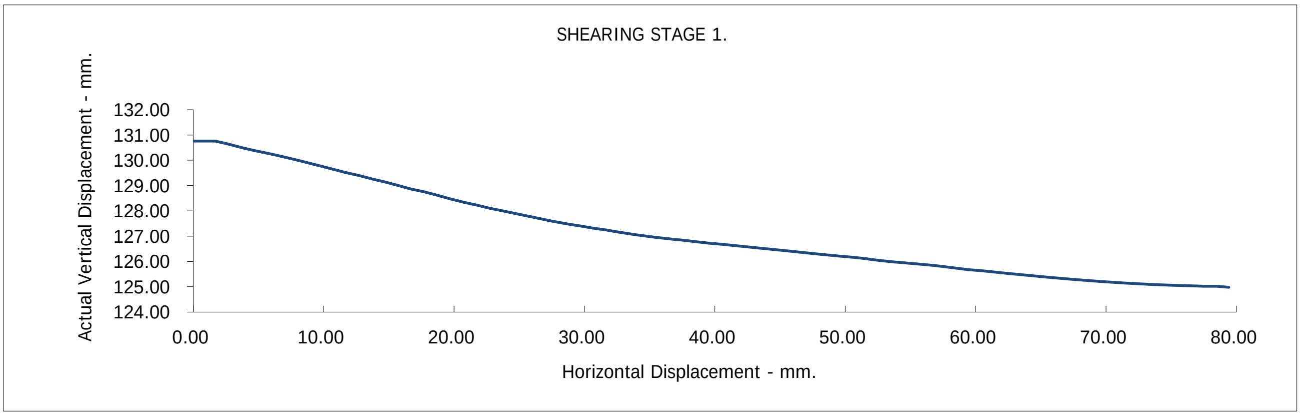
Contract No.:
46217

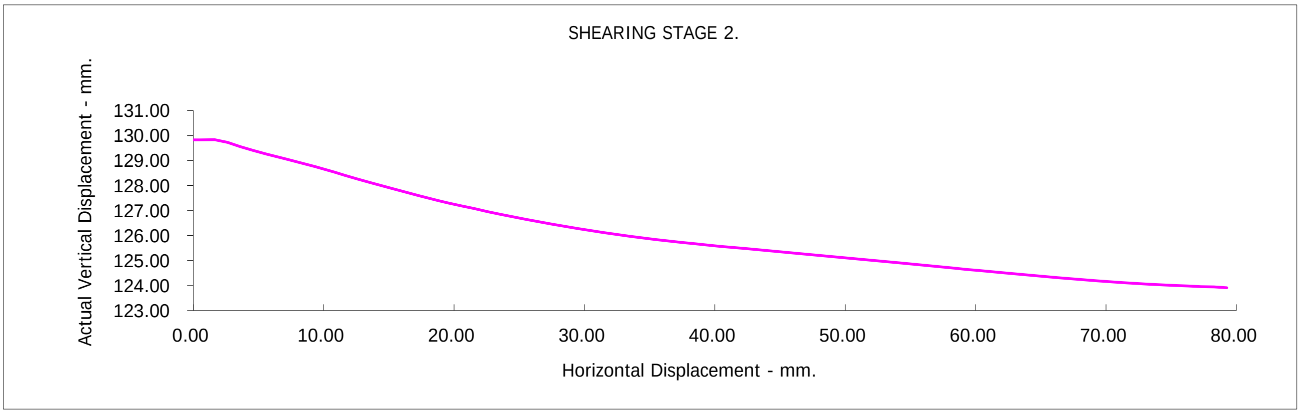
Client Ref Number:
7234e.02

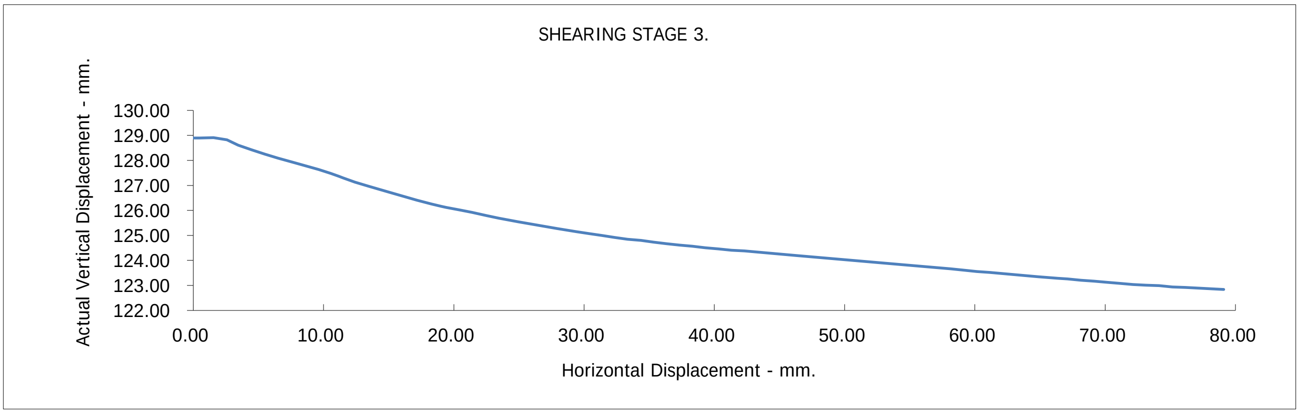
Figure.

Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.
BS1377:Part 7:5 :1990.

Borehole/Sample Number: TP104 Depth (m): 1.00







Contract No.:
46217

Godre'r Graig

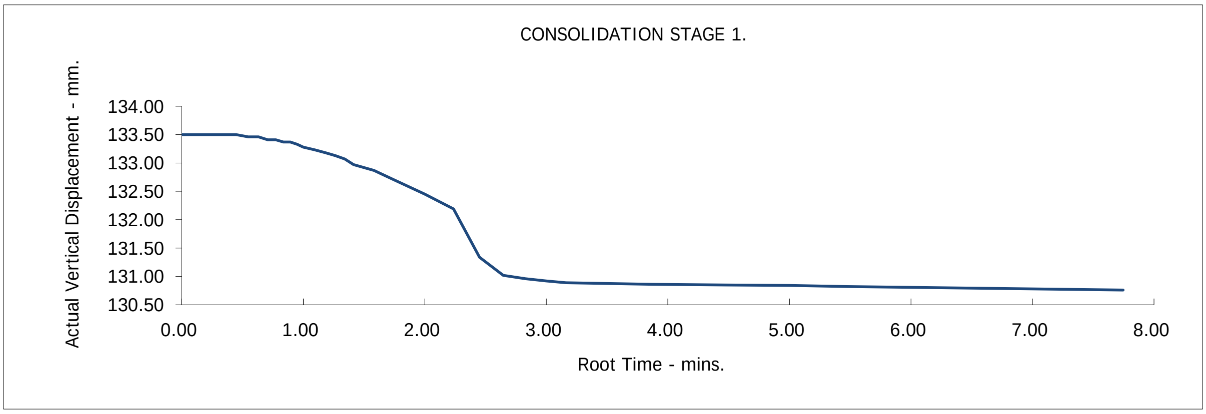
Client Ref Number:
7234e.02

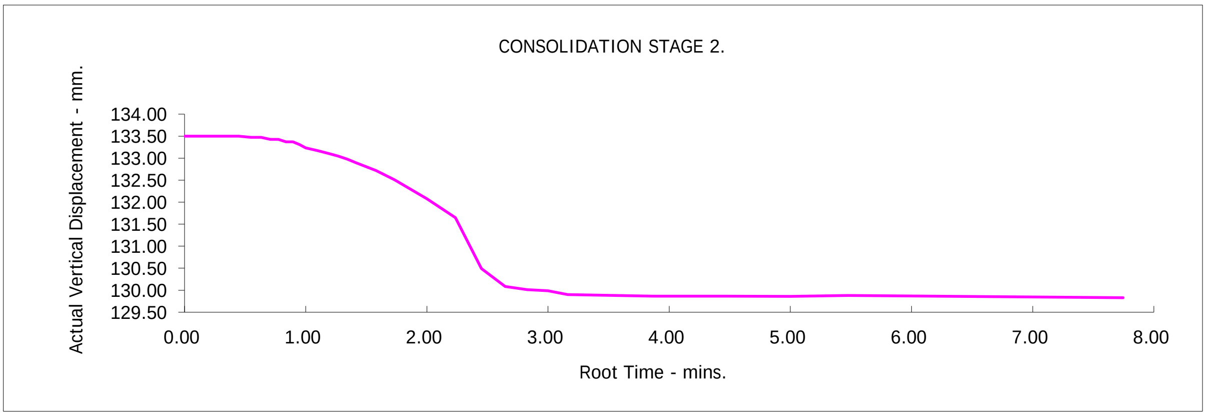
Figure.

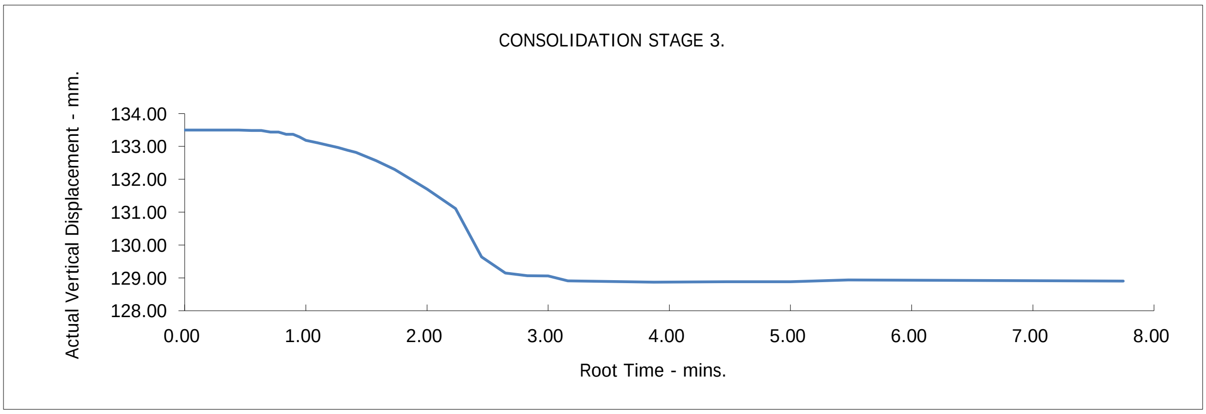
Test Report: CONSOLIDATED DRAINED LARGE SHEARBOX TEST.

BS1377:Part 7:5 :1990.

Borehole/Sample Number:	TP104	Depth (m):	1.00







Contract No.:
46217

Godre'r Graig

Client Ref Number:
7234e.02

Figure.

APPENDIX K GEOPHYICIAL SURVEY (TERRADAT, 2019)

GEOPHYSICAL SURVEY REPORT

Project

A geophysical investigation into the thickness of superficial / backfill material and potential slip surfaces

Location

Godre'r Graig Primary school, Ystalyfera, South Wales

Client

Earth Science Partnership

Head Office
Unit 1
Link Trade Park
Penarth Road
Cardiff CF11 8TQ
United Kingdom

Telephone: +44 (0)2920 700127
www.terradat.co.uk

down to earth geophysics

Job reference: 6738
Date: November 2019
Version: 1

GEOPHYSICAL SURVEY REPORT

Project

A geophysical investigation into the thickness of superficial / backfill material and potential slip surfaces

Location

Godre'r Graig Primary school, Ystalyfera, South Wales

Client

Earth Science Partnership

Project Geophysicist	R Stevens MESci (Int) FGS
Reviewer:	S Hughes PhD BSc FGS
Job Reference:	6738
Date:	November 2019

CONTENTS

FIGURES

APPENDICES

- Resistivity tomography
- Resistivity tables
- Seismic refraction
- Seismic MASW
- Electronic appendix – location map of seismic and ERT profiles

1 EXECUTIVE SUMMARY

A geophysical survey was carried out as part of the ground investigation into the stability of a spoil tip situated above the primary school in Godre'r Graig village, within the Swansea Valley. The survey work was commissioned by Earth Science Partnership (the Client). The work was designed to provide detailed information on the thickness of superficial / backfill deposits and identify potential slip surfaces, in order to compliment the corresponding intrusive investigation. The survey took place between the 21st and 24th October 2019.

A combination of Electrical Resistivity Tomography (ERT), seismic refraction and Multichannel Analysis of Surface Waves (MASW) surveys were acquired along three profile lines. Even though the position of the profile lines were somewhat constrained by the access along the steep slope, the line layout comprised of two perpendicular cross-lines and one down-slope profile.

The geophysical survey has delineated zones of contrasting resistivity values and seismic velocities that reflect the variable ground conditions at the site and both methods display a good correlation with the intrusive investigations. The ERT survey has defined four geoelectrical units; the upper two units are interpreted as backfill material with varying moisture and clay content, while the lower units represent sandstone and mudstone bedrock strata. The analysis of both seismic data has identified distinct velocity layers that relate to the stiffness/strength of the sub-surface material.

By considering the combined results, it has been possible to define the extent and depth of the backfill material within the survey area. It is suggested that the quarry has been significantly backfilled and this backfill material may extend beyond the survey towards the southwest.

There are no obvious thin weak/conductive layers with the data set, which are suggestive of potential slip planes. However, given the presence of extensive clay-rich material within the backfill material, this could act as a zone of weakness. There are also a number of lateral discontinues that have the potential to influence slope failure.

2 INTRODUCTION

A geophysical survey was carried out as part of the ground investigation into the stability of spoil material at Godre'r Graig. The survey work was commissioned by Earth Science Partnership (the Client) and was designed to complement the invasive investigation. The survey took place between on the 21st and 24th October 2019. The key aims of the geophysical survey were to (i) provide information on the thickness of superficial / backfill deposits and (ii) identify any potential slip surfaces.

2.1 Site description

The survey area was situated above the primary school in Godre'r Graig, on the northern side of the Swansea Valley with National Grid reference 275050E, 206975N. The focus of the survey was a historical spoil tip, which is located halfway up the hillside and consists of very uneven ground that was covered in vegetation (ferns, brambles and wooded areas). The survey comprised of three profile lines (Figure 1 and Plate 1); one slope parallel and two slope perpendicular profiles. To allow access along the profiles lines, a trackway to the centre of the area was installed and vegetation clearance was carried out prior to the survey.

Historically, the area has been extensively mined for coal with two coal levels recorded within the study area (Figure 1B). Quarrying has also occurred within the area, and evidence suggests that this ended before 1877 (Figure 1C).

Plate 1: *(Left) Survey location looking south east along profile 1 and (right) looking northeast along profile 3*

2.2 Geological setting

British Geological Survey records GeoIndex (NERC, 2019) and borehole logs (ESP 2019) indicate the presence of the following bedrock and superficial deposits at the site:

Superficial:

- Made ground deposits of unknown/unclassified rock type

Bedrock:

- Llynfi Member, which comprises of micaceous lithic arenites with thin mudstone/siltstone, seat earth interbeds and thin coals. The Llynfi member is separated into a sandstone member and a mudstone, siltstone and sandstone member.

2.3 Survey objectives

The primary objective of the survey is to determine the thickness of superficial / backfill deposits and identify potential slip surfaces.

2.4 Survey design

Given both the survey brief and the success of a similar survey acquired over the same geology (for the same Client, Terradat report 6025), it was decided to adopt an integrated survey approach comprising the following techniques*:*

- **Electrical Resistivity Tomography (ERT) (Wenner-Schlumberger configuration)** to provide electrical cross-sections along selected survey profiles that allow identification of geological boundaries, structures and lateral heterogeneities including variation in material composition, weathering, and faulting.

- **Compressional (P) wave seismic refraction** – to provide seismic velocity model sections that indicate the thickness of superficial deposits and the depth to non-rippable bedrock, in correlation with standard tables.

- **Shear (S) wave seismic refraction** – to provide seismic velocity model sections that indicate the depth to compacted sediments, weathered rockhead and more competent (higher shear strength) bedrock.

- **MASW (Multichannel Analysis of Surface Waves)** – to derive shear velocity (‘S-wave’ or ‘V_s’) from rolling surface waves, which can be used where velocity inversions are encountered.

Correlation of the models derived from the compressional (P) wave survey, shear (S) wave surveys and MASW can increase the degree of certainty for both seismic methods since they exploit different physical properties of the ground. In addition, overlying the seismic model results on the resistivity sections allows calibration in terms of identifying potential structural features that extend below rockhead.

2.5 Quality control

The geophysical data sets were collected in line with normal operating procedures as outlined by the instrument manufacturer and TerraDat company policy. On completion of the survey, the data were downloaded from the survey instrument on to a computer and backed up appropriately. The acquired data set was initially checked for errors that may be caused by instrument noise, low batteries, positional discrepancies, etc. and any field notes are either written up or incorporated in the initial data processing stage. The data set is then processed using the standard processing routines and once completed; the resulting plots are subject to peer review to ensure the integrity of the interpretation. Our quality control standards are BS EN ISO 9001: 2015 certified.

3 SURVEY DESCRIPTION

The survey was carried out using the following geophysical methods as outlined above in Section 2.4:

- Electrical resistivity tomography
- P-wave seismic refraction (employs compressional waves)
- S-wave seismic refraction (employs shear waves)
- MASW (Multichannel Analysis of Surface Waves)

Background information on the survey methods is provided in the appendices and descriptions of the actual survey work carried out on the site are provided in the sections below.

3.1 Survey limitations and considerations

For the geophysical surveys to fulfil the survey brief, there must be a measurable response between the target features and host material. Some of the main limitations and consideration are included below.

In addition to providing information on the various lithologies, one of the main objectives of the resistivity tomography survey is to target potential slip zones. Ideally, weak/broken zones in the rock where clay-rich material/ water have infiltrated, or a loss of fine-grained sediment voiding, will sufficiently alter the local ground resistivity to allow detection.

The survey output from both the P and S-wave refraction surveys are cross-sectional models that describe the bulk physical properties of the ground in terms of superficials, weathered rock and competent rock layers. There will be local variations in strength within the interpreted layers as a result of weathering, groundwater, lithology and the fracturing.

Seismic refraction requires that the velocity of the materials in the subsurface increases with the depth of burial. This is usually the case since (i) the degree of compaction within the overburden typically increases with depth, and (ii) bedrock condition improves with depth as weathering is reduced, both of which lead to higher seismic velocities. Therefore, one limitation of the refraction method is the inability to resolve localised weak zones within rock where it resides at a depth below the competent non-weathered rock.

3.2 Survey layout

Based on on-site considerations and overall project scope, three profile lines were established; one parallel to the slope and two cross (slope perpendicular) profiles (Figure 1). The start and end coordinates for each profile are provided in Table 1. They are also provided in electronic format on an accompanying AutoCAD plan. The overall line length was limited by a combination of accessibility (steep slopes) and the initial vegetation clearance. The profiles were surveyed using a

TOPCON HiPer Pro dGPS system, with an accuracy of +/- 2.5 cm and referenced to National Grid (OSTN02) using the Topcon network correction.

Profile Line ID	Start		End		Horizontal line length
	Eastings	Northings	Eastings	Northings	
P1_ERT	274987.28	207027.39	275105.31	206936.61	150
P1_Seismic	275000.93	207018.62	275100.99	206939.58	128
P2_ERT	275031.90	206923.79	275096.26	207025.77	120
P2_Seismic	275032.60	206923.53	275095.47	207025.26	120
P3_ERT	275003.74	206961.88	275107.33	207055.65	142
P3_Sesimic	275003.74	206961.88	275108.31	207056.47	142

***Table 1:** Profile start and end coordinates*

3.3 Resistivity Tomography (ERT)

3.3.1 Resistivity tomography – field activity

A 72-channel *IRIS SYSCAL* resistivity system (Plate 2) was used to acquire resistivity tomography profiles using the Wenner-Schlumberger electrode array. To ensure suitable resolution, ground coverage and depth of penetration, the resistivity surveys employed an electrode spacing of two meters, yielding modelled sections approximately 20 m deep.

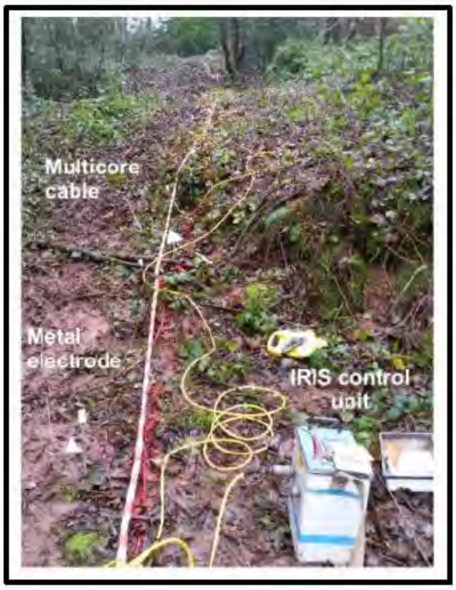


***Plate 2:** Typical resistivity tomography field set-up (library photo).*

3.3.2 Resistivity survey data processing

The resistivity data were downloaded from the SYSCAL instrument and initially edited using the dedicated PROSYS software package. For the tomography data set, the ground levels for each electrode were incorporated and the resistivity data set was subsequently processed (inverted) using RES2DINV software to derive modelled ‘true’ electrical cross-sections of the subsurface. The final inversion models used have an RMS error of less than 10 and are the third iteration. The resulting resistivity section was plotted using SURFER and then exported to CorelDraw for final annotation and presentation.

3.4 Seismic survey – P and S-wave refraction

A seismic survey involves generating a shock wave signal at the surface to investigate the geological structure beneath a chosen profile line. A series of vibration sensors (geophones) are deployed along the line and are used to record the travel times of incident seismic signal as it returns from below ground. Features such as rockhead, the water table, made ground, soft sediments and dense tills all have distinct velocity ranges and can be imaged in cross-section using a seismic refraction survey. A description of the field activity is provided below, and some further background information on the survey method can be found in the appendix.

3.4.1 Seismic survey field activity - Compressional (P) wave refraction

P-wave seismic refraction data were acquired along profile lines using a high precision 72 channel *GEODE* seismic system (Plate 3a). To target the broad depth range, low frequency (10 Hz) geophones were deployed at two-metre intervals providing individual geophone spread lengths of 142 m where possible. The seismic wave was generated by a combination of sledgehammer striking a plastic plate and Seismic Impulse Device (SID) firing a sequence of 12 and 8 gauge black powder cartridges (Plate 3b). To build up the refraction data set, seismic shots were taken at several positions along the geophone spread (usually every six geophones) and at set distances beyond the geophone spread. For this particular survey, the ‘offend’ shots were typically taken at 10, 30, and 60 m. Offend shot positions were chosen to ensure signals from the competent rock were recorded along the entire survey line in both forward and reversed directions.

Plate 3: *a) Field set-up and b) Seismic Impulse Device deployment (library picture).*

3.4.2 Seismic survey field activity - Shear (S) wave refraction

The S-wave seismic refraction data were acquired using a similar geophone cable and *GEODE* seismic recording system as the P-wave survey, but utilising the horizontal sensors instead. A weighted S-wave ‘H’ plate struck sideways with a sledgehammer was used as the energy source (Plate 4). At each shot location, the ‘H’ plate was aligned perpendicular to the profile line and subsequently struck on both ends sequentially to generate two sets of shear wave recordings with opposite polarity. This enables precise identification of the shear component of the seismic signal on the field records. Shots were deployed at several positions along the geophone spread and beyond both ends, typically at the same locations as the P-wave survey.

Plate 4: *S-wave source plate (library photo).*

3.4.3 Seismic refraction survey - data processing

The data processing was carried out using *PICKWIN* and *PLOTREFA* software. The first stage involved the accurate determination of the first-arrival times of the seismic signal (time from the shot going off to each recording geophone) for every shot record using *PICKWIN*. This is an involved process and is done manually since auto-picking routines are not reliable for on land environments.

Time-distance graphs showing the first-arrival times were then generated for each seismic line and analysed using *PLOTREFA* software to determine the number of seismic velocity layers. Modelled depth profiles for the observed seismic velocity layers were produced by a tomographic inversion procedure that was revised iteratively to develop the best-fit model. A transitional tomography velocity model may be considered if distinct layers are not expected or velocity contrasts between layers are marginal.

The final output of a seismic refraction survey is a velocity model section of the subsurface based on an observed layer sequence with measured velocities that correspond to physical properties such as levels of compaction/saturation in the case of sediments and strength/rippability in the case of bedrock. The final sections were then exported to *CorelDraw* for annotation and presentation.

3.5 Seismic survey – MASW

Multichannel Analysis of Surface Waves (MASW) employs ‘rolling’ surface waves to derive shear velocity. This is achieved through analysis of the dispersion that occurs as surface wave energy propagates through the subsurface and separates into different frequencies travelling at different velocities depending on the stiffness of the sediments and/or rock encountered.

This technique utilises Rayleigh-type surface waves (normally considered noise in seismic refraction/reflection surveys and called “ground roll") recorded by multiple geophones deployed on an even spacing and connected to a common recording device (seismograph), as shown in Plate 5.

As the dispersion of the seismic wave can be dependent on the geology and ground conditions (i.e. variability, terrain, etc.), MASW profiles are usually limited to relatively flat areas or where the ground is more homogenous.

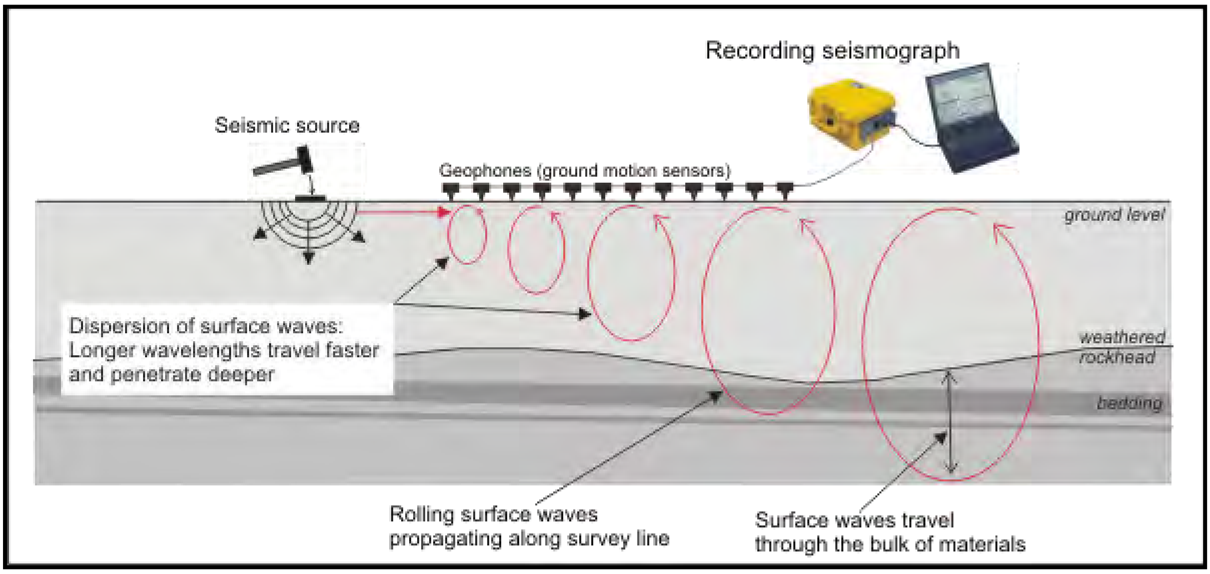


Plate 5: *MASW survey setup*

3.5.1 Seismic survey field activity: MASW

For this particular survey, a static geophone spread approach which was similar to the refraction set-up was used. However, instead of a discrete number of shot points, shots were acquired at every other geophone position along the profile. In this case, low frequency (10Hz) geophones were set at two-meter intervals, and the data were acquired using a sledgehammer plate. 18 geophones were used to create the dispersion curve; this is why the MASW section is shorter than the refraction data sets.

3.5.2 Seismic survey data processing - MASW

Analysis of surface waves recorded on multichannel shot records was carried out using SurfSeis™ 6.0 software, which considers the dispersion properties of all types of waves (both body and surface waves) through a wave field-transformation method. This directly converts the multichannel record into an image, where a dispersion pattern is recognised, and the necessary dispersion properties are extracted. These dispersion properties are used to generate modal dispersion curves that are subsequently inverted and used to produce the resultant shear-wave velocity (Vs) profile.

For this particular data set, only the fundamental mode was picked, and for consistency between the models, the same initial layer model parameters were used in the inversion process. Where it was not possible to pick a dispersion curve, the sounding was replaced with linear infill, between adjacent soundings. The final velocity sections are created in SURFER then exported to CorelDraw for annotation and presentation.

4 RESULTS AND DISCUSSION

The results of the geophysical surveys are presented as modelled ERT sections in Figures 2 to 3 and modelled seismic velocity sections in Figures 5 to 7. Important boundaries identified by the seismic refraction surveys are overlain on the resistivity sections to aid interpretation. Boreholes and trial pit data within 6 m of the profiles were also overlaid. A general description of the interpretation process and summary findings for each technique is given below.

4.1 Resistivity tomography (ERT)

The results of the resistivity tomography survey are presented as colour-contoured, scaled sections of the subsurface showing changes in resistivity. The same colour scale has been used for all sections to allow comparison between the recorded values. The vertical and horizontal axes display elevation above ordnance datum and chainage along the profile respectively. To illustrate the spatial relationship, a 3D representation of the ERT profiles is also included (Figure 2). To provide some depth calibration with both layers 3 and 4 from the shear wave refraction boundaries have been overlaid. Layer 3 is interpreted as dense soil /

weak rock, and layer 4 is interpreted as competent bedrock (please refer to section 4.2.2 for more detail).

4.1.1 Background to ERT interpretation

The interpretation of the modelled resistivity sections is generally based on both published electrical properties of typical sub-surface materials (see appendix), and when available, correlation with on-site information or observations. Table 2 shows the typical relationship between resistivity and geological setting. Values <100 Ohm.m are generally considered to be clay-bearing with increasing clay content proportional to the declining values (though moisture, where present and depending on its chemistry can also reduce resistivity values). Values over 100 Ohm.m indicate the increasing dominance of granular material and a reduction in moisture content. Where they occur at shallow depths, very high values typically indicate relatively more granular materials, where deeper they typically indicate the presence of competent bedrock

Resistivity (ohm.m)	Typical geological setting
High	Dry, granular clay-deficient material, air-filled voids, bedrock.
Intermediate	Mixed sediments, weathered bedrock.
Low	Clay-rich and/or water-saturated sediments.
Very Low	Metallic interference, leachate, ash.

***Table 2**: A simplified relationship between resistivity and geological setting*

4.1.2 ERT – summary discussion

The resulting ERT sections display a good correlation in terms of resistivity and features and the overall range of values (~90-1300 Ohm.m) is consistent with the expected geology. Based on the character of the profiles, it is possible to recognise four distinct layers.

Upper resistive layer (F1): This consists of both high and intermediate resistive material (400-1300 Ohm.m) and varies between 1 and 10 m thick.

Mid conductive layer (F2): This represents a layer of lower resistivity values (90-500 Ohm.m) that extends in places from near-surface to around 4 to 18 m bgl. This reduction in resistivity is likely to result from increased moisture and clay content, which based on the seismic results, it is predominantly within the backfill material.

Lower resistive layer (F3): This resistive layer (700-1300 Ohm.m) is laterally extensive across Profiles 2 and 3 and confined to the central region of Profile 1. Based on the seismic results and some very limited borehole information, this is interpreted as representing sandstone bedrock.

Lower conductive layer (F4): The lower conductive layer (90–200 Ohm.m) underlies Layer **F3** and due to the increased depth of penetration, it is only observed on Profiles 1 and 2. Based on the geological sequence (i.e. lithology and dip), this is believed to represent a mudstone unit

Within each layer, there are localised variations in terms of both resistivity values and geometry and these are discussed in more detail below.

Profile 1 (ERT)

There is a good correlation between layer **F1** and the gravel and cobble dominated made ground recorded in the intrusive investigation. This layer appears to increase in thickness and become more defined towards the northern end of the profile.

At 28 m chainage, there is a sub-vertical resistive feature (**F1a**) which could be a localised extension of Layer **F1** or is a separate feature within Layer **F2**. It is possible that this is due to a change in tipped material, or infilling of a hollow/extensional crack.

Within Layer **F2**, there appear to be three internal zones: **F2a** is the most northerly upslope zone and seems to be deeper than the other two. This is supported by the shear wave data, which suggests that the bedrock is at least 19 m bgl. This localised increase in the thickness of the backfill material correlates with the extents of the former quarry from the historical maps (Figures **1C** and **1D**).

Zone **2b** spans between 60 and 70 m chainage and extends to 11 m bgl. Given the position, it is possible that this may be connected with sub-vertical conductive feature (**F3a**) seen in the underlying resistive layer **F3**. The initial interpretation for the **F2b** zone is to suggest the infilling of surface hollow caused by a normal faulting or potentially, rotational slumping. Alternatively, this could be caused by an excavation of the Upper Pinchin Coal and subsequent backfilling. This alternative interpretation is further supported by the mapping of small audits on the same strike further northeast (Figures 1B and 1D).

Further downslope, layer **F2** increases in the thickness and becomes more laterally defined (**F2c**). At the southern end of the profile, this mid-conductive layer becomes almost indistinguishable to the mapped mudstone unit which was possibly encountered in the trial pit at the base of the slope.

Profile 2 (ERT)

The resulting resistivity section has a simpler layered structure compared to Line 1. The extent of the high resistive thin near-surface layers **F1b** is much more limited and the layer **F1** is more dominated by intermediate values.

Layer **F2** has a relatively undulating base and varies in thickness between 4 and 9 m. To the north of 90 m chainage, it is uncertain if it is the case that this layer pinches out or merges with more conductive material within layer **F1**. This could result from an absence of superficial / backfill material.

There is a very good correlation between the upper boundary of Layer **F3** and the lower S-wave refraction boundary, both of which support the sandstone bedrock interpretation.

Profile 3 (ERT)

To the east of 40 m chainage, the resulting section is again relatively simple and comparable with Profile 2. The most significant variation is a more laterally extensive near-surface high resistive material (**F1b**) and potentially Layer **F2** pinching out/outcropping towards the north.

Between 20 to 30 m chainages, there is a marked increase in the thickness of the upper resistive layer (**F1c**), which either relates to the tipping history or infilling of a former surface hollow.

There is a marked ‘step’ in the lower S-wave refraction boundary that seems to be associated with an apparent increase in the thickness of the mid conductive layer (**F2c**) and a termination of the lower resistive layer (**F3**). This also coincides with the change in lithologies from mudstone to sandstone. These deeper features occur near the end of the profile, therefore, they are not fully captured, and any interpretation will be limited. At this stage, it is uncertain if this deeper rockhead boundary is a result of geological processes or mining-related.

4.2 Seismic Refraction – compressional (P) and shear (S) wave

Interpretation of the refraction sections (Figures 5 to 7) is based on the widely understood and published velocities of common sub-surface materials as displayed in Figure 4. Given the prevailing ground conditions, the quality of the seismic data was comparatively good, especially as at some locations, where it was difficult to achieve good ground coupling with the geophones.

4.2.1 Compressional (P) wave

Analysis of the P-wave refraction data for this site suggests that up to four distinct layers of contrasting velocity (V_p) are present (Table 2). This analysis is based on the examination of the time-distance graphs in combination with the development of a best-fit model that follows an iterative process of forward modelling and tomographic inversion. Initially, the results are considered regarding transitional models and then if appropriate, transformed into a layered model. The key aim is to produce a best-fit layered velocity model that is in equilibrium with both the seismic data and the local geology.

As a guide, the resolution of a given refraction boundary is typically considered to be about 10% of its depth below ground level, which for a boundary at 10 m depth, would be +/- 1m. However, at very shallow depths, the resolution may vary/decrease as a function of geophone spacing and ground consistency. It is worth noting that the seismic refraction section represents the measured bulk characteristics of the subsurface and in some cases, it can prove difficult to correlate with point source data (boreholes/trial pits) where the underlying material is variable.

Layer	P-wave velocity	Soil/Rock Description
P1 (pink)	230-250 m/s (very low)	Weak near-surface layer of made ground/colluvium.
P2 (orange)	484-783 m/s (Low velocity)	Consolidated superficial/backfill material.
P3 (green)	1643 - 1746 m/s (medium velocity)	Very dense/wet sediments or soft/weak/fractured bedrock.
P4 (turquoise)	>2537 m/s (high velocity)	More competent/less weathered bedrock strata.

***Table 2:** A guide to P-wave velocity related to superficial/rock description for the site.*

Layer **P1** has a distinctly low velocity and usually relates to the loose near-surface superficial material (i.e. soft soil/ lose spoil). The range of velocities exhibited by Layer **P2** reflects increase consolidation of the dry superficial/backfill material.

Layer **P3** can be more intricate to discriminate as the overlap in velocities means that it can represent both sediments (dry compact or wet) and in some cases bedrock strata (weathered/weak/fractured). The most effective way to differentiate between sediment and rock type material is to consider the corresponding S-wave velocity, as discussed below.

Layer **P4** represents the highest (and deepest) velocity unit and is likely to reflect a competent boundary within the bedrock strata.

4.2.2 Shear (S) wave

By carrying out a similar analysis of the S-wave refraction data, the subsequently derived four-layer velocity model (Table 3) may be correlated against the standard S-wave velocity tables (Figure 4). In general, the shear-wave velocity (V_s) is much more sensitive than the P-wave velocity (V_p), where the ground becomes abruptly stiffer due to increases in rock strength. For this reason, it is possible to use the V_s to distinguish between sediments and 'rock' (i.e. cemented) material, which is particularly useful for differentiating the P-wave layer **P3**. A further advantage of shear waves is that they are unaffected by the groundwater table.

Layer	S-wave velocity (m/s)	Soil/Rock Description
S1 (pale grey)	70-73 m/s	Soft soil - weak near-surface layer.
S2 (light grey)	319-335 m/s	Stiff soil - poorly consolidated sediments.
S3 (medium grey)	458-470 m/s	Dense soil / weak rock.
S3 (dark grey)	>846 m/s	Competent bedrock.

Table 3: *A guide to S-wave velocity related to superficial/rock description for the site.*

When comparing the resulting P-wave and S-wave velocity sections, there is a rough 'rule of thumb' with regards to the ratio of the velocities. For unconsolidated sediment, V_p/V_s is usually between 4.0 to 8.0, while for consolidated rocks, the V_p/V_s ratio can vary between 1.5 to 2.0. Even though these are accepted values, they can vary between sites depending on the geology and ground conditions.

When cross-correlating the respective P-wave and S-wave refraction boundaries, in some instances there can be discrepancies in observed depth values. This depends on the prevailing geology and can reflect different survey parameters (horizontal/vertical polarised S-waves, spacing, etc.), weathering profile (vertical and horizontal), lithology or bedding structure. It has been noted on some sites that the S-wave or P-wave refractor appears to correlate with internal bedding units as opposed to the general rock mass.

4.2.3 MASW

The results of the MASW survey are presented as colour contoured S-wave velocity panels showing changes in velocity (i.e. ground stiffness) below the surface. The vertical and horizontal axes respectively display depth/elevation and chainage along the profile line. In principle, an increase in velocity usually indicates a relative increase in material stiffness. The velocity panels have been overlaid with the interpreted S-wave and P-wave refraction boundaries, which can assist the interpretation. The MASW technique can often resolve velocity layers (especially 'hidden' low-velocity layers) which are not detectable by the refraction method. Generally, though, the calculated S-wave velocities from the MASW survey can be slightly underestimated compared to the refraction survey due to the 'averaging' effect of the seismic wave dispersion.

Even though the resulting dispersion curves were marginal in terms of quality, the derived S-wave velocity panels appear to be consistent with the geology and seismic refraction results.

4.2.4 Discussion of seismic results

The three profiles are discussed in detail below.

Profile 1 (Figure 5 Seismic results)

This profile is parallel to the slope; it crosses a number of different mapped geological units. The apparent dip of the bedrock bedding is similar to the topography.

The near-surface **P1** undulates in thickness between 2 and 4 m, this does not directly correlate with the boreholes present along with the profile, Layer **S1** correlates well with the made ground topsoil boundary, varies in thickness from 0.2- 2 m the layer and thins out on the steepest sections of the profile.

Layer **P2** forms an irregular layer which represents less consolidated; dry sediments interpreted as superficial/backfill material (V_p 484 m/s). In Profile 1, this layer varies in thickness from around 0 to 7 m, with decreased thickness downslope. **S2** bisects **P2** and is interpreted to represent local variation in the weathering/consolidation of the made ground.

The top of layer **P3** is (V_p 1643 m/s) is undulating 2-7 m bgl and decreases in thickness from the northwest to the southeast (i.e. downslope) from 2 to 7 m respectively. The top of this unit is currently logged as made ground with SPT values of greater than 50 within the layer, however, the trial pit at the base of the slope interprets this layer as possibly natural clay. Therefore, it is thought **P3** comprises of both compacted saturated sediment and weathered bedrock.

The lower P-wave refraction boundary (**P4**) is relatively flat and varies in depth of between 5 and 12 m bgl, this correlates with the apparent dip of the bedding. There is a lateral velocity transition within layer **P4**, from 2537 m/s to 3739 m/s, northwest to the southeast respectively. This could represent a transition in bedrock type and based on the P-wave velocity (V_p) of greater than 2537 m/s, this lower refraction boundary represents a more competent/less weathered boundary within the bedrock strata.

Based on the velocity of $>V_s$ 846 m/s, the lower S-wave boundary (**S4**) is interpreted as competent bedrock. The deviation between the P and S-wave boundaries can be relatively common on sites where there are local variations in the weathering profile or subtle changes in lithology/groundwater. Between 30 and 90 m chainages, there is a large variation between the P and S-wave boundaries, the **S4** boundary decreases in depth from 18 m to approximately 7 m bgl, whilst **P4** remains at approximately 18 m bgl. This is interpreted to be caused by the P-wave boundary being guided along more competent strata within the bedrock. The S-wave refraction boundary (**S4**) is consistent with the ERT **F4** unit.

The corresponding MASW velocity panel displays a general increase in stiffness (i.e. S-wave velocity) with depth. There is an apparently elevated region within the central section that is consistent with the S-wave refraction.

Profile 2 – (Figure 6 Seismic results)

This is the lower of the two slope perpendicular profiles, the profile also traverses upslope towards the northeast. The profile length was limited to the northeast as the slope angle made it inaccessible.

All the P-wave refraction layers consistently thin from the southwest to the northeast; layer **P3** thins most significantly, from 5 to 1 m. This is interpreted as a thinning of the superficial deposits towards the northeast. **S1** correlates with the made ground topsoil layer and **S2** correlates with the transition between gravel and clay dominated made ground. Where Profile 1 intersects Profile 2, the upper two P-wave layers are consistent; however, **P3** has an increased depth of 7 m in P1. This disparity is due to the issue with lower refraction boundary below Profile 1, which has already been discussed above.

The shear wave boundaries are consistent between Profiles 1 and 2 where they intersect. There is a noticeable decrease in the depth of **S4** from 15 m to 4 m bgl across the profile from southwest to northeast this is potentially due to the decrease in backfill material. The ‘step’ decrease in the depth of **S4** at 80m chainage possibly represents the edge or internal boundary within the spoil tip. This corresponds to where the topography slope angle starts to dramatically increase and when discussed with the client, it is concurrent with the inferred edge of the spoil tip based on stereoscopic imagery.

The MASW panel for Profile 2 also displays an increase in velocity at the **P4**/**S4** boundary, the velocity contrast is more transitional. Significantly there are no velocity inversions observed. The MASW suggests that the ground is more heterogeneous than observed in the S-wave refraction.

Profile 3 (Figure 7 Seismic results)

This is the upper of the two slope perpendicular profiles it runs along the trackway built to access the site and has a number of nearby intrusive investigations. The resulting section is very consistent with Profile 2.

The top two layers for both the P and S wave are almost sub-parallel to ground level. **S1** correlates well with the made ground topsoil. Layer **P2** noticeably pinches out between 40-50 m chainage but is generally 2 to 5 m thick. **P2** is 2 m thick in Profile 1 and is not present on Profile 3. At boreholes 03 and 02 SPT values of >50 coincide with the top of **P2** (783 m/s). The intersection of the S-wave Profiles 1 and 3 correlate very well.

As observed with Profile 2, there is a marked (~12 m) disparity between the lower P-wave boundaries which has already been discussed above. On both the lower seismic boundaries (**P4** and **S4),** between 0 and 32 m chainage the boundary is 15 m bgl and then shallows to 8 m bgl after 32 m chainage. This deepening correlates with the ERT and the change in the mapped lithology from mudstone to sandstone. At this stage, it is uncertain if this deeper rockhead boundary is a result of geological processes (weathering/faulting) or mining-related.

The MASW panel correlates well with the boundary for **P4** and **S4** after 40 m chainage, prior to this the increase in shear strength is approximately 5 m above the refraction boundary. This is an area of poor dispersion with limited data coverage.

5 CONCLUSIONS

- The geophysical survey has provided a non-invasive means for investigating the subsurface with a high degree of spatial coverage in an area of difficult access. The resulting sections exhibit similar features throughout the area that reflects the consistency of the ground conditions.

- The modelled resistivity sections were characterised by zones of contrasting resistivity values that reflect lithological, hydrogeological, structural and weathering variations within the sub-surface. Four layers have been identified based on their geo-electrical properties and correlation with the seismic boundaries and intrusive investigations.

- The ERT survey has defined four geoelectrical units; the upper two units are interpreted as backfill material with varying moisture and clay content, while the lower units represent sandstone and mudstone bedrock strata. Within each of these units, there are some localised variations which may be significant to understanding the sub-surface conditions.

- The analysis of both the P and S-wave refraction data has identified distinct velocity layers that provided detailed information to assist with the bulk characterisation of the shallow subsurface. There is a reasonably good correlation between the corresponding P-wave and S- wave velocity boundaries. However, there are some disparities, which can be relatively common where there are local variations in the weathering profile or subtle changes in lithology/groundwater.

- By considering the combined results, it has been possible to define the extent and depth of the backfill material within the survey area. It would appear that the quarry has been significantly backfilled and this backfill material may extend beyond the survey towards the southwest.

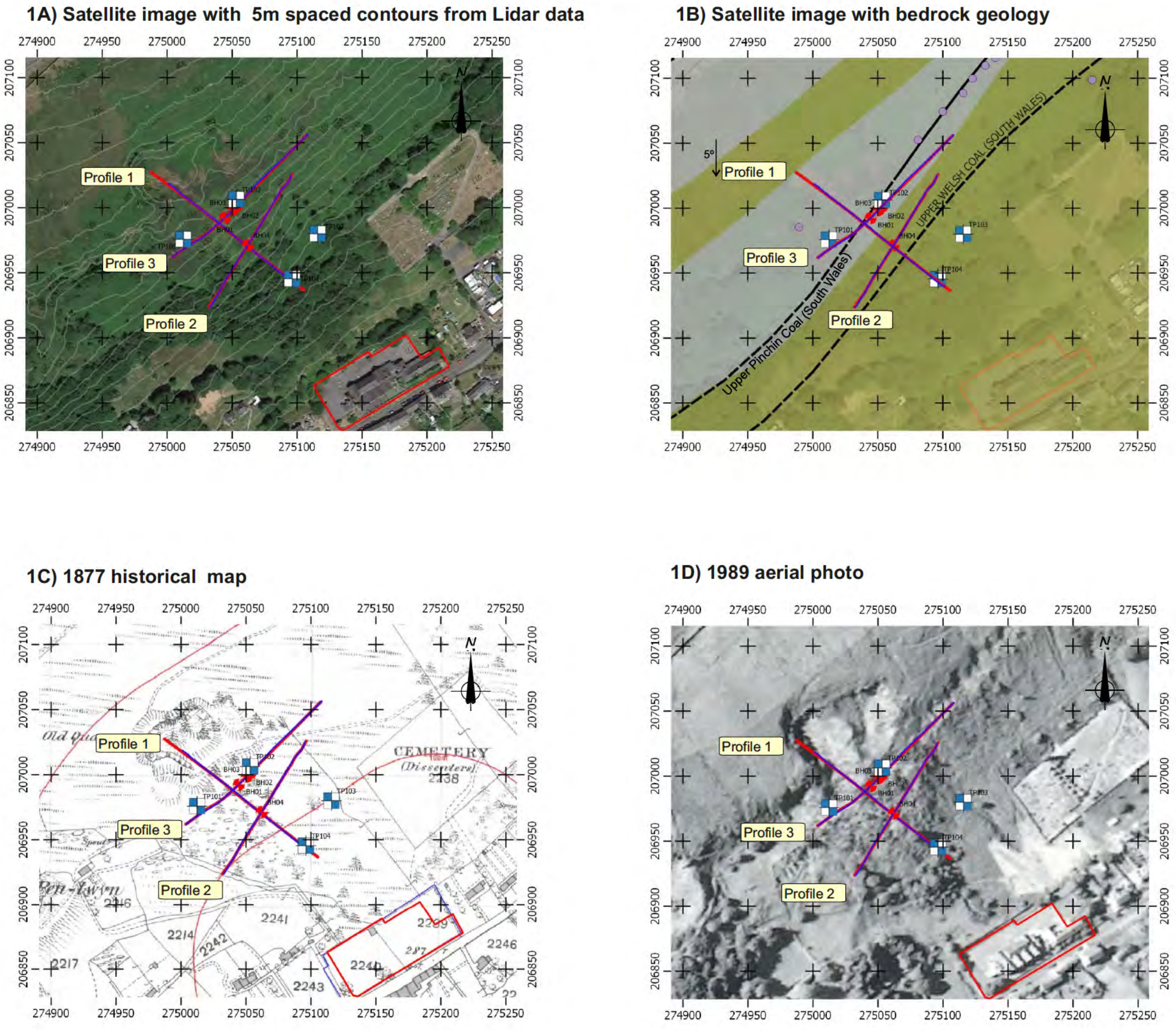
- On the identification of potential slip planes, there are no obvious thin weak/conductive layers with the data set. However, given the presence of extensive clay-rich material within the backfill material, this could act as a zone of weakness. There are also a number of lateral discontinues that have the potential to influence slope failure.

- An electronic AutoCAD plan (OSTN02 coordinates) of the resistivity tomography profiles and seismic refraction profiles is included. Handheld GPS instruments are not accurate in this area, and survey-grade dGPS units should be used for locating features.

Disclaimer

This report represents an opinionated interpretation of the geophysical data. It is intended for guidance with follow-up invasive investigation. Features that do not produce measurable geophysical anomalies or are hidden by other features may remain undetected. Geophysical surveys complement invasive/destructive methods and provide a tool for investigating the subsurface; they do not produce data that can be taken to represent all of the ground conditions found within the surveyed area. Areas that have not been surveyed due to obstructed access or any other reason are excluded from the interpretation.

FIGURES

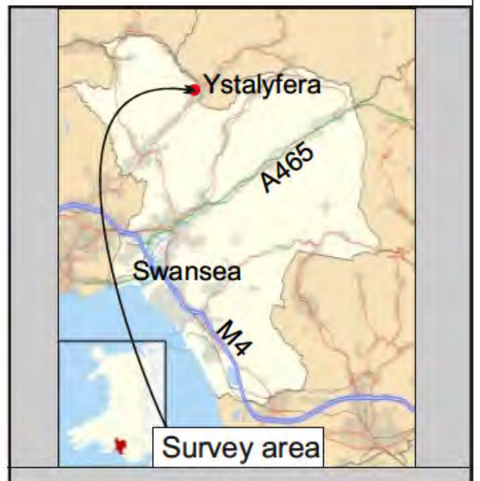


1A) Satellite image with 5m spaced contours from Lidar data

1B) Satellite image with bedrock geology

1C) 1877 historical map

1D) 1989 aerial photo



KEY

🟥	Electrical resistivity tomography profile
🟦	Seismic refraction and MASW techniques profile
▭	Primary school boundary
▦	2019 ESP trial pit locations
◐	2019 ESP borehole locations
●	Mine entires from coal authority

Geological KEY

🟩	Llynfi Member sandstone
⬜	Llynfi Member mudstone, siltstone and sandstone
╱	Coal

Notes

Source: Map data ©2019 Google.

Contains: Ordnance Survey data © Crown copyright and database right 2019

Contains: British Geological Survey materials © NERC [2019]
Contains: Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved.

Contains: client basemap, historical map and aerial photo

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Title:

LOCATION MAP

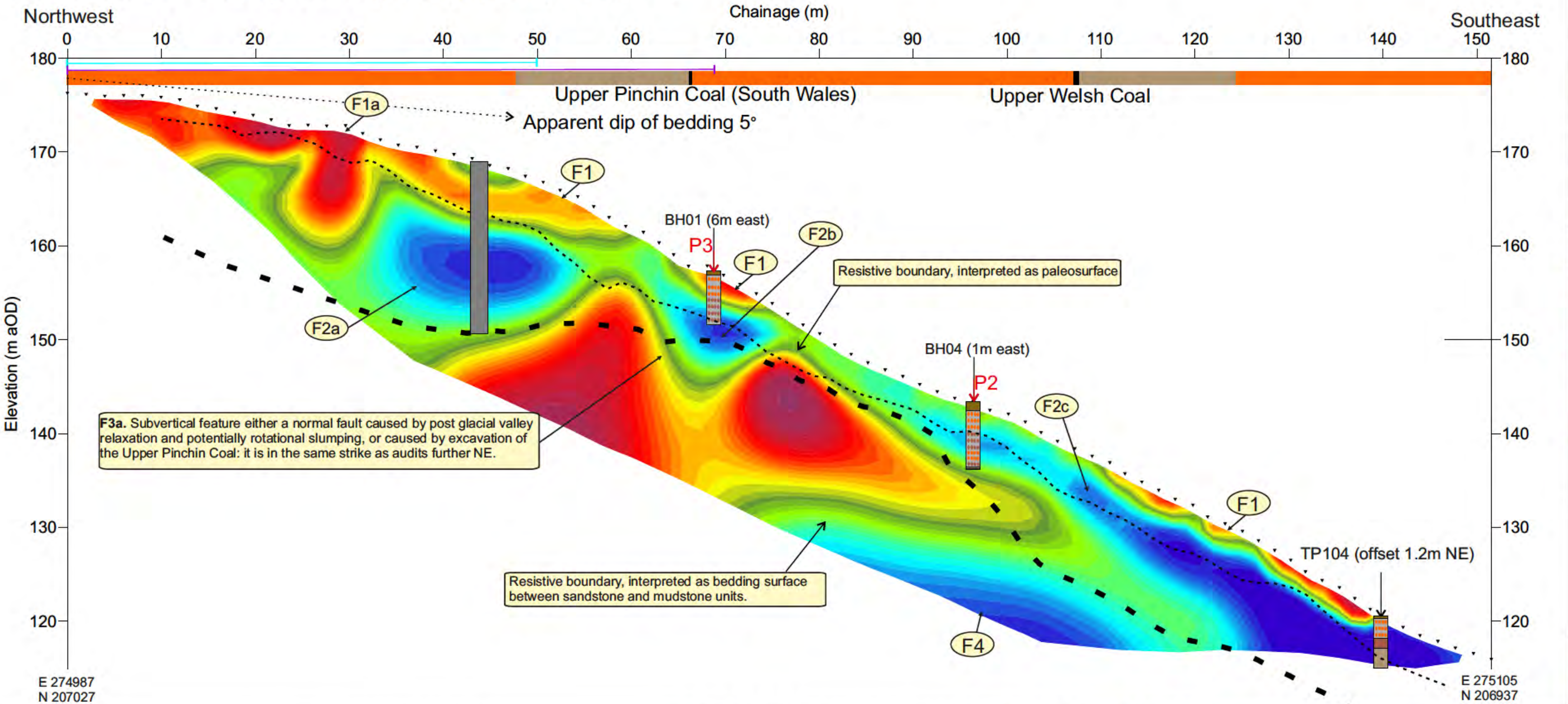
Project:

Godre'r Graig Primary school, Ystalyfera

Scale: 1:3000 at A3
Drawn by/Ref: RS/6738/1
Date: 19th November 2019

FIGURE 1

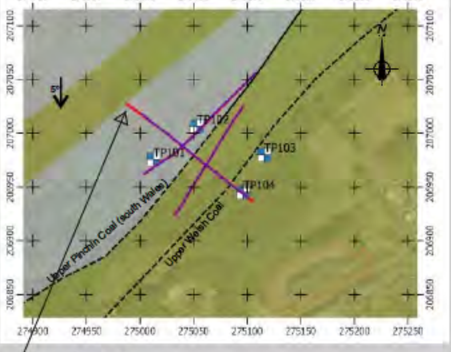
Electrical resistivity tomography (ERT) Profile 1



F3a. Subvertical feature either a normal fault caused by post glacial valley relaxation and potentially rotational slumping, or caused by excavation of the Upper Pinchin Coal: it is in the same strike as audits further NE.

Resistive boundary, interpreted as bedding surface between sandstone and mudstone units.

Location Plan (NTS)



Profile 1

KEY

- ▼ Electrode location
- ⬭ Highlighted feature
- P* Indicates the intersection of the Profile and its number
- 🟧 Sandstone
- ▬ Mudstone, siltstone and sandstone
- ▌ Coal
- ⊢⊣ Extents of quarry fill in 1877
- ⊢⊣ Extents of quarry fill in 1989

Shear (S) wave seismic velocity (m/S)

- ····· Layer 3 (470 m/s) (interpreted as dense soil / weak rock)
- ▪ ▪ ▪ Layer 4 (929 m/s) (interpreted as competent rock)

COLOUR SCALE

Increasing resistivity →

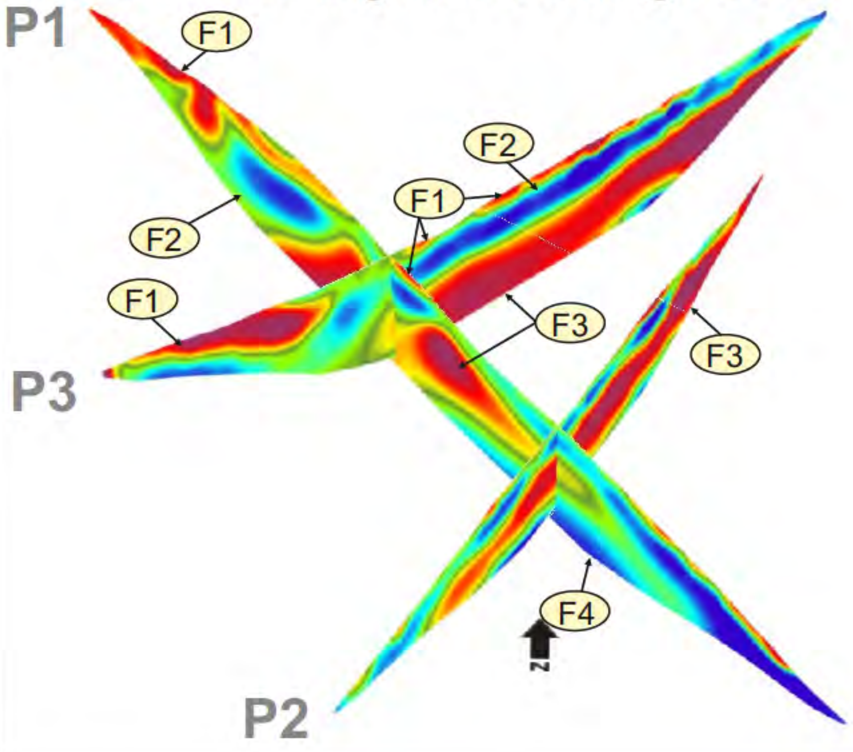
96.08, 172.5, 214.4, 246.4, 284.1, 316.5, 345.2, 378.2, 423.1, 466.2, 527.6, 590.2, 655.9, 742.8, 833.3, 976.1, 1272

Modelled "true" resistivity (ohm-m)

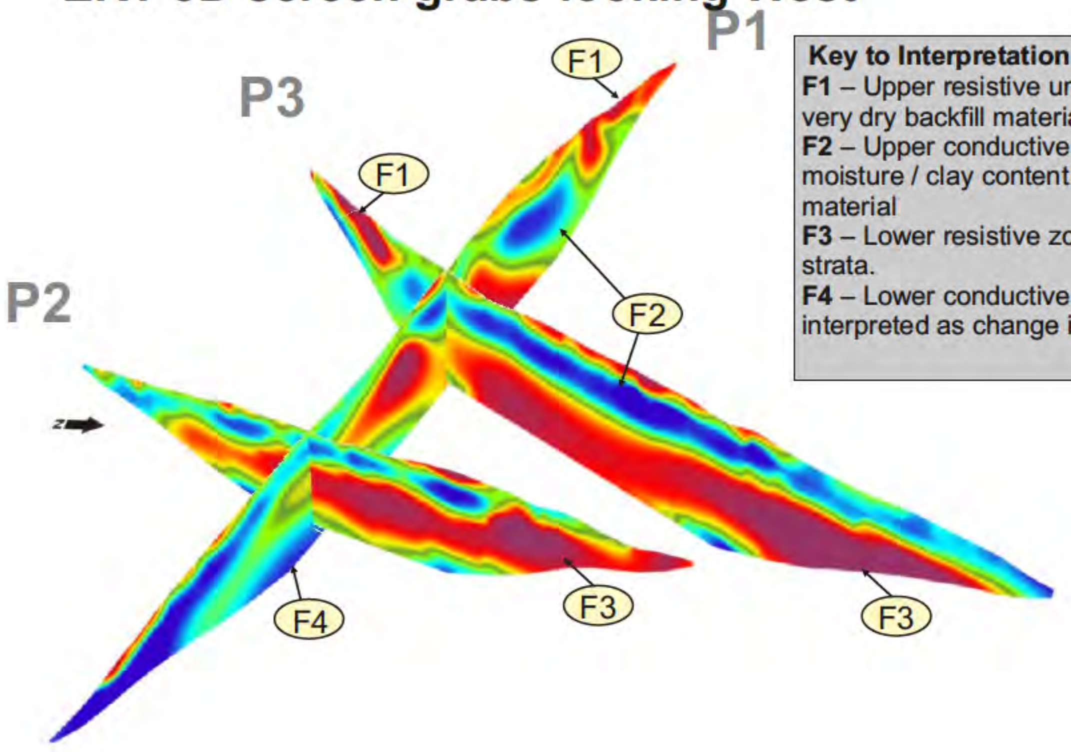
Key to trial pits and boreholes

- ■ Made ground topsoil
- □ Made ground spoil tip
- ▨ Made ground (Gravel & Cobbles)
- ▨ Made ground (Clay)
- ■ Clay
- ■ Clay - possible weathered upper coal measures
- — Ground water strike
- TP** (**m *) Trial pit locations
- BH** (**m *) Borehole locations

ERT 3D screen grabs looking North



ERT 3D screen grabs looking West



Key to Interpretation

F1 – Upper resistive unit interpreted as clay deficient very dry backfill material

F2 – Upper conductive unit interpreted as increased moisture / clay content in the superficial / backfill material

F3 – Lower resistive zone, interpreted as bedrock strata.

F4 – Lower conductive unit beneath resistive unit interpreted as change in lithology to mudstone.

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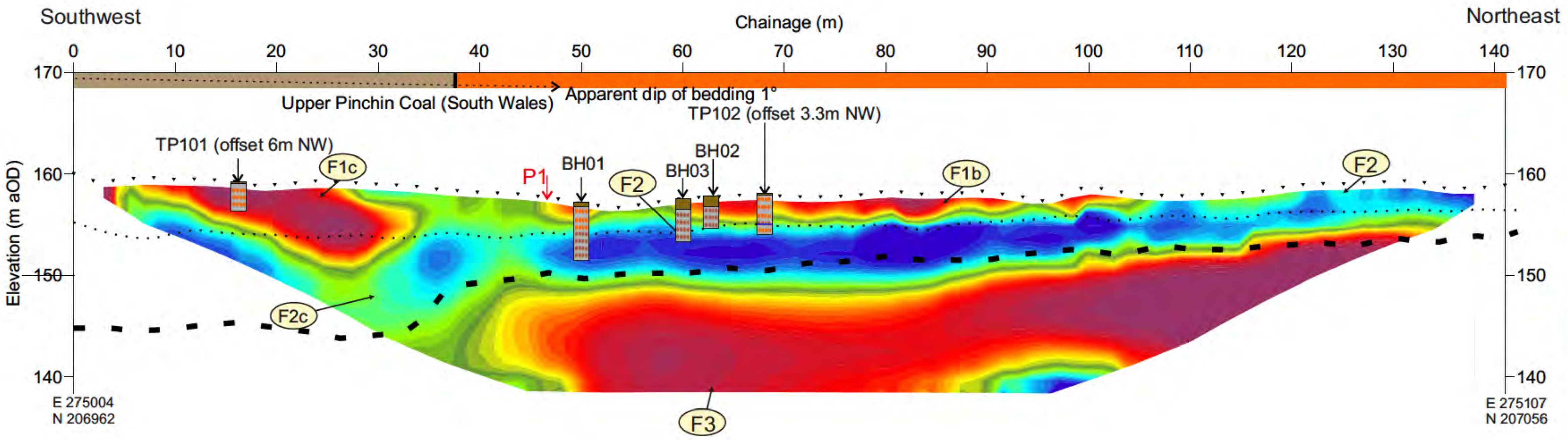
Title:
ELECTRICAL RESISTIVITY TOMOGRAPHY RESULT PROFILE 1 AND 3D SCREENGRABS

Project:
Godre'r Graig Primary school, Ystalyfera

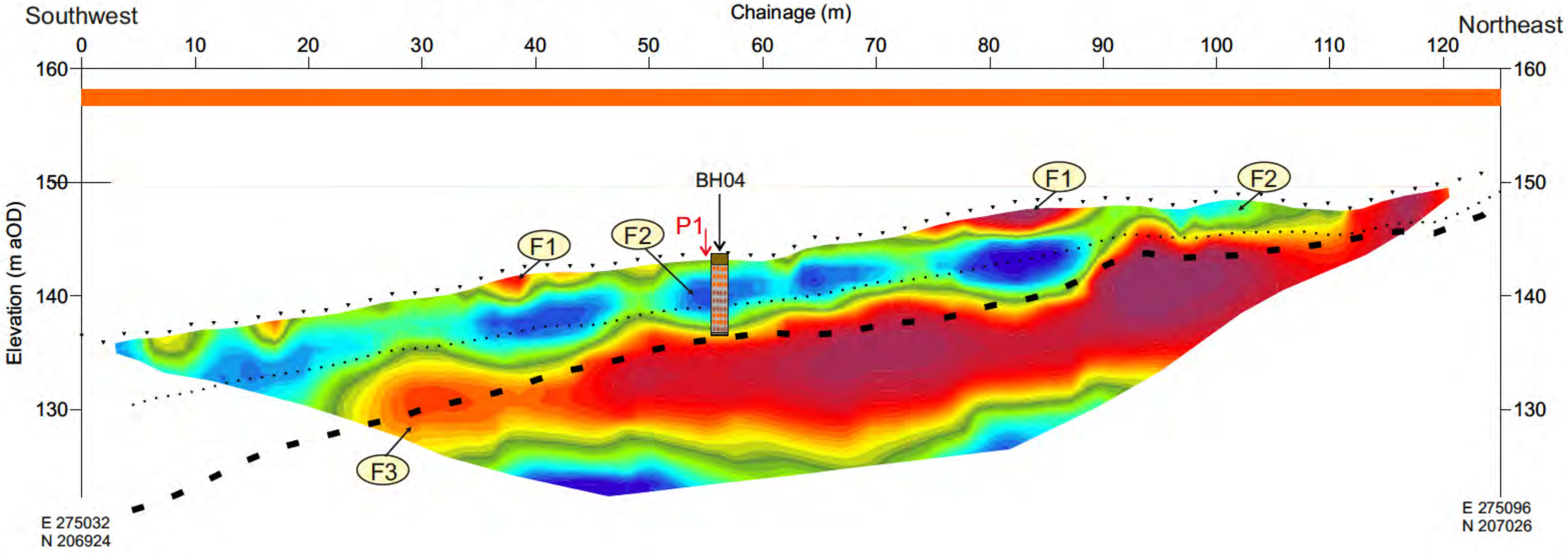
Scale: 1:500 at A3
Drawn by/Ref: RS/6738/2
Date: 19th November 2019

FIGURE 2

Electrical resistivity tomography (ERT) Profile 3



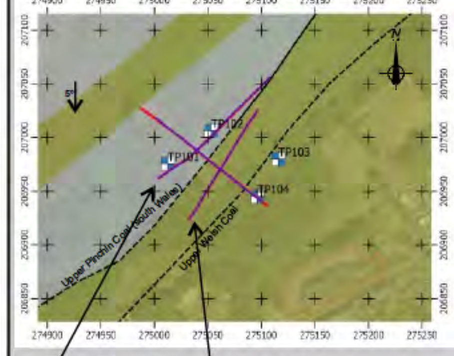
Electrical resistivity tomography (ERT) Profile 2



Key to Interpretation

F1 – Upper resistive unit interpreted as clay deficient very dry backfill material
F2 – Upper conductive unit interpreted as increased moisture / clay content in the superficial / backfill material
F3 – Lower resistive zone, interpreted as bedrock strata.
F4 – Lower conductive unit beneath resistive unit interpreted as change in lithology to mudstone.

Location Plan (NTS)



KEY

- ▼ Electrode location
- ⬭ Highlighted feature
- P* Indicates the intersection of the Profile and its number
- 🟧 Sandstone
- ▨ Mudstone, siltstone and sandstone

Shear (S) wave seismic velocity (m/S)

- ⋯ Layer 3 (470 m/s) (interpreted as dense soil / weak rock)
- ▪ ▪ ▪ Layer 4 (929 m/s) (interpreted as competent rock)

COLOUR SCALE

Increasing resistivity →

96.08, 172.5, 214.4, 246.4, 284.1, 316.5, 345.2, 378.2, 423.1, 466.2, 527.6, 590.2, 655.9, 742.8, 833.3, 976.1, 1272

Modelled "true" resistivity (ohm-m)

Notes: Profiles are aligned on profile 1

Key to trial pits and boreholes

- ▨ Made ground topsoil
- ☐ Made ground spoil tip
- ▨ Made ground (Gravel & Cobbles)
- ▨ Made ground (Clay)
- ▨ Clay
- ▨ Clay - possible weathered upper coal measures
- — Ground water strike

TP** (**m *) Trial pit locations
BH** (**m *) Borehole locations

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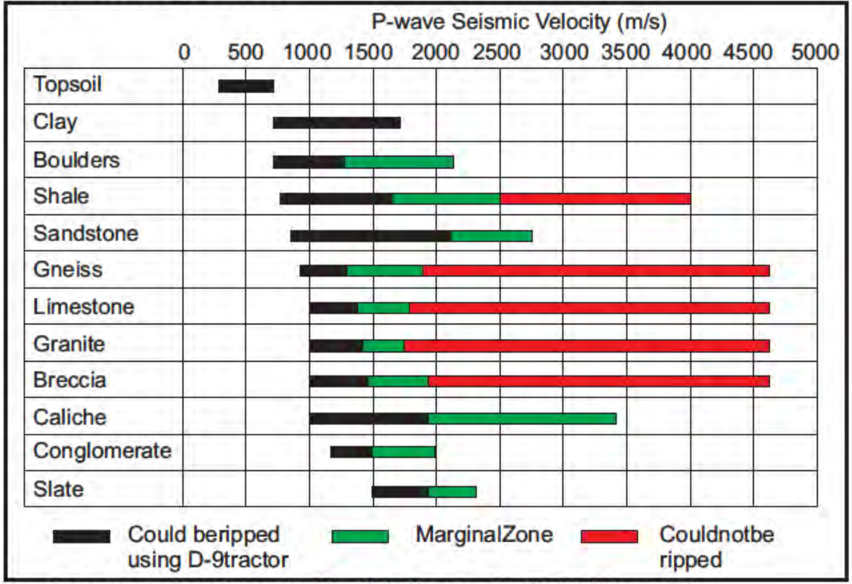
Title:
ELECTRICAL RESISTIVITY TOMOGRAPHY RESULTS FOR PROFILES 2 AND 3

Project:
Godre'r Graig Primary school, Ystalyfera

Scale: 1:500 at A3	FIGURE 3
Drawn by/Ref: RS/6738/3	
Date: 19th November 2019	

Rippability Chart



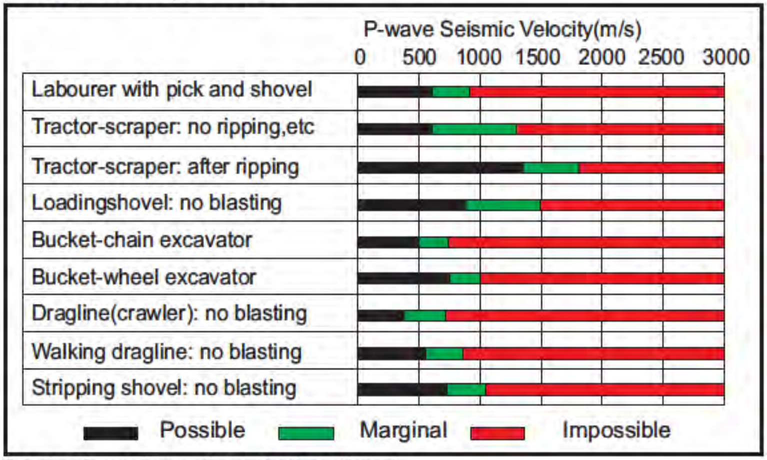
Ground preparation by ripping in open pit mining, Mining Magasine, 122, 458-469. Atkinson, 1970

Compressional P-wave velocity

Unconsolidated materials	***Vp (m/s)***
Sand (dry)	200 - 1000
Sand (water saturated)	1500 - 2000
Clay	1000 - 2500
Glacial till (water saturated)	1500 - 2500
Permafrost	3500 - 4000
Sedimentary rocks	
Sandstones	2000 - 6000
Tertiary sandstones	2000 - 2500
Pennant sandstone (Carboniferous)	4000 - 4500
Cambrian quartzite	5500 - 6000
Limestones	2000 - 6000
Cretaceous chalk	2000 - 2500
Jurassic limestones	3000 - 4000
Carboniferous limestones	5000 - 5500
Dolomites	2500 - 6500
Salt	4500 - 5000
Anhydrate	4500 - 6500
Gypsum	2000 - 3500
Igneous/Metamorphic rocks	
Granite	5500 - 6000
Gabbro	6500 - 7000
Ultramafic rocks	7500 - 8500
Serpentite	5500 - 6500
Other materials	
Steel	6100
Iron	5800
Aluminium	6600
Concrete	3600

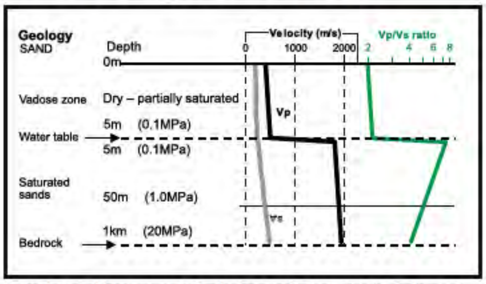
An introduction to Geophysical Exploration 3rd Ed.
Kearey, Brooks & Hill: 2002

Diggability Chart



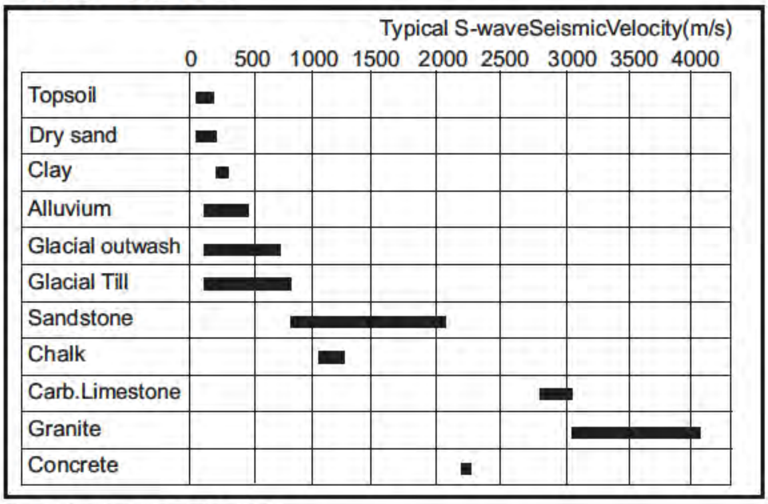
Selection of open pit excavation and loading equipment.
Transactions of the Institute of Mining and Metallurgy, 80, A101-A129, Atkinson 1971

Effect of ground water



Prasad et al., Measurement of velocities and attenuation in shallow soils,
Near-Surface Geophysics Volume II Case Histories, SEG, Tulsa (2004)

Shear Waves



Rock / Soil Description (top 30m)	**S-wave velocity (m/s)**
Hard rock (*strong**)	> 1,500
Rock (*moderately strong**)	760 - 1,500
Very dense soil / soft (*weak**) rock	360 - 760
Stiff soil	180 - 360
Soft soil	<180

The NEHRP Recommended Provisions for seismic regulation for new buildings, (FEMA-222A and FEMA-223A, 1994)

** UK equivalent classification (Waltham, 1994)*

Applied Geophysics, Telford et al, 1990
Shear wave velocity determination of unlithified geologic materials (CUSEC region) Illinois State Geological Survey, Bauer, 2004.
Bauer et al., 2007, Illinois State Geological Survey.
Shear Wave Velocity, Geology and Geotechnical Data of Earth Materials in the Central U.S. Urban Hazard Mapping Areas.
An Introduction to Geophysical Exploration, 3rd Edition, Keary and Brooks, 2002.
Conceptual Overview of Rock and Fluid Factors that Impact Seismic Velocity and Impedance,
Stanford Rock Physics Laboratory, n.d.

PUBLISHED SEISMIC VELOCITY TABLES

Godre'r Graig Primary school, Ystalyfera

Scale: NTS
Drawn by/Ref: RS/6738/4
Date: 19th November 2019

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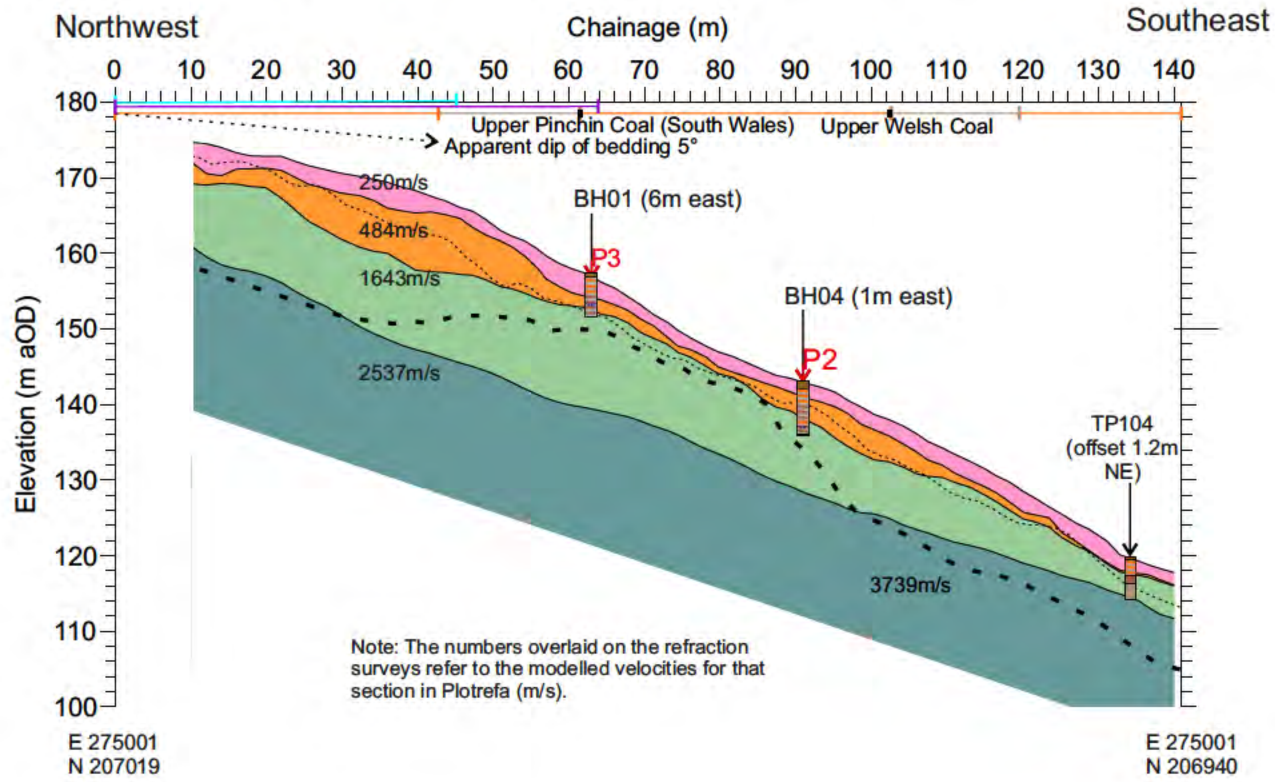
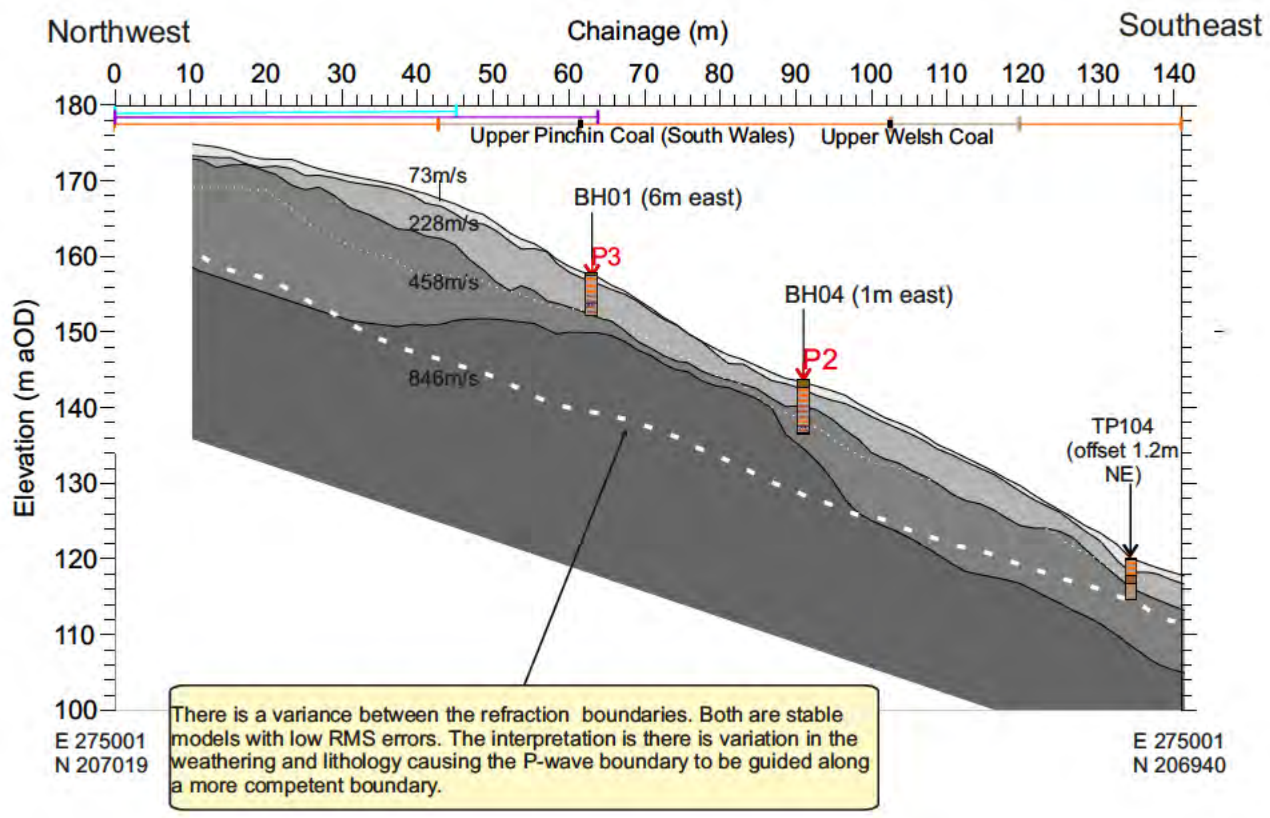
FIGURE 4

Seismic P-wave Refraction Profile 1



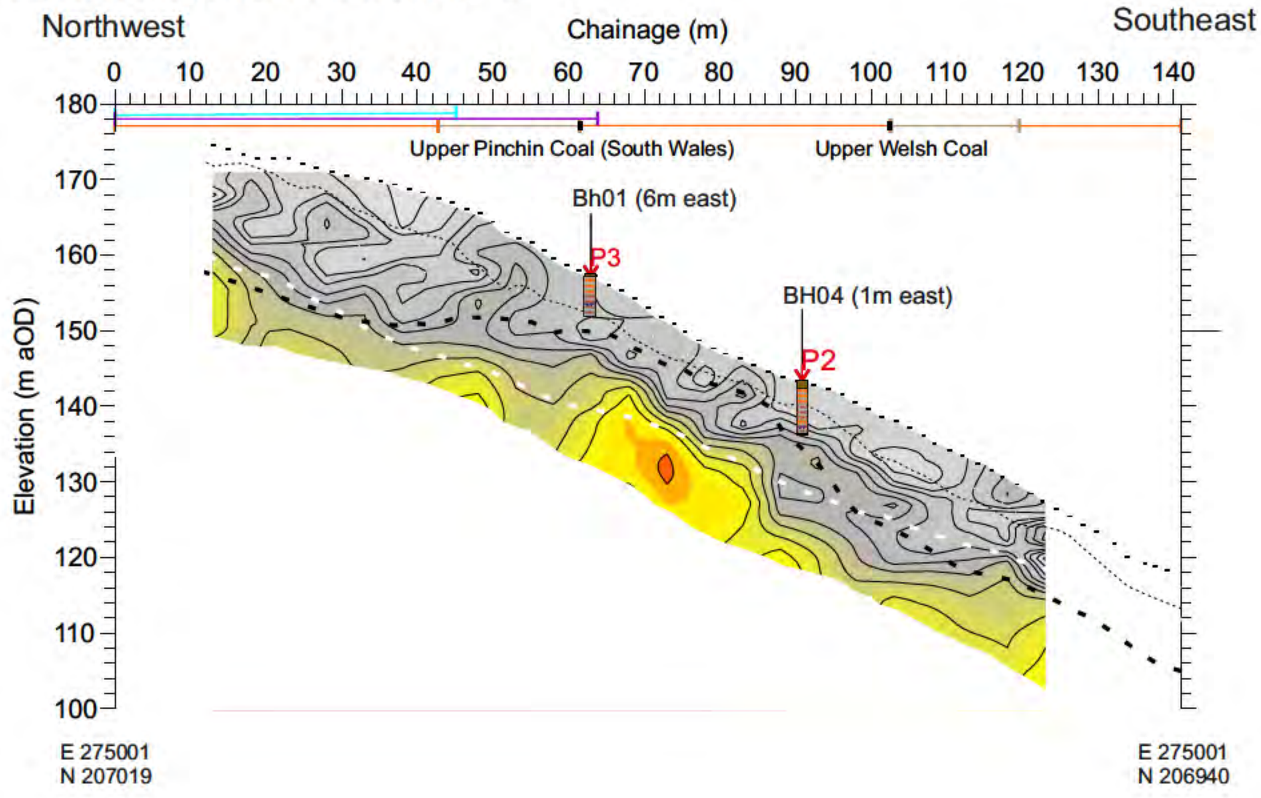
Note: The numbers overlaid on the refraction surveys refer to the modelled velocities for that section in Plotrefa (m/s).

Seismic S-wave Refraction Profile 1

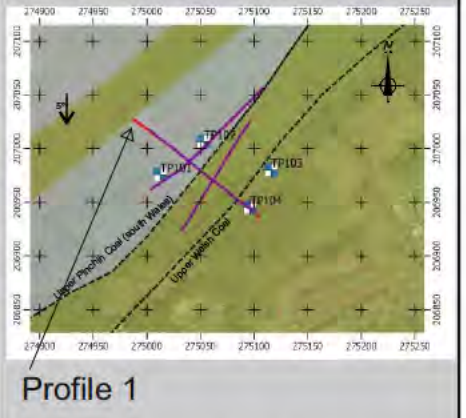


There is a variance between the refraction boundaries. Both are stable models with low RMS errors. The interpretation is there is variation in the weathering and lithology causing the P-wave boundary to be guided along a more competent boundary.

Seismic MASW Profile 1



Location Plan (NTS)



Refraction compressional (p) wave velocity (m/S)

- ■ Layer 1 (230 - 250 m/s)
- ■ Layer 2 (484 - 783m/s)
- ■ Layer 3 (1643 - 1746 m/s)
- ■ Layer 4 (2537- 3789m/s)
- Major shear wave boundaries overlain

Refraction Shear (S) wave seismic velocity (m/S)

- ■ Layer 1 (70 - 73 m/s)
- ■ Layer 2 (228 - 230 m/s)
- ■ Layer 3 (458 - 470 m/s)
- ■ Layer 4 (846- 929 m/s)
- Major P-wave boundaries overlain

MASW Shear (S) wave seismic velocity (m/S)

160.9 200.4 243.8 287.2 314.1 356.9 406.5 453.2 489.1 529.3 579.7 654.2 718.4 777.5 886.5 1094

Key to trial pits and boreholes

- ■ Made ground topsoil
- ■ Made ground spoil tip
- ■ Made ground (Gravel & Cobbles)
- ■ Made ground (Clay)
- ■ Clay
- ■ Clay - possible weathered upper coal measures
- SPT >50
- Ground water strike
- TP** (**m *) Trial pit locations
- BH** (**m *) Borehole locations

KEY

- P* Indicates the intersection of the Profile and its number
- Sandstone
- Mudstone, siltstone and sandstone
- Coal
- Extents of quarry fill in 1877
- Extents of quarry fill in 1989

Note:

The numbers overlaid on the refraction surveys refer to the modelled velocities for that section in Plotrefa (m/s). In profile 1 it was necessary to use two velocities within layer 4 of the P-wave refraction.

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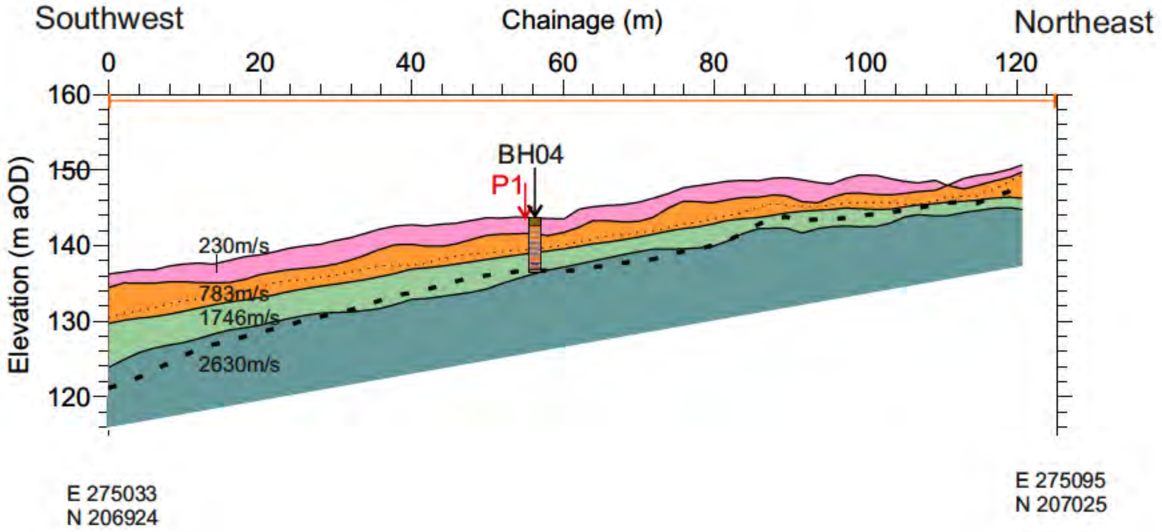
Title:
SEISMIC RESULTS FOR PROFILE 1

Project:
Godre'r Graig Primary school, Ystalyfera

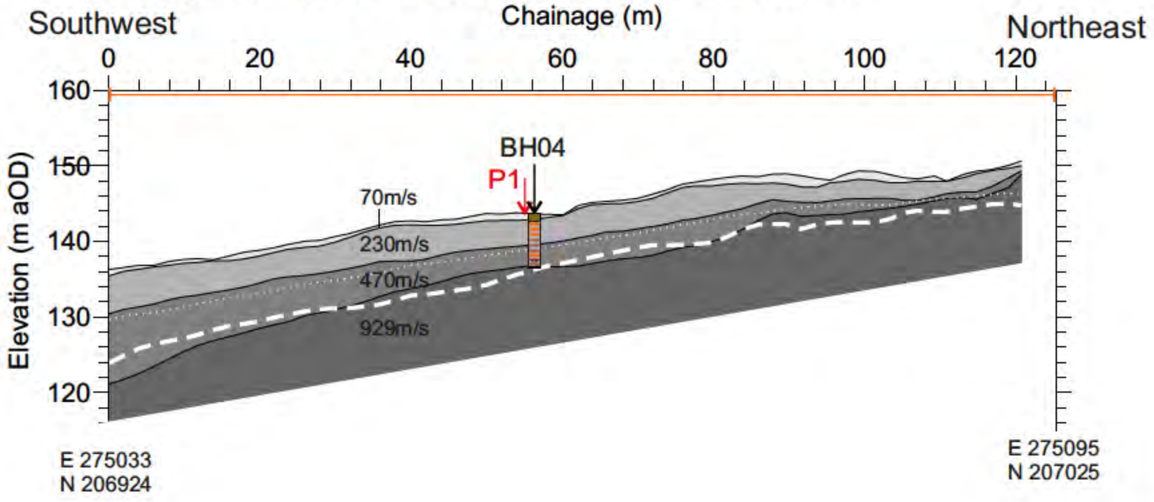
Scale: 1:1000 at A3
Drawn by/Ref: RS/6738/5
Date: 19th November 2019

FIGURE 5

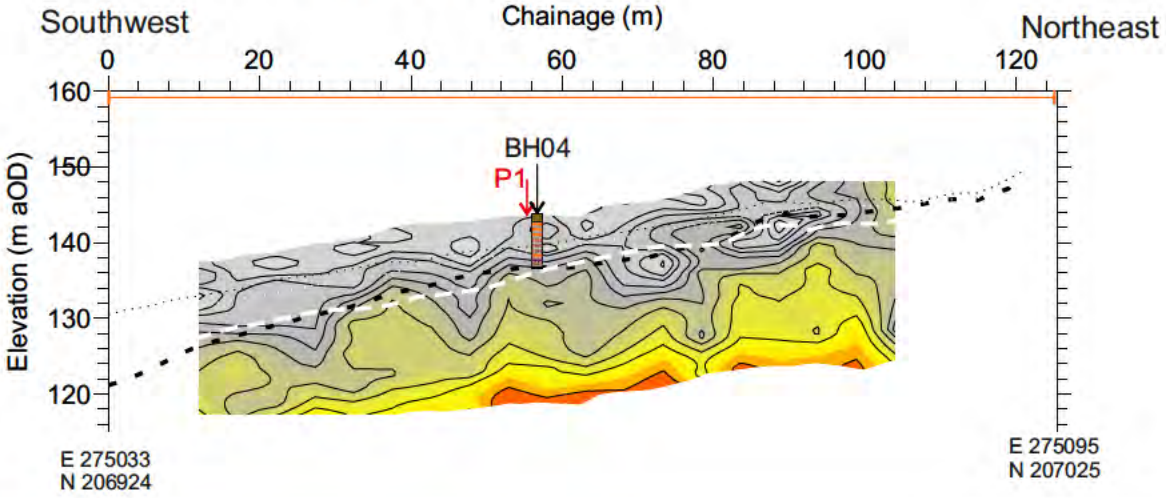
Seismic P-wave Refraction Profile 2

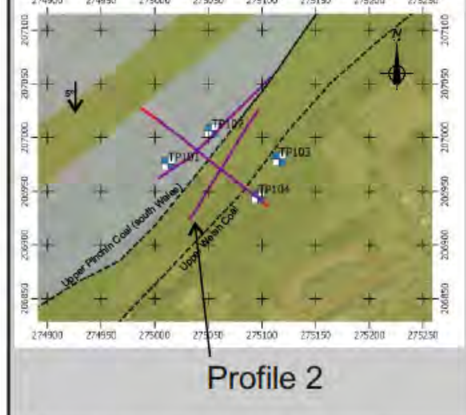


Seismic S-wave Refraction Profile 2



Seismic MASW Profile 2





Refraction compressional (p) wave velocity (m/S)

- 🟪 Layer 1 (230 - 250 m/s)
- 🟧 Layer 2 (484 - 783m/s)
- 🟩 Layer 3 (1643 - 1746 m/s)
- 🟦 Layer 4 (2537- 3789m/s)
- Major shear wave boundaries overlain

Refraction Shear (S) wave seismic velocity (m/S)

- ⬜ Layer 1 (70 - 73 m/s)
- ⬜ Layer 2 (228 - 230 m/s)
- ⬛ Layer 3 (458 - 470 m/s)
- ⬛ Layer 4 (846- 929 m/s)
- Major P-wave boundaries overlain

MASW Shear (S) wave seismic velocity (m/S)

160.9 200.4 243.8 287.2 314.1 356.9 406.5 453.2 489.1 529.3 579.7 654.2 718.4 777.5 886.5 1094

Key to trial pits and boreholes

- ■ Made ground topsoil
- ■ Made ground spoil tip
- ▨ Made ground (Gravel & Cobbles)
- ▨ Made ground (Clay)
- ■ Clay
- ■ Clay - possible weathered upper coal measures
- SPT >50
- Ground water strike
- TP** (**m *) Trial pit locations
- BH** (**m *) Borehole locations

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KEY

P* Indicates the intersection of the Profile and its number

Sandstone

Note:

The numbers overlaid on the refraction surveys refer to the modelled velocities for that section in Plotrefa (m/s).

Title:
SEISMIC RESULTS FOR PROFILE 2

Project:
Godre'r Graig Primary school, Ystalyfera

Scale:	1:1000 at A3
Drawn by/Ref:	RS/6738/6
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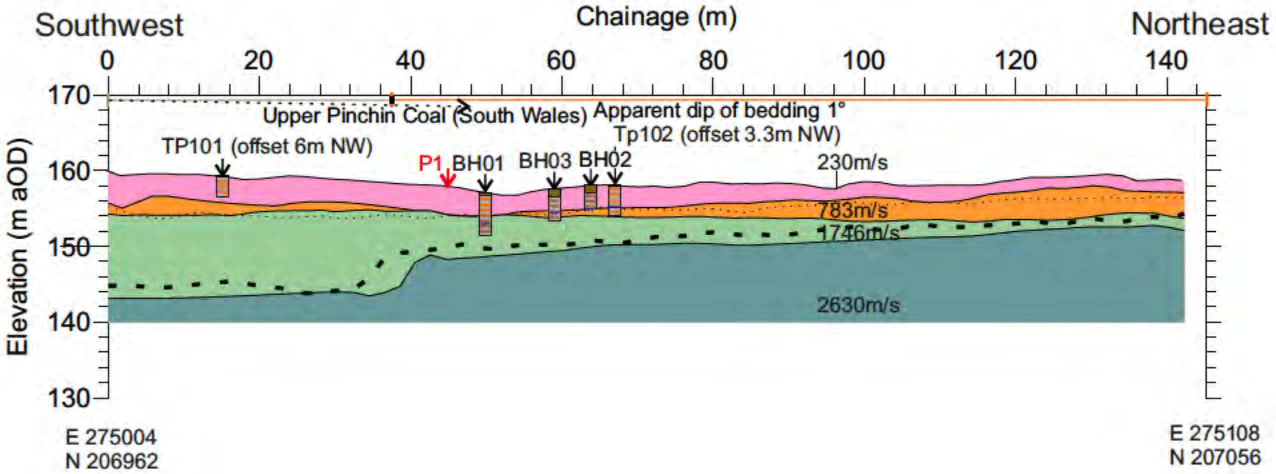
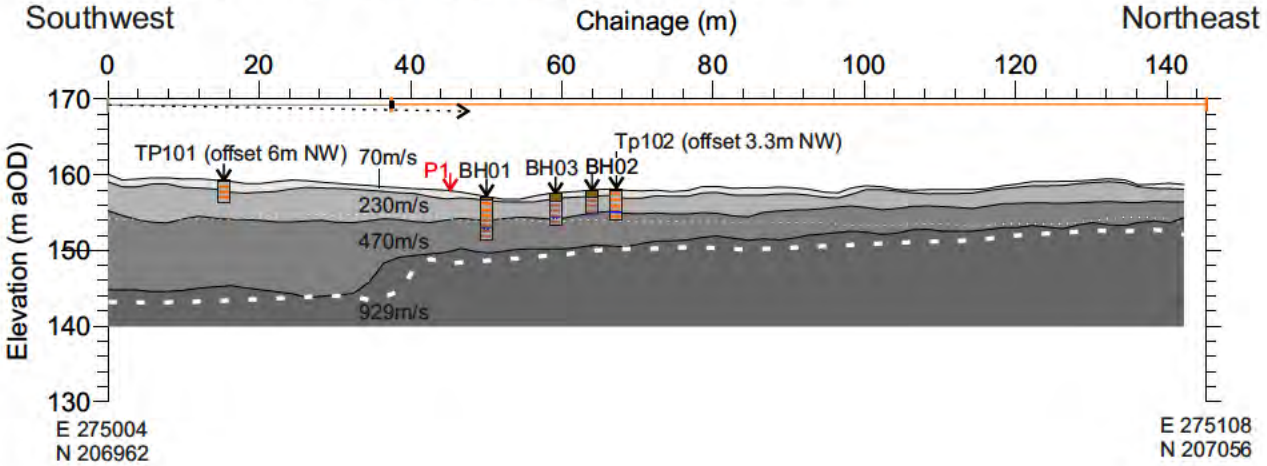
FIGURE 6

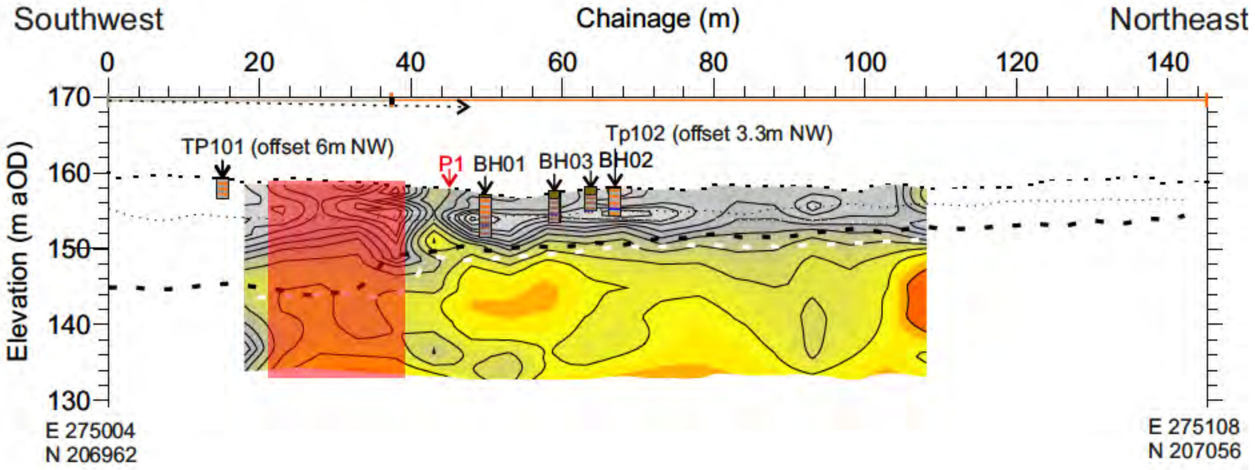
Seismic P-wave Refraction Profile 3



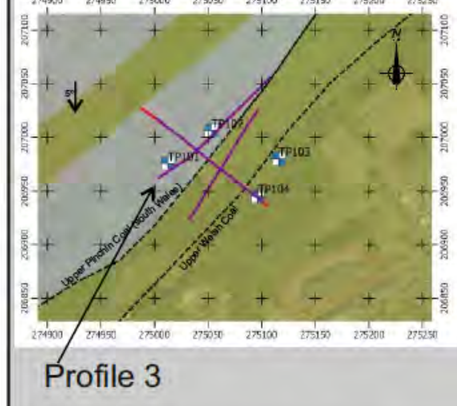
Seismic S-wave Refraction Profile 3



Seismic MASW Profile 3



Location Plan (NTS)



Refraction compressional (p) wave velocity (m/S)

🟪 Layer 1 (230 - 250 m/s)

🟧 Layer 2 (484 - 783m/s)

🟩 Layer 3 (1643 - 1746 m/s)

🟦 Layer 4 (2537- 3789m/s)

Major shear wave boundaries overlain

Refraction Shear (S) wave seismic velocity (m/S)

⬜ Layer 1 (70 - 73 m/s)

▨ Layer 2 (228 - 230 m/s)

▨ Layer 3 (458 - 470 m/s)

■ Layer 4 (846- 929 m/s)

Major P-wave boundaries overlain

MASW Shear (S) wave seismic velocity (m/S)

160.9	200.4	243.8	287.2	314.1	356.9	406.5	453.2	489.1	529.3	579.7	654.2	718.4	777.5	886.5	1094

Key to trial pits and boreholes

- ■ Made ground topsoil
- ☐ Made ground spoil tip
- ▨ Made ground (Gravel & Cobbles)
- ▨ Made ground (Clay)
- ■ Clay
- ■ Clay - possible weathered upper coal measures
- SPT >50
- Ground water strike
- **TP** (**m *)** Trial pit locations
- **BH** (**m *)** Borehole locations

KEY

- P* Indicates the intersection of the Profile and its number
- Sandstone
- Mudstone, siltstone and sandstone
- 🟥 Zone of limited data

Note:

The numbers overlaid on the refraction surveys refer to the modelled velocities for that section in Plotrefa (m/s).

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SEISMIC RESULTS FOR PROFILE 3

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Scale: 1:1000 at A3
Drawn by/Ref: RS/6738/7
Date: 19th November 2019

FIGURE 7

APPENDICES

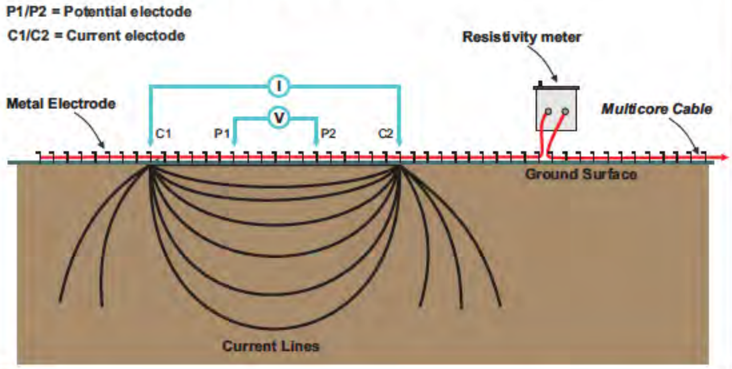
Appendix - Resistivity Tomography

The Resistivity technique is a useful method for characterising the sub-surface materials in terms of their electrical properties. Variations in electrical resistivity (or conductivity) typically correlate with variations in lithology, water saturation, fluid conductivity, porosity and permeability, which may be used to map stratigraphic units, geological structure, sinkholes, fractures and groundwater.

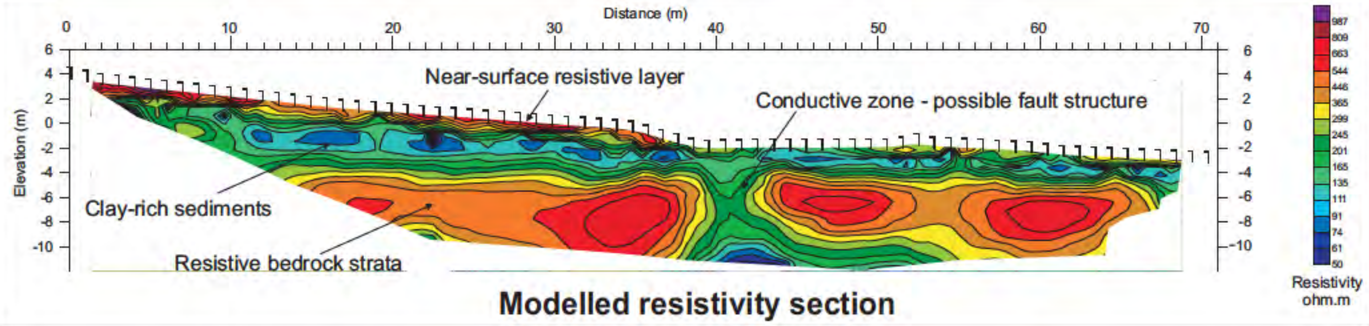
The acquisition of resistivity data involves the injection of current into the ground via a pair of electrodes and then the resulting potential field is measured by a corresponding pair of potential electrodes. The field set-up requires the deployment of an array of regularly spaced electrodes, which are connected to a central control unit via multi-core cables. Resistivity data are then recorded via complex combinations of current and potential electrode pairs to build up a pseudo cross-section of apparent resistivity beneath the survey line. The depth of investigation depends on the electrode separation and geometry, with greater electrode separations yielding bulk resistivity measurements from greater depths.

The recorded data are transferred to a PC for processing. In order to derive a cross-sectional model of true ground resistivity, the measured data are subject to a finite-difference inversion process via RES2DINV (ver 5.1) software.

General resistivity principle



Typical field set-up



Modelled resistivity section

Data processing is based on an iterative routine involving determination of a two-dimensional (2D) simulated model of the subsurface, which is then compared to the observed data and revised. Convergence between theoretical and observed data is achieved by non-linear least squares optimisation. The extent to which the observed and calculated theoretical models agree is an indication of the validity of the true resistivity model (indicated by the final root-mean-squared (RMS) error).

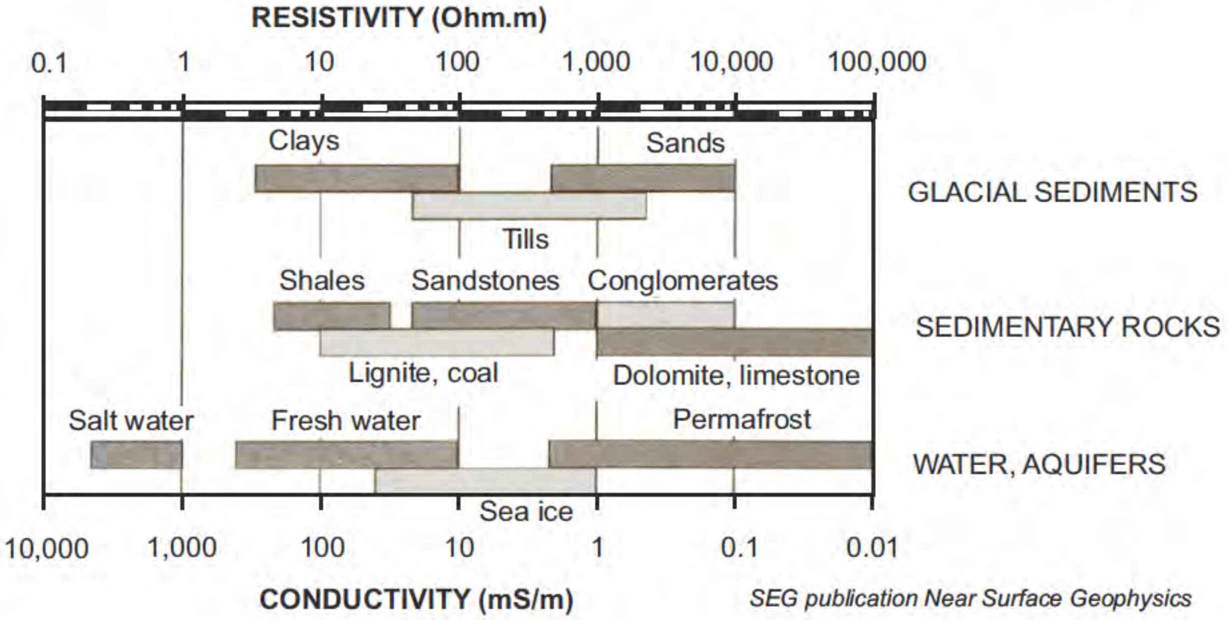
The true resistivity models are presented as colour contour sections revealing spatial variation in subsurface resistivity. The 2D method of presenting resistivity data is limited where highly irregular or complex geological features are present and a 3D survey maybe required. Geological materials have characteristic resistivity values that enable identification of boundaries between distinct lithologies on resistivity cross-sections. At some sites, however, there are overlaps between the ranges of possible resistivity values for the targeted materials which therefore necessitates use of other geophysical surveys and/or drilling to confirm the nature of identified features.

Constraints:

Readings can be affected by poor electrical contact at the surface. An increased electrode array length is required to locate increased depths of interest therefore the site layout must permit long arrays. Resolution of target features decreases with increased depth of burial.

Appendix - Resistivity tables

Sedimentary Environments



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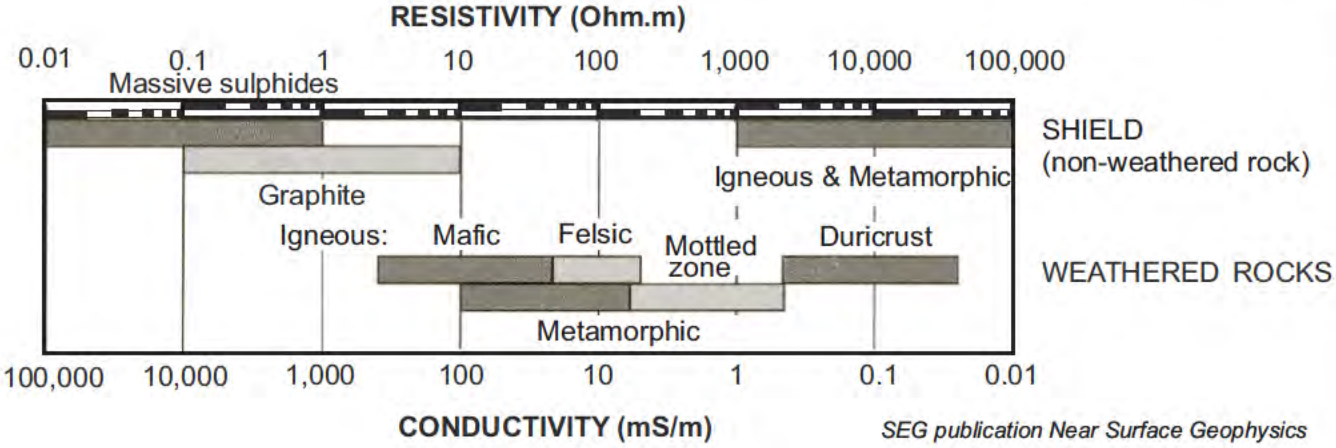
Igneous Environments



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Appendix - Surface Wave Surveys

MASW survey in progress

Hammer and plate source - the most

Multi-channel Analysis of Surface Waves (MASW) is a very useful method for investigating shallow geological structure and, in particular, the relative shear strength of subsurface materials. By incorporating density values for the local bedrock and overburden sediments it is possible to derive their shear modulus often referred to as dynamic ground stiffness.

The technique is based on the recording of seismic waves that roll much like a seawav e along the surface and extend down to depth beneath the survey line. At each new location it is essential to carry out initial tests to determine optimum acquisition parameters including geophone spacing and shot offset distances. Typically a hammer and plate or buffalo gun is used as the seismic source with the latter offering more power for difficult sites. Surface waves travel more slowly than other seismic signals and are recorded over long time intervals by comparison. The recorded data are first processed to produce dispersion curves for each shot. These curves are then modelled individually to produce 1D depth profiles of shear wave velocity and then combined to produce a depth cross-section revealing the shear wave velocity structure of the ground.

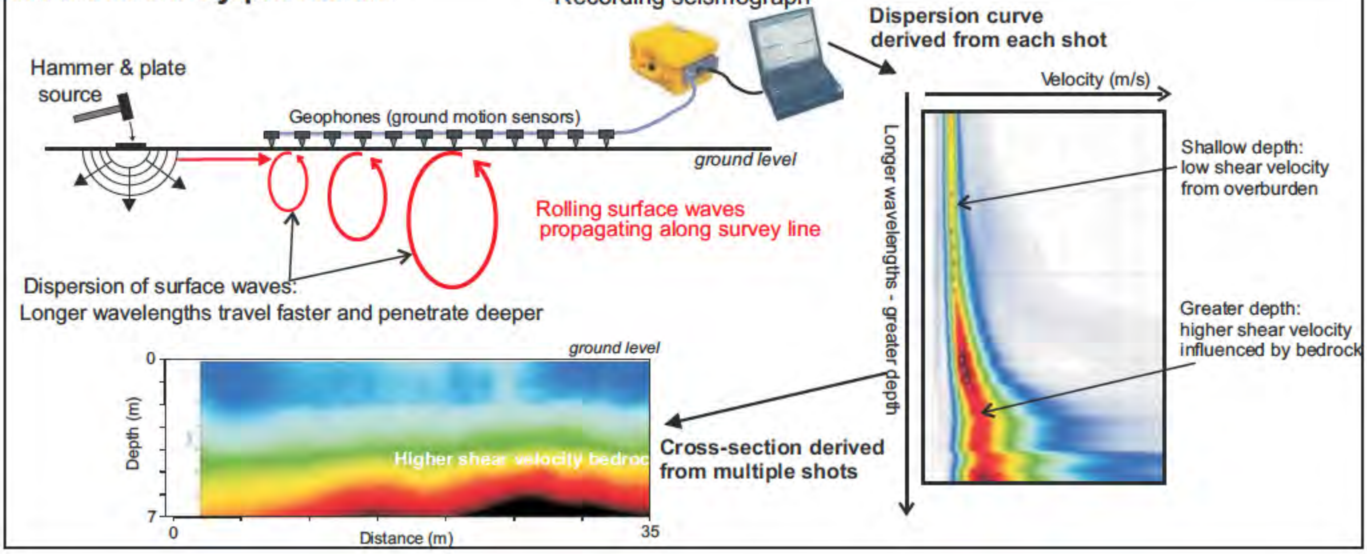
Typical Targets:

Dynamic stiffness modulus
Foundation strength for turbines/structures
Weak but cemented rockhead
Weathered rock beneath dense overburden
Shear strength of landslide materials

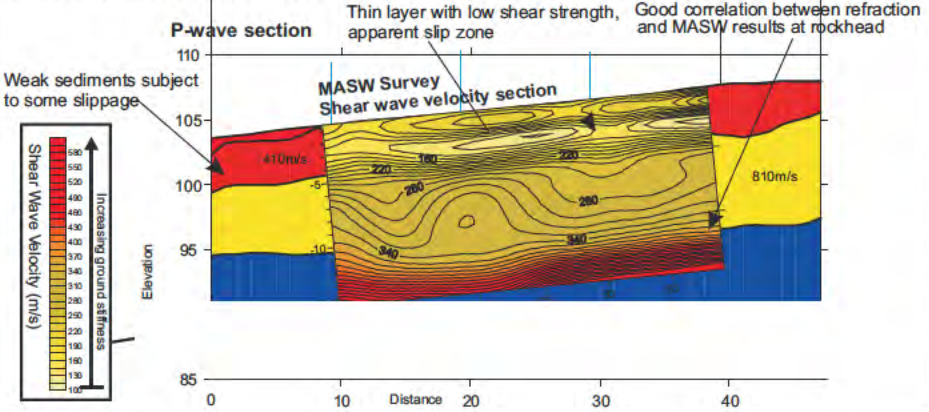
Benefits of MASW:

Low Cost
High productivity
Continuous profiles
Non-invasive
Environmentally friendly

MASW Survey procedure



Combined MASW and Refraction Survey



(ABOVE) A schematic illustration of the MASW data acquisition and processing procedure leading to a final section.

(LEFT) Results of a combined seismic refraction and MASW survey targeting shallow geological structure on an active landslide. The MASW survey results reveal spatial variation in shear wave velocity and dynamic ground stiffness. A shallow zone of low shear strength is clearly observed.

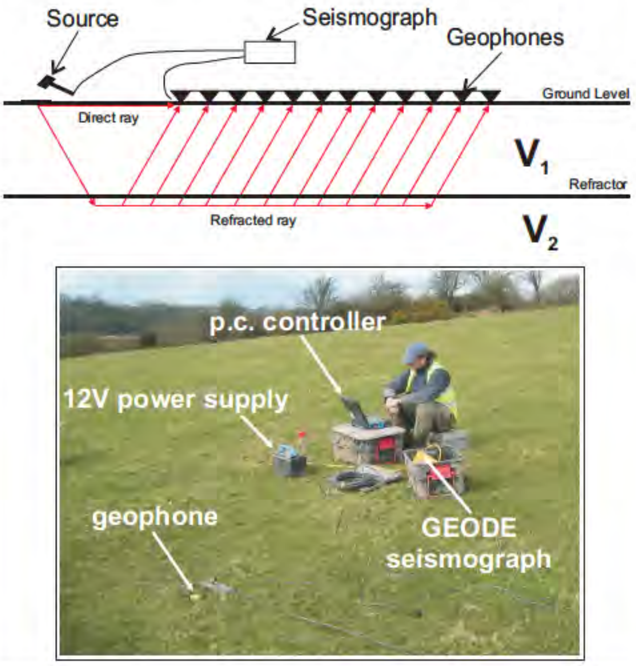
Appendix - Seismic Refraction Survey

Seismic refraction is a useful method for investigating geological structure and rock properties. The technique involves the observation of a seismic signal that has been refracted between layers of contrasting seismic velocity, i.e., at a geological boundary between a high velocity layer and an overlying lower velocity layer.

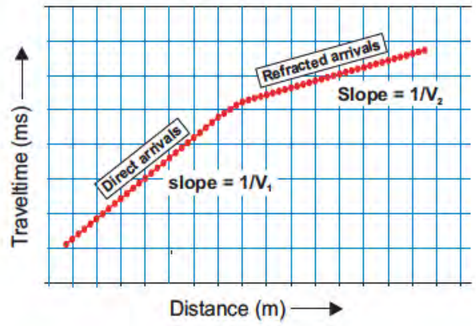
Shots are deployed at the surface and recordings made via a linear array of sensors (geophones or hydrophones). Refracted seismic signal travels laterally through the higher velocity layer (refractor) and generates a 'head-wave' that returns to surface. Beyond a certain distance away from the shot, the signal that has been refracted at depth is observed as first-arrival signal at the geophones. Observation of the travel-times of refracted signal from selectively deployed shots enables derivation of the depth profile of the refractor layer. Shots are typically fired at locations at and beyond both ends of the geophone spread and at regular intervals along its length.

The results of the seismic refraction survey are usually presented in the form of seismic velocity boundaries on interpreted cross-sections. Seismic sections represent the measured bulk properties of the subsurface and enable correlation between point source datasets (boreholes/trialpits) where underlying material is variable. Reference to the published seismic velocity tables enables derivation of rippability values.

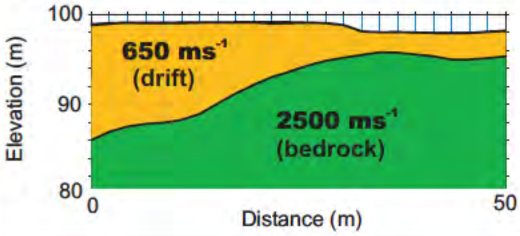
Typical field set-up



Travel-time curve



Modelled velocity section



The data processing is carried out using PICKWIN & PLOTREFA (OYO ver2.2) software. The first stage involves accurate determination of the first-arrival times of the seismic signal (time from the hammer blow to each recording hydrophone) for every shot record, using PICKWIN. Time-distance graphs showing the first-arrival times were then generated for each seismic shot record and analysed using PLOTREFA software to determine the number of seismic velocity layers. Modelled depth profiles for the observed seismic velocity layers are produced by a tomographic inversion procedure that is revised iteratively to develop a best fit-model. The final output of a seismic refraction survey is a velocity model section of the subsurface based on an observed layer sequence with measured velocities that correspond to physical properties such as levels of compaction/ saturation in the case of sediments and strength/rippability in the case of bedrock.

Constraints

Layer velocity (density) must increase with depth; true in most instances. Layers must be of sufficient thickness to be detectable. Data collected directly over loose fill (landfills) or in the presence of excessive cultural noise may result in sub-standard results. In places where compact clay-rich tills and/or shallow water overly weak bedrock an S-wave survey may be used to profile rockhead where insufficient velocity contrast may prevent use of a P-wave survey.