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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

DRAFT

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

Revision	Status	Date	Written by	Checked and Approved by
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Contents

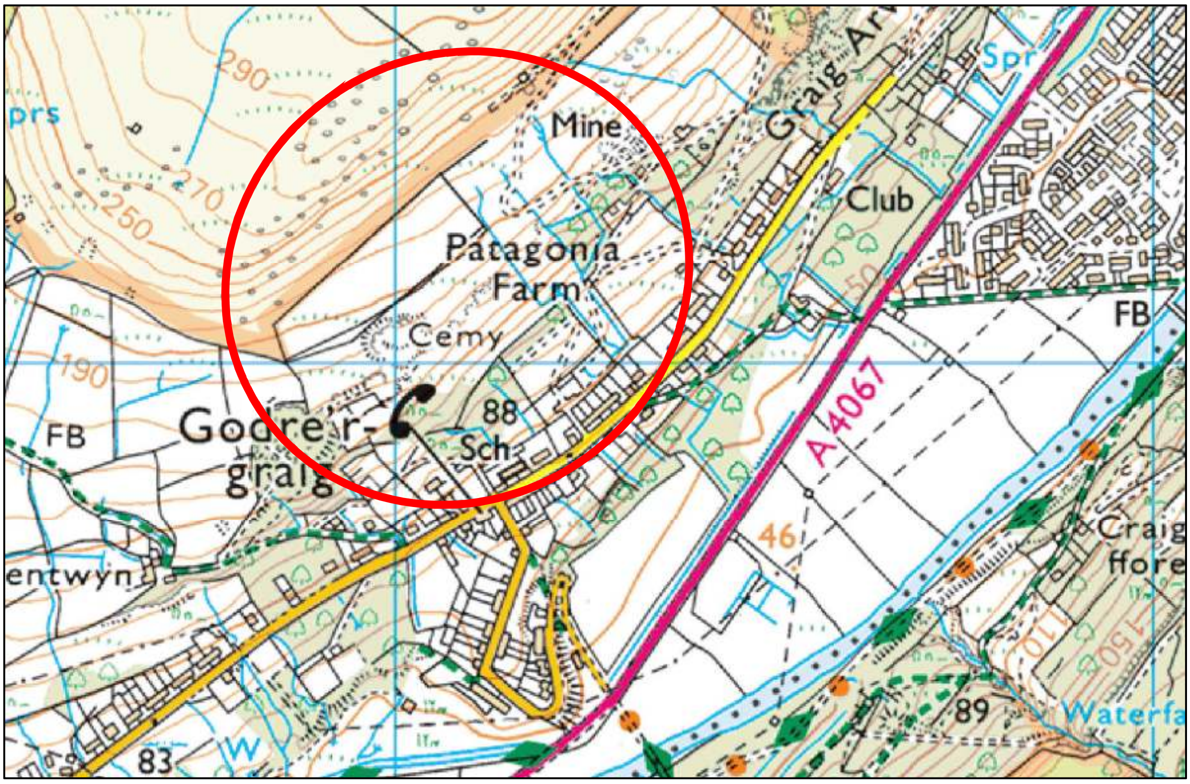
1 Introduction

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.

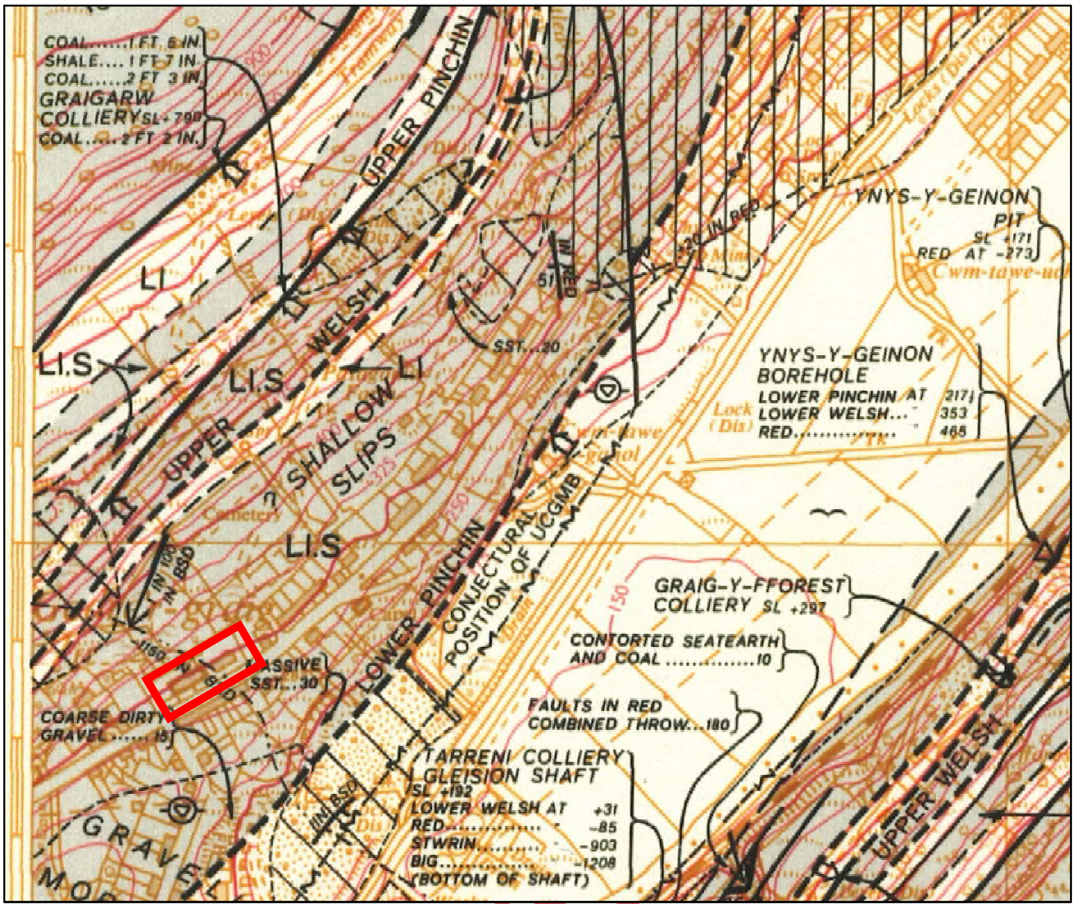


Insert 1: General Study Area 1:10,000 (Ordnance Survey License No.: AL100015788).

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 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'rgraig 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.

[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.

Due to dense vegetation and steep slopes, it was not possible to undertake a wide ranging investigation at this time. Groundwater water monitoring is planned for the coming weeks.

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 done 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 Instrumentation

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 will be monitored over the coming weeks.

4.3 Geotechnical Laboratory Testing

Geotechnical laboratory testing is underway, and this report will be updated once available.

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 anticipated at depth.

Made Ground: encountered to a maximum depth of 1.7m as a dark grey o 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 gravelly clayey 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 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.

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, there is an in persistent groundwater body within the Diamicton.

6 Hazard Identification and Risk Assessment

6.1 Introduction

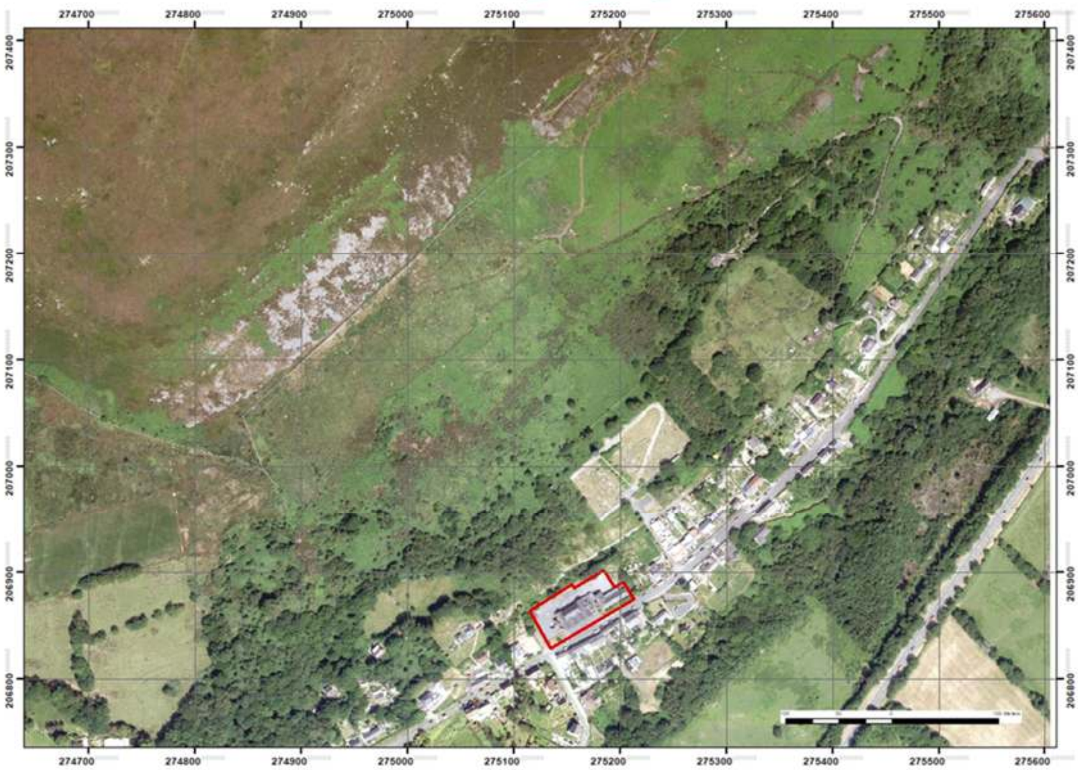
A Landslide hazard and risk assessment for the terrain above Godre'r Graig School ("the School"), Godre'r Graig, South Wales (Insert 1 and 3) has been undertaken. This has been carried out in collaboration with Steve Parry[2].

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 purchased.

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
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.



Insert 3: Location Plan. School outlined in red.

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.

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:

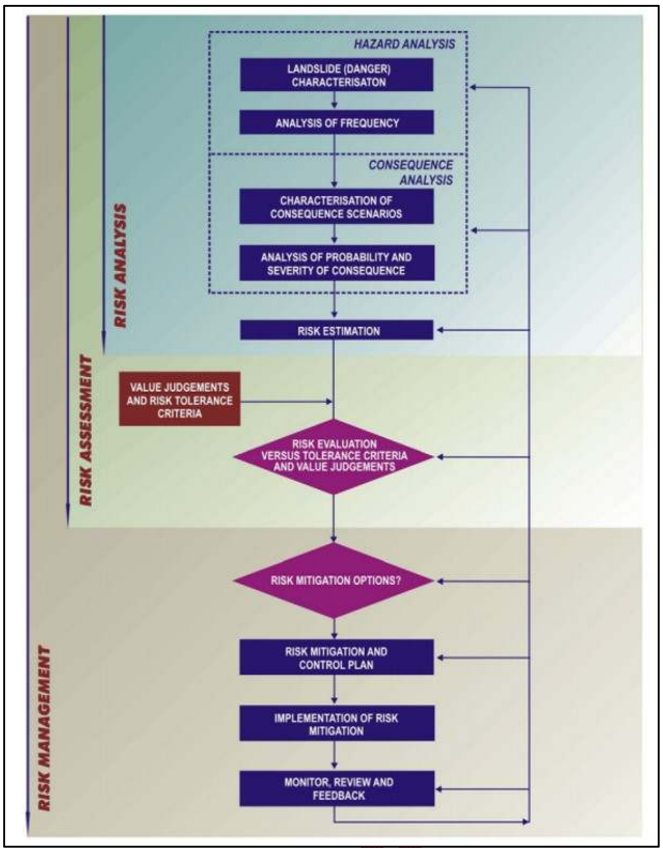
- Qualitative risk estimations are "*those where both likelihood and adverse consequences are expressed in qualitative terms. They are therefore highly subjective estimations*"
- Semi-quantitative risk estimations which are "*combinations of qualitative and quantitative measurements of likelihood and 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 can be undertaken and risk mitigation.



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 3).

Table 3: *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/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 (accompanied by Mat Elcock of 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 (apx 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 eth 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.

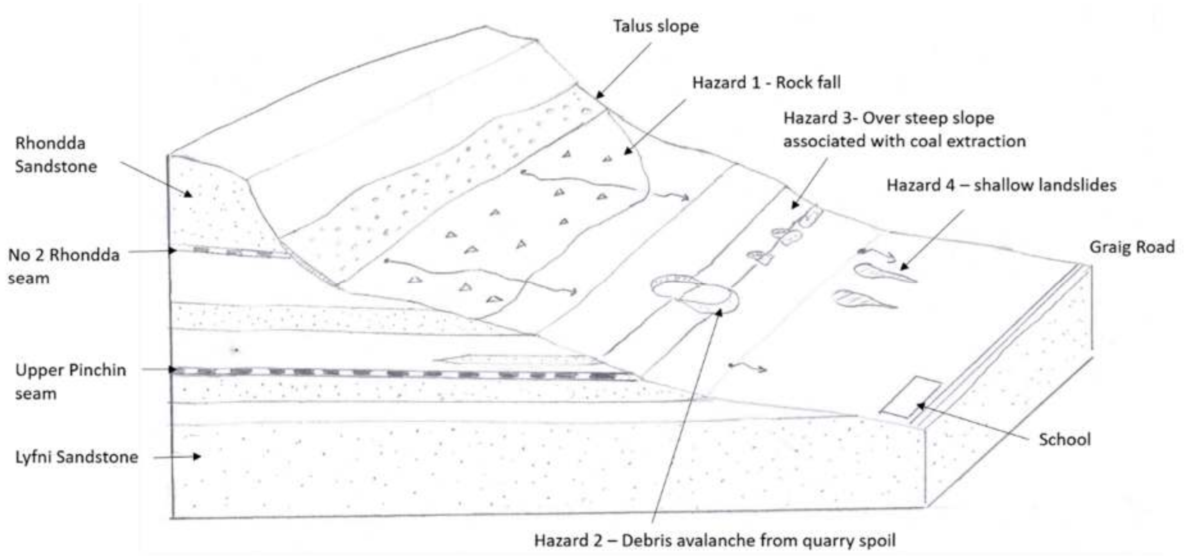
The area of "shallow slips" comprises a series of shallow depressions associated with springs and hydrophilic vegetation. A small cut slope 0.2m – 0.3m high, associated with a former tramway crosses the toe of these features. This exposes of clayey silt with occasional sub angular, medium to coarse gravel 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;
- Hazard Type 2. Debris avalanche initiating from quarry spoil;
- Hazard Type 3. Debris avalanches initiating from over steep slope; and
- Hazard Type 4. Shallow earth slides.



Insert 7: Conceptual Engineering Geological Model of site from API

Evaluation of these potential hazards 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 192mOD, 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 could 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 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 could result in a risk to life where individuals are within the playground. Where individuals are within building, and provide the volume is relatively small, it is likely that the debris poses a relatively low risk to life and is likely to result in limited structural damage.

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 could result in a risk to life where individuals are within the playground. Where individuals are within building, and provide the volume is relatively small, it is likely that the debris poses a relatively low risk to life and is likely to result in limited structural damage.

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 result in a very low risk to life and limited structural damage.

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.

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 10s to 100s 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.

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 4: 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	-	-

*assessed separately

6.7 Conclusions on natural 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 to the school building is considered to be very low.

7 Summary Risk Assessment and Implications

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, this 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 the risk to property only.

The modified descriptions and risk rankings used in this assessment are presented below. Table 5 provides a qualitative measure of likelihood and Table 6 presents a qualitative measure of consequences.

Table 5: 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 circumstances over the design life	Unlikely	D
	$5x10^{-5}$		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 6: 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 considered risk to property.

The associated levels from Table 5 and 6 are then used in Table 7 to provide a qualitative risk ranking and Table 8 provides example implications for each risk ranking.

Table 7: 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 8: 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.	

The qualitative analysis has been undertaken using the information gained from this assessment, 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.

7.1 Natural Landslide Hazards

7.1.1 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.

7.1.2 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 such features either.

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

7.2 Man-made Landslide Hazards

7.2.1 Hazard Type 2

Impact from debris avalanche initiating from quarry spoil.

If a major failure of the tip material above the school occurred it could potentially reach Godre'r Graig School; investigation and slope stability assessment is recommended.

The visual observations made during our combined walkover surveys suggest that the tip comprised coarse, probably free draining material. However, a stream was noted to be passing through the tip and re-emerging in certain areas. If the stream were to become blocked, in a severe weather event, there is a possibility that water levels and pressures in the tip could increase and induce a failure in the tip which would flow downhill.

We have considered the findings, and using the AGS qualitative risk assessment, we suggest that there is a possible likelihood of this occurring and using a likely consequence of medium the risk of this occurring is medium.

The AGS guidelines state 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 the risk to low risk should be implemented as soon as practicable.

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.

7.2.2 Hazard Type 3

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

Although some evidence of landslides with former adit location have been identified, the locations of the adits and overstep slopes suggests that there is a low risk posed to the school.

7.3 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.

7.4 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.

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