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Godre'r Graig Primary School, Godre'r Graig
Tip Remediation Assessment

Report Reference: ESP.7234e.04.3564

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Godre'r Graig Primary School
Tip Remediation Assessment

Prepared for:
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Report Reference: **ESP.7234e.04.3564**

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Notes:	1. Once issued this document is Uncontrolled, for the latest version and/or to confirm you have authorisation to use it please contact the Earth Science Partnership at enquiries@earthsciencepartnership.com or by telephone at 029 2081 3385. 2. This document has been optimised for double sided printing and therefore may produce some blank pages when printed single sided.			

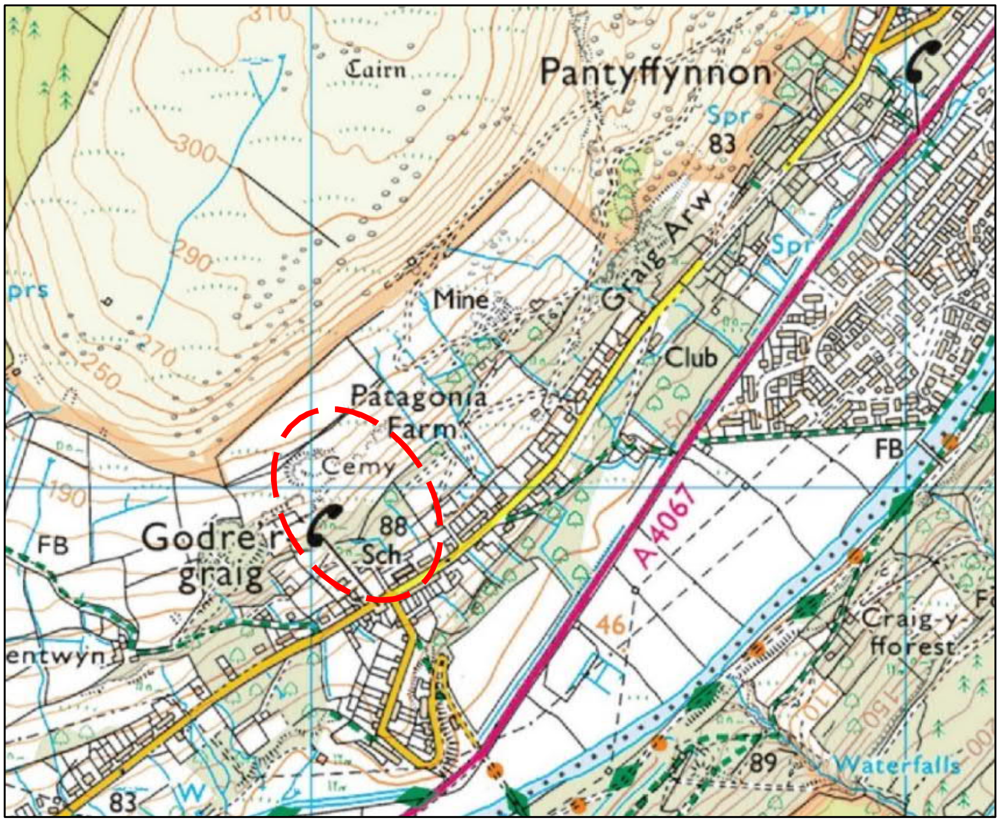
Contents

1 Introduction

1.1 Background

Neath Port Talbot County Borough Council (NPTCBC), hereafter known as the Client, have instructed Earth Science Partnership Ltd (ESP) to undertake an assessment of remediation options for the Quarry Spoil Tip that is located on slopes above Godre'r Graig Primary School (the School), located in the Tawe Valley.

The general location of the school and tip are shown in Insert 1 below.



Insert 2: School and surrounding area with tip above shown by red circle.
1:10,000 (Ordnance Survey License No.: AL100015788).

ESP have undertaken previous assessments for the area that included consideration of risks to school users and separately, village residents. The details of the previous reports are provided below:

Godre'r Graig School

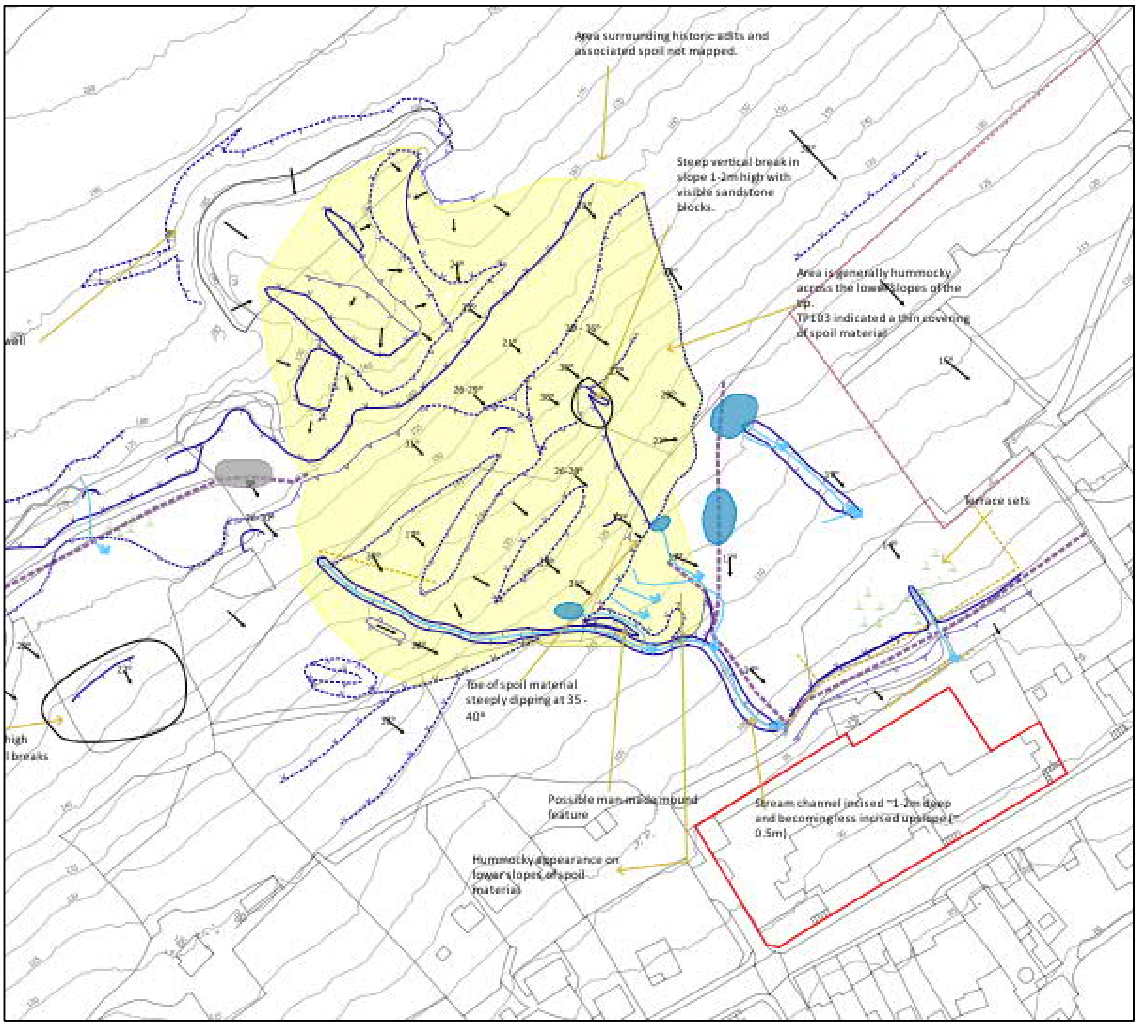
- Preliminary Landslide Hazard and Risk Assessment – ESP.7234e.3221 Rev 1 (August 2019); and
- Preliminary Investigation and Additional Assessment – ESP.7234e.02.3302 Rev 2 (February 2020)

Wider Godre'r Graig Village

- Preliminary Landslide Hazard and Risk Assessment - ESP.7372e.3337 Rev 2 (June 2020)

Executive summaries for the above assessments have also been produced and issued to avoid repetition and for clarity they are not referred to in this document. In addition, a Land Stability Summary was prepared that combined all the above information, again, this is not discussed in this report for clarity.

The extents of the Quarry Spoil Tip are shown in Insert 2 below. The Tip is located on relatively steeply sloping ground above the school, and it is well vegetated. There are no formal or easy access routes to the Tip, and we understand that all access is via private land.



Insert 2: Quarry Spoil Tip boundary plan – Tip shown by yellow shaded area

The previous work included a risk management or mitigation options assessment, where different options were scored for effectiveness, durability, practicability, sustainability, and cost. The scoring system was given +1, for a positive impact, 0 (or zero) for a neither negative or positive impact and a -1 for a negative impact, all relative to the other options. The risk management or mitigation options that scored the highest were:

1. A combined approach of incorporating drainage to create betterment only, install monitoring points and produce warning system, 2 points; or

2. Close the school such that the tip no longer represents a risk to school users, 1 point.

In addition, the assessment showed that physically removing the tip or some combination of hard engineered structure(s) were unfavourable, with -1 point and -4 points respectively.

1.2 Updated Monitoring

1.2.1 Introduction

As discussed in Section 1.1, an intrusive investigation of the Quarry Spoil Tip was carried out in 2019 and early 2020. This investigation included the installation of ground movement monitoring equipment, inclinometers, which were installed in three boreholes (BH01, BH04 and BH05).

In addition to the previous phase, the inclinometers were recently monitored on three occasions, between May 2021 and July 2021, the full inclinometer results are provided in Appendix A and the data from each position described below.

1.2.2 BH01

The inclinometer was installed to a depth of 5.3m and the base of the Quarry Spoil Tip in this borehole is at 4m depth. Monitoring has shown movement between depths of about 3.5m to 2.5m toward the valley floor (downhill), in the order of 14mm.

1.2.3 BH04

The inclinometer in BH04 was installed to a depth of 7.2m and the quarry Spoil Tip extends to a depth of 6m. The data from the monitoring is not conclusive; it may be that the base of the installation is moving with surrounding soils. The graphs do however suggest movement, in the region of 25mm, and for the lower half to be moving more than the upper half.

1.2.4 BH05

The quarry Spoil Tip material extends to a depth of 5.2m in BH05 and the inclinometer extends to a depth of 11.2m. Monitoring has shown movement toward the base of the Quarry Spoil Tip and potentially in the underlying soils at a depth of around 5m to 6m, where it has cumulatively moved approximately 18mm. Movement has also been measured at shallow depth in the installation, within the body of the Quarry Spoil Tip material.

1.2.5 Summary

The results from BH04 are not conclusive; however, the two other installations clearly show downward movement of the Quarry Spoil Tip (towards the school).

Our previous assessment suggested that the Quarry Spoil Tip was Marginally Stable, i.e., that it was likely to fail at some time in response to destabilising forced reaching a certain level of activity. The information from the inclinometers suggest that the Quarry Spoil Tip is moving and is Actively Unstable, i.e., destabilising forces are producing continuous or intermittent movements.

1.3 Objective and Scope of Works

An option from our previous assessment (ESP.7234e.02.3302 Rev 2 (February 2020)) was a combined approach of incorporating drainage to create betterment, installing monitoring points and producing a warning system. NPTCBC have confirmed this option has been discounted due to:

- Uncertainties at this stage in achieving a 'stable' condition that meets modern design standards.
- Confidence in the efficacy of a warning system, and safeguarding of school users, without significant investment in supplementary investigation, long-term ground monitoring and assessment. It is likely the school would remain displaced until defined.
- The unknown scale of remedial work following any future ground movement with a remaining risk of future displacement of the school.

In June 2021 NPTCBC instructed ESP to investigate design options and produce budget estimates for works associated to the tip, to include, but not limited to:

1. The development of a design and production of a budget estimate for the removal of the spoil materials associated with Cilmaengwyn tip (Godre'r Graig Tip).
2. The development of a design and production of a budget estimate for a hard engineering solution in the form of bunds, catch walls etc., to protect Godre'r Graig Primary School from the slip of any spoil material associated with Cilmaengwyn Tip (Godre'r Graig Tip); and
3. The development of a design and production of a budget estimate for demolition of Godre'r Graig Primary School building and reusing the site with a community benefit. This option will have to take into account the effect on properties downhill of the school from the slip of any spoil material associated with Cilmaengwyn Tip (Godre'r Graig Tip).

To achieve the above, ESP commenced with a review of our previous assessments and formed a project team with other specialists (Civil and Structural Engineers, Earthworks and demolition Contractors) to provide robust and current commercial information on possible cost and design.

1.4 Report Format

The report provides information required by the brief in separate sections. The option for removing the tip and all associated works and costs are provided in Section 2. The selection process and anticipated costs for a hard engineered solution is provided in Section 3 and Section 4 discussed demolition costs and a risk assessment for houses down gradient of the school. The report concludes with a discussion as Section 5.

This report is issued in a digital format only.

1.5 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.

2 Removal of Quarry Spoil Tip

The remediation option to remove the tip was discussed in our February 2020 report (ESP.7234e.02.3302 Rev 2) and removes the risk from school users, such that the school could continue to be used once removal is complete.

Practicalities, sustainability and cost were negative reasons for this option, however, it probably proved the most effective and durable solution as the hazard and risk is removed and also retains the school.

2.1 Removal Method

Suitably experienced contractors were asked to assist in preparing an outline scheme to remove the tip and their assessment follows site inspections.

Initial proposals suggest that access to the tip could be made via two points, and both will be required to remove all the Quarry Spoil Tip safely; the details of such access points are provided in Appendix A.

A compound could be set up in the school, largely utilising existing access routes. Some betterment to existing routes would be required and costs to achieve this has been estimated.

The exact method of removal would be subject some further investigation, which is allowed for but will generally comprise removing spoil from the top down. Temporary barriers have been allowed for to protect from small detachments, rocks and small boulders.

Conventional plant will be used, including 20t and 30t tracked excavators, D6 bulldozer, a25 articulated trucks and road lorries.

There would be a pre-commencement period of around 6 weeks to ensure risk assessments are completed and removal is estimated to take 51 weeks, based on 40 lorry loads of material removed from site per day.

2.2 Costs

The costs are provided in Table 1 below, which outlines the main items covered and the general process of the tip removal.

Table 1: Work items and costs for Tip removal

Description	Quantity	Unit	Rate (£)	Amount (£)
Additional Investigation and Assessment for production of safe method of work.	1	Provisional Sum	60,000	60,000
Preliminaries (inc. supervision and accommodation)	1	No	210,082.66	210,082.66
Security	1	No	71,253.14	71,253.14
Road Sweeping	1	No	86,014.31	86,014.31
Site Clearance	17,479	m^2	4.35	76,033.65
Stockproof fencing	550	m	10.88	5,984.00
Excavate and dispose to on site stockpile	87,395	m^3	10.54	921,143.30

Description	Quantity	Unit	Rate (£)	Amount (£)
Dispose off-site from stockpile	87,395	m^3	44.91*	3,924,909.45
Access tracks, widening for road and site lorries	1	Provisional Sum	500,000.00	500,000.00
Full Time Engineer Supervision and Support including reporting	1	Provision Sum	205,720.00	205,720.00
Contamination and Geotechnical testing	1	Provisional Sum	10,000	10,000
Reinstatement of original ground surface, streams etc. Investigation to check remaining stability			TBC	TBC
Access through third-party land			Client	Client
Estimated Total (exc VAT)				**6,071,140.51**
Notes: *Inert waste classification and rate assumed. To be confirmed with further testing.				

2.3 Assumptions

Calculations were made to estimate the volume of the Quarry Spoil Tip. This was achieved by using the mapped area of the tip (Insert 2), a combination of the topographical information and LiDAR information and an assumed general thickness of 5m. This allowed a digital model to be generated and the assumed volume of the tip is 87,395m^3. Additional work has been allowed to confirm this quantity before commencement.

The cost has been prepared on the assumption that the Quarry Spoil Tip is to be removed to landfill, at an inert rate. In reality, there may be some soils that will not be inert but quantities at this stage are not known, or easily estimated. Thus, the landfill cost could be higher.

The proposed access routes pass through private land and agreements would need to be made by the client with specific landowners on access, and possible compensation agreed. No rate has been included in the above costing for these agreements and works associated with third party land access or any reinstatement requirements.

The whole Quarry Spoil Tip would need to be cleared of vegetation and access routes would be made that would impact local ecology. No assessment to this regard has been made and it is assumed that such impacts will be acceptable, or off set with other schemes. The costs for such impacts are not considered.

It may be possible to reduce the landfill costs through processing the material as a recycled aggregate. Permits, exemptions or management plans would be required to enable this.

3 Engineered Structure

Some form of hard engineered solution was discussed in our February 2020 report (ESP.7234e.02.3302 Rev 2). There are numerous types of hard engineering solutions available that could provide betterment, but not all are suitable.

The quantity of material that could fail is not predictable without robust site investigation and assessment. Modern-day structures are designed to resist a set amount of force and there are uncertainties and limitations in selecting structure types. It must be appreciated that there is a great deal of uncertainty on how much soil and rock material may move downslope and therefore the effectiveness of this method of protection is unknown.

Ongoing monitoring of the condition of the tip and structure are critical. Continuing maintenance and repair are likely to be required due to damage from falling material and reconstruction is likely to be required following large ground movements.

The current wall/engineered structure design is not intended to protect the school from a failure of the whole Quarry Spoil Tip. The initial design of the wall is to provide some protection for the school users from early and small ground failures/detachments; if a failure occurred it would be necessary to vacate the school until a safety assessment is made. The duration of any remedial works will influence the timescales of reoccupation of the school following ground movement; school staff and pupils will be temporarily displaced.

Engineered solutions fared poorly in our previous remediation options assessment; however, it is considered below as part of the brief provided by NPTCBC. This assessment has been implemented with suitably qualified and experienced civil and structural engineer partners.

3.1 Engineered Solution Selection

3.1.1 Introduction

Several options for the form of the retaining structure have been considered and these can be grouped into the following categories:

- Gravity retaining;
- Reinforced concrete cantilever;
- Reinforced soil retaining; and
- Embedded wall.

Gravity retaining walls rely on their self-weight to retain the wall behind, they are designed such that their mass prevents them from overturning, and they also rely on the friction between the underside and the soil beneath.

Reinforced concrete cantilever walls act in a similar manner but partially rely on the self-weight of the soil that is retaining. The bases of both of these types of walls are shallow and considering the potentially considerable depth of quarry spoil, these types of wall will bear on to the soil that has the potential to slide. Therefore, these types of walls have been discounted.

Reinforced soil walls utilise a system of anchors embedded into the retained earth but the quarry spoil is of a significant depth so the anchors will be within the soil that has the potential to slip and therefore this type of wall has also been discounted. The soil anchors would require to be embedded into the weathered bedrock and in the event of a landslide the nails may bend and fail.

Embedded retaining walls will pass through the quarry spoil (if located on the tip) and penetrate the underlying competent strata and would be designed such that it is not reliant on the quarry spoil. Embedded retaining walls may be designed as a continuous line of bored piled or as a 'King Post' wall using steel columns spaced at centres commonly between 1m and 3m with the space between infilled with precast concrete panels. It has therefore been concluded that the embedded retaining wall option is the most viable option for the retaining structure solution and with the need for the structure to project above the existing ground surface to catch any potential landslip overtopping the structure and reaching the school, a King Post wall is considered the preferred solution.

Insert 3: King Post Retaining wall example

3.1.2 King Post Retaining Wall

King Post walls involve drilling a hole with a continuous flight auger (CFA) large diameter piling rig, then inserting a steel column and infilling with concrete. The steel column will protrude above the ground and precast concrete panels will be inserted into the spaces between them. Their advantages include:

- They are fast to construct;
- They are generally more cost effective than other types of embedded retaining walls;
- Their installation is generally vibration free due to the use of a CFA rig;
- The steel sections require little or fixings thus reducing the requirement or working space on site;
- They are suitable for use in hard ground (the ground investigation indicated underlying bedrock);

- There is little or no spoil generated on site; and
- They are less affected by groundwater.

The main disadvantage of this type of wall is the limited site access, however this will be common to all solutions. The location of the proposed wall is shown in red on the insert below, and measures some 110m in length.

Insert 4: Possible location of wall

3.1.3 Other Options Discounted

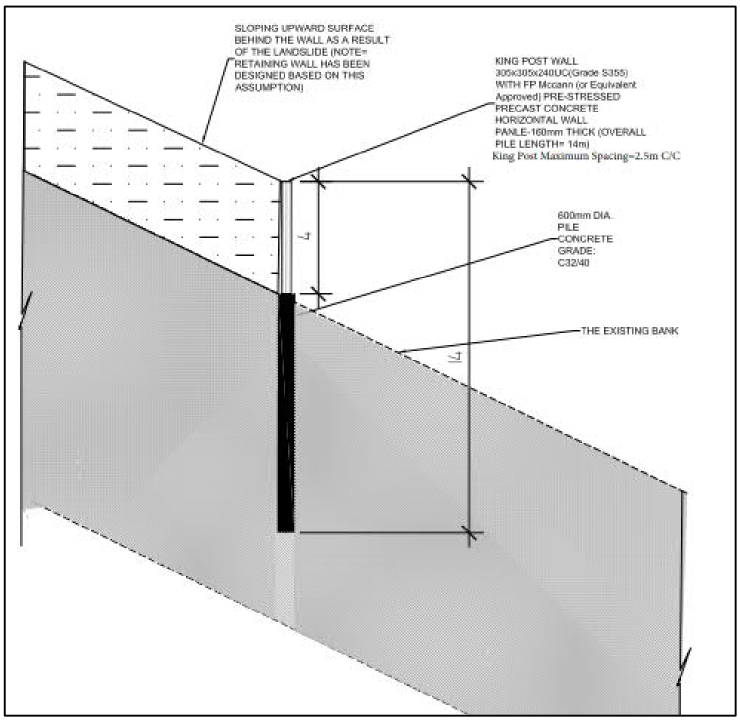
Consideration was given to some form of netting with soil nailing. Specialist installers confirm that both options would be unsuitable for the site due to the morphology of the tip and variable thickness circa 5 to 19m.

Rock netting has been considered as an infill between the king posts as an alternative to precast concrete panels as they will have less of a visual impact and will reduce the construction period. However, at this stage, this option has been discounted for two reasons. Firstly, there is a concern that in the event of a landslide occurring after a prolonged period of rainfall then the quarry spoil may act as a slurry so netting will be less effective. Secondly, rock netting is generally suited for local loads such as rocks and boulders travelling at high speed and not a larger landslide failure. Examples of rock netting are provided below:

Insert 5: Rock Netting examples

3.2 Design of Barrier

A retained height of 4m has been estimated for the purposes of this design and has been derived from the geophysical survey that shows the depth of spoil reducing near the bottom of the embankment. Detailed analysis may inform that a height of greater than 4m is required and if that is found to be the case, then a different form of retaining wall may be required with an associated increase in cost that is likely to more than double what is considered within this assessment. With an overall retaining height of 4m, the embedded retaining wall is comprised of steel king posts with the pre-stressed precast horizontal wall panels. The normal maximum spacing of the king post is 2.5m (centre to centre). The minimum embedment depth of the king post section is 10m therefore the overall length of the king post is about 14m. The steel king post section is 305x305x240 UC (grade S355). The thickness of the horizontal wall panel is 160mm and should be satisfactory to resist and transfer the lateral actions as a result of the earth pressure. Preliminary scheme design calculations of the proposed retaining wall are provided in Appendix B, and are illustrated below in Insert 6.



Insert 6: Typical Section view of King Post Wall.

3.3 Construction Method Including Temporary Works

It is considered that the existing primary school could be used as the site compound for site welfare and material storage. The existing access road could be widened to form the main access to the site, see insert 7 below.

Insert 7: Existing School Entrance to be widened.

The improved and widened access road would also provide access to the work area for operatives and large plant (such as a piling rig and craneage). The location near the proposed retaining wall would need to be cleared of topsoil, vegetation and levelled for works to commence. A suitable working platform would need to be constructed prior to piling and lifting activities (in the area shown in the photograph below). Following piling, the wall would then be installed utilising a crane, after installation the site would be demobilised and the car park returned to normal operation. It is proposed (if acceptable), that the widened road (school access) would be left as a permanent install.

Insert 8: Existing School Entrance to be widened.

3.4 Costs

The budget costs make some assumptions at this stage and are indicative only. However, they are accurate enough for this assessment.

A detailed site investigation would need to be carried out to enable accurate design of the wall, and this is based upon a 10m embedded depth of the wall and the ground conditions we expect at this stage.

Table 2: Work items and costs for Wall

Description	Quantity	Unit	Rate (£)	Amount (£)
Additional Investigation and Assessment for production of safe method of work.	1	Provisional Sum	250,000	250,000.00
Site Surveys		See breakdown in Appendix C		10,000.00
Site Establishment and Clearance		See breakdown in Appendix C		67,100.00
Site Access roads and Working Platforms		See breakdown in Appendix C		103,039.96
Piling		See breakdown in Appendix C		91,500.00
Retaining Structure		See breakdown in Appendix C		484,262.00
Landscaping		See breakdown in Appendix C		28,160.00
Preliminaries		See breakdown in Appendix C		117,609.29
Professional Costs and inc. 10% project contingency on construction.		See breakdown in Appendix C		234,434.52
Possible variation due to emerging conditions				Unknown variable
Access through third-party land			Client	Client
Diversion of overhead cable			Client	Client
Regular Inspections by Qualified Person			2,000 / year	TBC
Ongoing Maintenance			TBC	TBC
Estimated Total (Exc. VAT)				**1,386,105.77**
Notes: *Inert waste classification and rate assumed. To be confirmed with further testing. Assuming no reinstatement of school access road Assuming no planning fees, regulatory actions/responses.				

3.5 Programme

The programme for the construction of this retaining structure options is estimated as 8 to 10 months, as detailed below:

- Procurement Period: 6-8 weeks.
- Pre-Construction: 12-16 weeks (predominantly led by material lead in times for the retaining structure). No programme allowance has been made for the following:
  - Liaising with local authority and acceptance of highway alterations.
  - Managing and delivery of service diversion to overhead power line.
  - Land ownership disputes.

- Construction: 16 weeks (see below):
  - Site establishment: 4 weeks.
  - Working platform and muck away: 4 weeks.
  - Construction of wall: 6 weeks.
  - Site Demobilisation: 2 weeks.

3.6 Assumptions

There are some design assumptions/risks, as detailed below:

- The proposed solution is based on high level information and will require a detailed analysis to inform the final design.
- A detailed design involving a finite element analysis to model the ground characteristics of the quarry spoil in a flow state and the underlying strata may require a more robust wall with a significantly greater construction cost than what is currently estimated.
- The proposed solution is based on an estimated volume of quarry spoil. The final design will require an accurate assessment of the volume of spoil that has the potential to move.
- Further ground investigation will be required to determine soil and rock parameters to inform the final design of the retaining wall.
- No planning permission costs are allowed, and specialists should be consulted if these will be required for any items of the scheme, such as the road widening, or permanent structure.

In addition, there are some possible construction risks, as discussed below:

- There is an existing retaining wall at the rear boundary of the school. No site traffic is to traverse, or no works are to be carried out within the zone of influence. The zone of influence will be determined at detailed design stage.
- The wall is to be constructed at the base of a slope that has been shown to be at risk from movement. Monitoring of the slope is to be in place prior to any construction work and shall remain in place for the full duration of the works.
- The works will traverse existing streams. The Contractor is to provide a method statement to ensure that these streams are not contaminated during the works.

4 Demolition of School and Assessment

The option to mitigate the risk from the Quarry Spoil Tip by abandoning the school was discussed in our February 2020 report (ESP.7234e.02.3302 Rev 2). This option was scored negatively on cost, but the option is effective and durable. Social and economic impacts were not easily assessed and should also be considered carefully by the client.

The closure of the school would lead to its requirement for demolition. A demolition contractor has been consulted to help provide budget costs for the school demolition.

Once the school is demolished, there is a possible increased risk to properties and people down gradient of the school from the Quarry Spoil Tip and this is assessed in Section 4.5.

4.1 Method of Demolition

Following an asbestos survey, suitably trained and qualified asbestos removal operatives should work to a specific Plan of Work to remove all remaining asbestos-containing materials identified on the Demolition Asbestos Survey provided in strict accordance with the Control of Asbestos Regulations 2012. The works should be undertaken concurrently with the soft strip.

Material arising from the internal clearance and soft strip works should be processed and segregated at the source and transported to a controlled waste collection zone.

Movements on and off the site should always be fully supervised by a Banksman operative and our site entrance/exit will be attended by a Gateman.

All demolition works will be planned and executed following BS6187:2011 'Code of practice for full and partial demolition' and following specific timescale within the tender documents.

A demolition specification excavator should work utilising specialist hydraulic demolition attachments to carefully remove the roof structure and then carefully reduce the exterior and interior walls on a section by section basis and all works carried out in a controlled methodical manner.

Extreme caution will be taken during the demolition of the building to ensure that all demolition arisings are brought inside the confines of the site and that no material goes out over the site boundary.

Once the superstructure demolition works are complete, the slabs and foundations of the building will be removed. Dust suppression should be applied to ensure that dust does not become an issue for neighbouring properties.

Trained and qualified demolition operatives should always be on hand to marshal the demolition excavator throughout this process whilst ensuring they are a safe distance away from the face of the demolition work.

The programme for the whole demolition works is about 11 weeks, and a detailed plan is provided in Appendix D.

4.2 Cost of Demolition

and costs anticipated for this option are provided in Table 3 below.

Table 3: Work items and budget costs for School Building Demolition.

Description	Quantity	Unit	Rate (£)	Amount (£)
Asbestos Survey	1	Provisional sum	5,000	5,000
Asbestos Removal	1	Provisional sum	25,000	25,000
Ecology Works	1	Provisional sum	5,000	5,000
Demolition Costs	1	Provisional sum	160,000	160,000
Cost of assessment and design works for site reinstatement – for ongoing landslide protection and ecological value[1]	1	Provisional sum	50,000	50,000
Costs for site reinstatement/construction				TBC
Estimated Total (exc VAT)				**245,000.00**

Notes:
1. Not including any investigation work required.
2. Consideration to any drainage/surface water management options not considered.
3. Costs of service disconnections/realignments not considered.

4.3 Assumptions

The costs for asbestos surveys and removal are approximate only and no access to the school was made to provide the costs, full access should be made to allow a final price to be provided.

The programme and costs allow to crush and leave material on site (e.g., 6F2 fill).

The end use of the area is not known and costs for this are not foreseeable. There will be some ecological costs, survey work and consultation that is not provided as a detailed budget and will need to be reviewed once proposal details are known.

4.4 Future Use

We understand that there are no development proposals for the site and consideration is being given to the use of the site for community and ecological benefit.

The use of the site will need to limit or prevent public access and we suggest it be landscaped by a suitable qualified and experienced ecologist to provide significant ecological benefit to Godre'r Graig.

As discussed below in Section 4.4, the future design of the site will need to incorporate some risk mitigation measures for properties downslope of the school, and this should be designed in parallel to any ecological scheme.

4.5 Risk Assessment

4.5.1 Introduction

Our previous reports have provided risk assessments for both Godre'r Graig Primary School (ESP.7234e.3221 Rev 1 August 2019 and ESP.7234e.02.3302 Rev 2 February 2020) and the Wider Godre'r Graig Village (ESP.7372e.3337 Rev 2 June 2020).

If the tip were to fail, detached material would move downhill perpendicular to the contours and thus only impacted the school. Removal of the school structure would remove a barrier for any downward moving failed material from the tip. This section provides an updated risk assessment for the properties down-gradient of the school.

There are other landslide hazards in the Godre'r Graig area; our Wider Village assessment showed that residential properties in Godre'r Graig are at a very low to low risk.

4.5.2 Updated Assessment – Quarry Spoil Tip impacting residential houses

The below assessment is qualitative, and generally based on a degree of believe assessment using the Australian Geomechanics Society (AGS, 2007), and subsequent papers to standardise its use worldwide (Fell et al 2008); as used in previous assessment for the site. It draws on previous knowledge of the site which is held in previous reports.

Table 4 provides a qualitative measure of likelihood and Table 5 presents a qualitative measure of consequences.

Table 4: 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	Rare	E

Approx. Annual Probability		Implied Indicative Landslide Recurrence Interval (years)		Description	Descriptor	Level
Indicative Value	Notional Boundary					
				circumstances over the design life.		
	$5x10^{-6}$		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 5: 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.	Moderate	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 4 and 5 are then used in Table 6 to provide a qualitative risk ranking and Table 7 provides example implications for each risk ranking.

Table 6: Qualitative Risk Analysis Matrix

LIKELIHOOD	CONSEQUENCE (TO PROPERTY)				
	1 Catastrophic	2 Major	3 Moderate	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 7: 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.

Our previous assessment suggested that movement of the Quarry Spoil Tip was possible and that if a detachment were to reach the school, moderate damage would occur. This resulted in a medium risk.

There are 12 residential houses located immediately downslope of the primary school, on the opposite site of Graig Road. These are terraced and semi-detached properties which front directly onto Graig Road, gardens are to the rear of the properties, i.e., to the south. The approximate horizontal distance between the toe of the Quarry Spoil Tip and these houses is 100m or more.

In comparison, the houses are located at a greater distance from the Quarry Spoil Tip to the school and there are no gardens between the Quarry Spoil Tip and houses. On this basis, a failure of the Quarry Spoil Tip has been assumed to cause minor damage to the residential properties, which using a possible likelihood, results in a medium risk. This medium risk is unlikely to be acceptable to the client and some risk mitigation measures will be required.

The simplest method of reducing the risk to the residential houses is to incorporate some landslide protection and this could be achieved by some form of barrier or bund on the lower and level school site. A possible outcome could be to use the (processed) demolition arisings of the school to create a 2m to 3m high engineered bund on the school site which would present an informal barrier. The bund would need to be designed and include adequate drainage for long term stability.

If an engineered bund were to be created on the school site and be situated between the Quarry Spoil Tip and the 12 residential houses, the anticipated damage to residential houses would be lowered, and we would assume that little damage would occur.

Assuming little damage were to occur, and a possible likelihood, the risk to the residential houses would be very low, which we assume would likely be acceptable by the Client. Based on similar studies, the risk to traffic and pedestrians is likely to be lower due to their transient nature. We recommend no public access to the school site and be designed such that it need no or very little maintenance. It is unlikely to be suitable to construct a similar soil/earth bund feature on the slope above the school for long term protection due to stability issues.

5 Discussion

5.1 Introduction

The brief provided by NPTCBC was to undertake an assessment of different mitigation options for the Quarry Spoil Tip that is located on slopes above Godre'r Graig Primary School. Previous work included risk management or mitigation options assessment; different options were scored for effectiveness, durability, practicability, sustainability, and cost. The highest scoring (most favourable) options were:

- A combined approach of incorporating drainage to create betterment only, install monitoring points and produce warning system, 2 points. This option has been discounted by NPTCBC, as described earlier in Section 1.3.

- Close the school such that the tip no longer represents a risk to school users, 1 point.

The assessment showed that physically removing the tip or some combination of hard engineered structure(s) were unfavourable, with -1 point and -4 points respectively.

Recent monitoring of the Quarry Spoil Tip has indicted clear ground movement towards the school (~15mm downhill movement to date, see results Appendix A). Our previous assessment suggested that the Quarry Spoil Tip was Marginally Stable, i.e., that it was likely to fail at some time in response to destabilising forces reaching a certain level of activity. The information from the inclinometers suggest that the Quarry Spoil Tip is moving and may be **Actively Unstable, i.e., destabilising forces are producing continuous or intermittent movements**.

Our brief from NPTCBC was to consider, and provide budget estimates for, works associated with the tip on the following three options:

1. The development of a design and production of a budget estimate for the removal of the spoil materials associated with Cilmaengwyn tip (Godre'r Graig Tip).

2. The development of a design and production of a budget estimate for a hard engineering solution in the form of bunds, catch walls etc., to protect Godre'r Graig Primary School from the slip of any spoil material associated with Cilmaengwyn Tip (Godre'r Graig Tip); and

3. The development of a design and production of a budget estimate for demolition of Godre'r Graig Primary School building and reusing the site with a community benefit. This option will have to take into account the effect on properties downhill of the school from the slip of any spoil material associated with Cilmaengwyn Tip (Godre'r Graig Tip).

5.2 Outcomes

The table overleaf summaries the main costs for each of the three options and provides high level comments on unknowns, assumptions, and other areas for potential costs.

Table 8: Review of three chosen remediation options

Option	Estimated Cost (Exc. VAT)	ESP Comments
Remove Quarry Spoil Tip	£6,071,140.51	• Long timescale, possible for unforeseen (un-investigated) ground hazard issues. • Most costly but retains the school. • Some unknowns with access; costs only known through further investigation, design, and consultation.
Landslide barrier/engineered solution	£1,386,105.77	• Detailed investigation and design required to ensure allowed wall sufficient to meet Client expectations on school protection. • Costs will increase significantly if a larger is structure required. • Unknowns on access and costs only known through further investigation, design, and consultation. • Ongoing inspection and maintenance costs (school and barrier). • We do not consider this a technically feasible option at present.
Demolition of school and Risk Assessment	£245,000.00	• Socio-economic impacts unknown. • Remediation/earthworks are required to lower risk to houses downslope of school. • Work could be done in tandem with ecological betterment. • Ongoing prevention of access is required unless further slope stability analysis undertaken.
Notes: No planning or third-party costs included unless discussed in separate estimates. Successful planning permissions for each option are assumed and fees to achieve this are not included.		

6 References

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