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Godre'r Graig Quarry Spoil Tip, Godre'r Graig
Initial Hydrology Assessment

Report Reference: ESP.7234e.06.3800

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Godre'r Graig Quarry Spoil Tip, Godre'r Graig Initial Hydrology Assessment

Prepared for:
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Report Reference: **ESP.7234e.06.3800**

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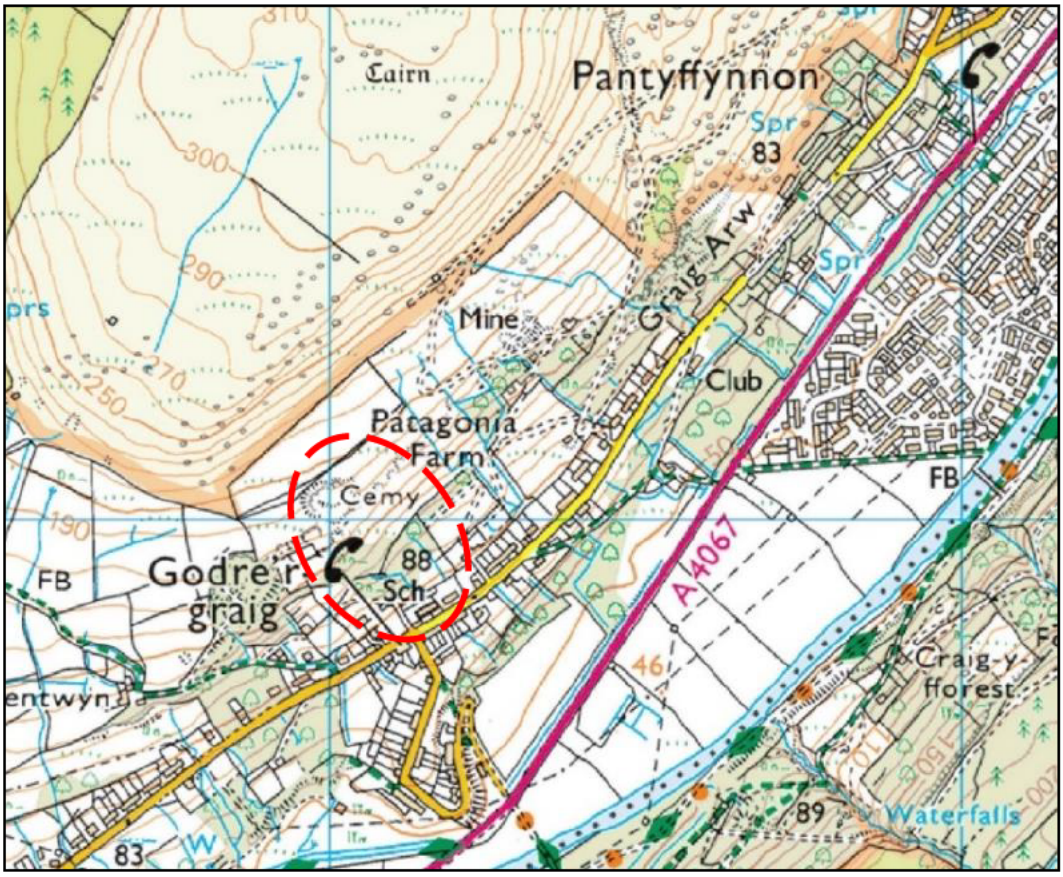
Contents

1 Introduction

1.1 Background

Neath Port Talbot County Borough Council (NPTCBC), hereafter known as the Client, have instructed Earth Science Partnership Ltd (ESP), Consulting Engineers, Geologists and Environmental Scientists, to undertake an initial hydrology assessment of a Spoil Tip on the slopes above Godre'r Graig Primary School (the School) in the Tawe Valley. The general location of the school and tip are shown in Insert 1 below.



Insert 1: 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 the primary 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);
- Preliminary Investigation and Additional Assessment – ESP.7234e.02.3302 Rev 2 (February 2020) ; and
- Tip Remediation assessment – ESP.7234e.04.3564 Rev 4 (September 2021).

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. Salient information from the previous assessments is summarised in Section 2.0, the previous reports should be referenced in full alongside this assessment.

The previous assessments and remedial options appraisals have identified that the implementation of drainage system and improvements to existing drainage in the area, is a feasible solution for betterment to increase the stability of the tip.

1.2 Objective and Scope of Works

The aim of this assessment is to develop further understanding of the hydrological setting of the slope behind Godre'r Graig Primary School, with specific reference to the Spoil Tip previously identified. The assessment will inform design of a formal drainage system with the aim of betterment of water flow within the Spoil Tip and to reduce ponding and saturated areas.

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

- Review of assessment and investigation information to date;
- Detailed mapping of informal surface water drainage networks, with a repeat visit following a period of heavy rainfall;
- Groundwater monitoring of existing groundwater wells;
- An assessment of current hydrological conditions and provision of a review of betterment options and action plan.

The contract was awarded on the basis of a competitive tender quotation. The terms of reference for the assessment are as laid down in the Earth Science Partnership proposal of 2nd August 2022 (email).

The investigation and assessment was undertaken in September and October 2022.

1.3 Report Format

This report includes a summary of the previous investigation and assessments in Section 2.0. Details of recent assessment and updated hydrological setting are provided in Section 3 and a discussion on the drainage betterment options and recommendations are provided in Section 4.0. 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.

As discussed in Section 1.1, this report encompasses the study area previously referred to as 'Site 2' (ESP, Aug 2019) comprising the Quarry Spoil Tip upslope from Godre'r Graig Primary School, the quarry above and the immediate surrounding vicinity.

Given the nature of the site, a number of limitations were imposed on the assessment. Limited access to the site was primarily due to constraints posed by dense vegetation and steeply sloping ground. Due to private land ownership, access to the site was restricted.

Our assessment was required in a relatively short period time and this placed some limitations on the amount of monitoring time available to feed into the ground model and assessment. At the time of writing, on a short period of monitoring has been undertaken and this may have missed some seasonal variations in the groundwater regime, or perhaps seasonal movement of the tip has not been identified. The monitoring should be continued, and the assessment should be updated accordingly.

It should be noted, that we have not considered Sustainable Drainage Systems (SuDS) as part of this assessment and we understand it is not required for the proposed development.

2 Summary of Previous Information

As discussed in Section 1.2, previous desk based assessments and intrusive site investigations have been carried out at the site, a summary of salient information is provided in the sections below.

2.1 Ground Conditions

The study area comprises the quarry spoil tip/heap associated with an old quarry on the lower slopes of Mynydd Allt-y-grug. The slopes underlying layered bedrock of the Llynfi Beds comprising sandstone and mudstone has results in a gently stepped topography which has since been anthropogenically modified and over-steepened as a result of quarry spoil tipping (Quarry Spoil Tip).

The previous site investigation (ESP, 2020) identified variable ground conditions, as summarised in the following general succession:

- **Made Ground – Topsoil:** encountered to a maximum depth of 0.2m across the site. Occasional angular sandstone cobbles and boulders were noted across the site surface below vegetation. This is unlikely to have been placed across the Spoil Tip and probably originates from decomposed, predominantly wind-blown or old organic debris.;
- **Made Ground – Coarse Discard:** encountered to a maximum depth of 6.0m in the mid and upper portions of the spoil tip and 2.3m depth on the lower portions of the spoil tip and generally comprising clayey sandy gravel with high to medium cobble content.
- **Made Ground – Fine Discard:** encountered to a maximum depth of 5.25m in the mid and upper portions of the site. Fine grained quarry spoil material was not encountered in the trial pits at the base of the slope. The material generally comprised soft to firm brownish grey and grey brown sandy very gravelly clay with low cobble content.
- **Probable Glacial Diamicton**: encountered beneath quarry spoil to a maximum depth of 3.4m in the trial pits in the lower portions of the slope. The material generally comprised a soft to firm orange-brown mottled grey silty sandy slightly gravelly clay with low to medium cobble content.
- **Weathered Llynfi Member Bedrock:** encountered to a maximum depth of 7.2m in BH04 and to a depth of 5.5m in the upper portions and base of the slope.
- **Llynfi Member Bedrock:** identified in BH05 below quarry spoil at a depth of 5.6m and proven to 11.1m depth. The upper strata were encountered as weak thinly laminated friable mudstone becoming medium strong and strong siltstone and sandstone.

2.2 Hydrogeological Setting

The combination of the geological setting and topography of the study area will dictate the hydrogeology, a summary of the key hydrogeological aspects is provided below:

- The study area of this assessment 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.

- The underlying bedrock comprises more permeable sandstone (Rhondda Member), overlying a series of mudstones, siltstones and sandstone beds of the South Wales Upper Coal Measures. The argillaceous rocks will likely limit downward migration of groundwater.
- Groundwater flow may also be controlled by fractures, and along bedding planes. Spring lines will likely form where more permeable strata overlie less permeable strata and several springs within the study area are noted to mirror the outcrop pattern.
- Spring lines may also occur in relation to coal seams and, any worked coal seams will likely provide a preferential pathway for groundwater to drain, and water will discharge through adits, which will form preferential pathways.
- Flow rates of water bodies associates with mine workings are likely to higher than natural springs. Given the presence of two coal seams that are likely to subcrop beneath the Quarry Spoil Tip , there is likely possibly two groundwater bodies that will be feeding into the tip, as the water is effectively 'trapped' by the tip to form a groundwater body within the tip.
- Porosities and permeabilities will vary in the tip due to material heterogeneity. If present (not certain at present), persistent zones or layers of cobbles or boulders near the base of the tip may act as a preferential drainage pathway; however, more evidence and confidence in the Ground Model is needed to define this.

The presence of several streams, and areas of standing water, or waterlogged ground at the base of the tip suggest that there is a body of water in the Quarry Spoil Tip . Previous observations have indicated water flow to be constants, suggesting a groundwater source rather than a response to rain/infiltration alone. It is considered that groundwater in the tip is hydraulically linked to groundwater in the hillside.

2.2.1 Previous Monitoring and Assessment

The previous monitoring data identified a body of water within the Quarry Spoil Tip, the vibrating wire piezometers suggest that the head of water changes over time, likely to be as a result of rainfall or increased groundwater inflows from rainfall on Mynydd Alt-y-grug.

The highest variation in head measured by the two vibrating wire piezometers is in BH04, which is positioned mid-slope. The higher variation might be due to the fact that groundwater in this area is connected to a larger body of water, perhaps associated with the main groundwater body in bedrock below Mynydd Allt-y-grug, a plausible path is through the (worked) coal seams in the valley.

Visual evidence of water emanating at points at the base of the tip, rather than all the way along, coupled with the possibility of a variable head of water in the tip suggests that the groundwater body varies in thickness under the tip, perhaps due to water following former hollows or depressions in former ground surface.

The groundwater conditions identified in the investigation are summarised in the table below.

Table 1: Summary of previous monitoring data from groundwater monitoring standpipes and VWP's. (ESP, 2020)

Well ID	SP Response Zone (m)	Strata	Recorded water depth range (m)		Comments
			Min	Max	
TP102	2.0 – 5.0m	Made Ground – Coarse Discard	4.0	4.95	Water levels standing within MG- Coarse Discard strata.
TP104	3.5 – 5.5m	Weathered Llynfi Member Bedrock	1.8	2.1	Water levels standing within MG- Coarse Discard strata, above fine grained Glacial Diamicton at 2.3m.
BH02	2.0 – 3.0m	Made Ground – Coarse Discard	2.6	2.9	Water levels standing within MG- Coarse Discard strata.
BH03	3.2 – 4.2m	Made Ground – Coarse/Fine Discard	2.6	2.9	Water levels standing within MG- Coarse Discard strata.
Well ID	**VWP Depth (m)**	**Strata**	**Recorded water depth range (m)**		
			Min	**Max**	
BH04	6.95m	Weathered Llynfi Member Bedrock	4.70m	7.02m	Water levels standing within MG- Coarse Discard strata and weathered Llynfi Member bedrock.
BH05	5.70m	Llynfi Member Bedrock	5.27m	5.87m	Water levels standing within weathered Llynfi Member bedrock.

Notes:
1. Full details of groundwater monitoring wells are displayed in ESP report (ESP.7234e.02.3302)

VWP – Vibrating Wire Piezometer SP – Standpipe

Investigation to date has not included monitoring of groundwater conditions outside of the tip and it is not possible to determine where the 'water table' is within the bedrock of Mynydd Alt-y-Grug.

2.3 Hydrological Setting

A review of the historical maps was undertaken as part of the previous assessment, which indicated a series of springs that emanate in the hillside above the tip. They all flow downhill, toward the east or southeast. No water features or areas of wet ground were identified within the boundaries of the Quarry Spoil Tip. The previous water features identified are shown on Figure 1.

These spring and streams were named S1 to S10 in order to provide a way to discuss their origin, path and end point. For continuity of previous assessments, we have kept the same stream naming for this assessment.

Features S1 and S4 to S10 have not be considered further in this assessment as the evidence to date does not suggest that they interact with the Quarry Spoil Tip, or drainage lines associated with the tip.

Streams S2 and S3 only are considered further in this assessment as the information to date indicates that they do, or may interact with the Quarry Spoil Tip. The descriptions, locations and changes of the streams discussed below are also shown in Figure 3; the reader is recommended to view this drawing in conjunction with this section.

The information previously obtained for streams S2 and S3 is summarised below:

Stream S2

- Shown on the historical mapping to flow from the eastern extent of the quarry (Q1) located upslope of the school, and to flow downhill in a south-easterly direction, terminating at the northern school boundary;
- S2 is not indicated on recent OS mapping (2022);
- During the previous assessment (ESP, 2020), S2 was not observed along most of the eastern boundary of the spoil tip, as it may be covered by the tip. It was found to emerge near the base of the tip by an area of waterlogged ground and a series of small streams that go on to flow into a relatively well developed ditch that flows to the eastern end of the school.

Stream S3

- The historical maps show it to originate near to Cwar Pentwyn Quarry (Q2) and to initially flow to the east, when it reaches the Quarry Spoil Tip it is shown to flow toward the southeast.
- Recent OS mapping also suggests that the stream now emerges further down slope than the 1877 historical mapping.
- The Coal Authority report (2019) suggested that this stream disappeared and reappeared in several locations.
- ESP site observations (2020) following vegetation clearance, identified the stream along much of the western boundary of the tip, but it was not traceable near the northwestern corner of the tip, as shown on Figure 1. The lower portions of the stream S3 was located within a well incised ditch.

Further unnamed streams and areas of waterlogged ground and ponding water were previously identified (ESP, 2021) at the base of the tip, as shown in Figure 1. These smaller streams form, what look to be relatively young streams that join streams S2 and S3 downslope.

3 Updated Hydrological Assessment

3.1 Introduction

Field mapping was undertaken by ESP on two occasions with the primary aim to identify the current hydrological status at the site including a review of surface water features and formal/informal drainage systems directly interacting with the Quarry Spoil Tip and immediate surrounding area. The first visit was undertaken on 28th September 2022, during dry weather conditions and following a period of dry weather. Visit two was undertaken on 13th October 2022 during dry weather conditions, following a period of relatively higher rainfall. It should be noted that no vegetation clearance was undertaken prior to the survey and as such, large areas of the site were inaccessible due to dense vegetation.

During the hydrological mapping visit discussed above, the location of the surface water features identified were surveyed using a Geode GNS3 unit.

3.2 Schedule of Surface Water Features

The site observations identified during the recent mapping are detailed in the table below which should be reviewed in conjunction with Figure 2.

Table 2: Schedule of surface water features

ESP Reference	Type	Feature Start	Feature End	Chainage (Ch.)	Approximate Width	Approximate Depth	Status	Flow Rate Comments		Additional Observations	Plates
								V1	V2		
Primary Surface Water Features											
S2	Watercourse	Unknown	Culverted	0-15	450mm	Underground	Culverted Stream – Underground pipe (400mm). with gravel surround.	Steady, low flow at pipe end (Ch.0).	Steady, low to moderate flow at pipe end (Ch.0).	Identified on historic and recent OS mapping.	1 & 2
				15 – 25	400mm	300mm	Incised channel. Gutter pipe and blue pipe leading to bathtub holding water.	Steady low flow.	Steady, low to moderate flow.	Rushes and waterlogged ground observed in wider area.	5
				25 – 35	n/a	n/a	Waterlogged ground surface. No obvious channel. 250mm underground pipe observed at ch.25 (partially blocked).	No obvious surface water flow.	Steady low surface water.	Rushes and waterlogged ground observed in wider area.	3 & 4
				35 – 40	n/a	n/a	No obvious channel. Surface water emanating from vegetated fence line.	Steady, low surface water flow.	Steady, low surface water flow.	Rushes and waterlogged ground observed in wider area.	3 & 4
				40 – 55	n/a	n/a	Unknown, not identified due to dense vegetation.[4]	-	-	-	n/a
				55 – 95 (approx.)	n/a	n/a	Not identified during visit 1. Visit 2 located stream emanating from two pipes at ch. 95.	-	Steady low to moderate flow at pipe end (Ch.95).	S2 feature beyond 45m chainage previously identified (ESP, 2020). Area immediately north noted as waterlogged with some surface water flow.	n/a
S3	Watercourse	Waterfall	Culverted (3 pipes)	0 – 15	3000mm	Underground	Culverted Stream – Underground pipe (300mm). with gravel surround	Very low flow observed from pipe end (Ch.0).	Steady moderate flow observed from pipe end (Ch.0).	Identified on recent OS mapping.	6 & 7
				15 – 45	500mm	400 – 500mm	Well defined incised channel. Vegetation debris (leaf, branches) partially obstructing flow. At ch.45 – channel splits (S3_A)	Steady, low flow.	Steady, low to moderate flow.	Stream channel present within large 'v' shaped ground feature.	8 & 9
				45 – 65	400 – 600mm	400 – 500mm	Well defined incised, stepped channel. Vegetation debris (leaf, branches) partially obstructing flow. At ch.65 – channel splits (S3_D)	Steady, low flow.	Steady, low to moderate flow.		8 & 9
				65 – 120	300 – 600mm	400 – 500mm	Well defined incised, stepped channel. Leaf/vegetation debris partially obstructing flow. Channel significantly meanders, not traced fully in this section due to heavy vegetation.	Steady, low flow.	Steady, low flow.		n/a
				120 – 140	700 – 1000mm	500mm	Well defined incised, stepped channel. Very steeply sloping ground. Leaf/vegetation debris obstructing flow.	Very low, intermittent flow.	Steady, low flow.		n/a
				140 – 165	400 – 500mm	300mm	Less defined, slightly incised channel. Feature observed to spring/sink regularly.	Very low, intermittent flow.	Intermittent, low flow.	-	n/a
				165 – 220	n/a	n/a	Not observed.	n/a	n/a	Feature S3 believed to be present below ground level.	n/a
				220 - 240	300mm	300mm	Defined, shallow channel. Clean. Water source identified as a waterfall from cliff face beyond accessible area. Stream observed to sink into ground at ch. 220.	Steady, low to moderate flow.	Steady, moderate flow.	As identified during previous investigation.	14 & 15

Secondary Surface Water Features											
S3 A	Tributary	Spring	Joins S3	0 – 20	300 – 400mm	500mm	Well defined channel with gravel/cobble base.	Very low, intermittent flow.	Steady, low flow.	Waterlogged ground conditions and rushes noted in area north of S3_A.	10
				20 - 45	300 – 600mm	200 – 400mm	Well defined, moderately incised channel, stepped base with leaf/vegetation debris. Spring observed at ch.45.	Very low, intermittent flow	Steady, low flow.	Waterlogged ground conditions and rushes noted in area north of S3_B.	n/a
S3 B	Channel	Spring	Joins S3A	0 – 15	300 – 500mm	100mm	Well defined, moderately incised channel, stepped base with leaf/vegetation debris.	Dry, no water flow observed.	Dry, no water flow observed.	Feature previously identified (ESP, 2020) and observed as emanating from an area of ponded water.	n/a
S3 C	Tributary	n/a	n/a	n/a	200mm	100mm	Poorly defined channel with leaf/vegetation debris.	Dry, no water flow observed.	Dry, no water flow observed.	Feature previously identified (ESP, 2020) to have flowing water.	n/a
S3 D	Tributary		Joins S3	0 – 25	300 – 600mm	100mm	Moderately defined channel, wide and shallow with leaf/vegetation debris.	Dry, no water flow observed.	n/a	Feature previously identified (ESP, 2020) and observed as emanating from an area of ponded water.	13

Notes:
1. The above table should be read in conjunction with Figure 2.
2. Descriptive terms (e.g. flow rate) are general terms only and do not constitute formal technical terminology.
3. Visit 1 (V1) undertaken on 28/09/2022 following generally dry weather conditions. Visit 2 (V2) undertaken on 13/10/2022 following a period of moderate rainfall.
4. Previous anecdotal information, from landowner indicates this stream formed the villages water supply and was culverted to tanks – the details, and remnants of the previous modifications are unknown.

3.3 Additional Observations

In addition to the schedule of features identified during the site inspection, the following site observations were made and are considered pertinent to the assessment. Where relevant, the location of observed ground conditions have been recorded on Figure 2.

- Generally, surface water flow was observed to be higher during the second visit and following a period of heavier rainfall;
- Waterlogged ground and rushes were regularly observed along the base of the Quarry Spoil Tip . The base of the Quarry Spoil Tip is generally observed by a significant break in slope.
- At approximate chainage Ch. 165, feature S3 is observed to be fed by multiple smaller springs and stream lines. Due to dense vegetation and the intermittent nature of the features, the exact courses could not be defined. It is possible this is the re-emergence of S3.
- The majority of the lower field in which feature S2 is located, and the access track, was observed to be waterlogged during both visits.
- Anecdotal information provided by a private land owner indicated that during periods of high rainfall, the upper extents of feature S3 (Ch. 140 – 165) would experience higher flow rates and would generally be more visible at ground surface.
- The upper extents of feature S2 and a source have not been clearly identified during the site mapping undertaken to date. This may be due to the source being covered/masked by the Quarry Spoil.

As discussed in Table 2, anecdotal evidence suggested the presence of large water tanks relating to feature S2. No evidence of these tanks has been observed during previous assessments, or this updated assessment.

3.4 Updated Groundwater Monitoring

During Visit 1, the previously installed groundwater wells were monitoring and the results are displayed in the table below.

Table 3: Updated groundwater monitoring (2022)

Well ID	SP Response Zone (m)	Strata	Recorded water depth (m)
TP102	2.0 – 5.0m	Made Ground – Coarse Discard	4.50
TP104	3.5 – 5.5m	Weathered Llynfi Member Bedrock	1.75
BH02	2.0 – 3.0m	Made Ground – Coarse Discard	2.75
BH03	3.2 – 4.2m	Made Ground – Coarse/Fine Discard	3.05

Notes:
1. Full details of groundwater monitoring wells are displayed in ESP report (ESP.7234e.02.3302)

The monitored groundwater levels generally align with the levels recorded during previous monitoring.

It should be noted that further groundwater monitoring and inclinometer monitoring visits are to be undertaken, the results of which will be provided separately.

3.5 Additional Client Supplied Information

As part of this initial hydrology assessment, drainage plans relating to the land to the rear of the School have been provided, dated 1999. The plans indicate the presence of two Inlet Bays, at the north east and middle, northern extent of the School.

The drawing shows a water course to enter a 300mm diameter concrete pipe and entering Inlet Bay 1, this is considered to represent feature S3 (Ch. 0 – 15).

A land drain is shown trending north to south and entering Inlet Bay 2, we consider this land drain to be representative of the underground section of feature S2 (Ch. 0 – 15).

4 Discussion of Betterment Options

4.1 Introduction

The previous assessments undertaken by ESP (See Section 1.1) identified a potential risk posed by the Quarry Spoil Tip, namely to the school that was located downhill of the tip.

Previous monitoring of the Quarry Spoil Tip has indicted clear ground movement towards the school. 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**

Remediation solutions such as the removal of the Quarry Spoil material and hard engineering solutions, were considered to be not feasible for the project.

Previous stability modelling (ESP, 2020), has shown that the stability increases if there is less water within the tip material. Site drainage offers a single solution but would need to be designed to ensure control of surface water and groundwater as discussed in the sections below.

Our brief was to recommend options for betterment of the tip drainage and an assessment on the current drainage. It was not to design a drainage scheme that would effectively stabilise, or drain the tip.

4.2 Summary of Findings

A review of the previous investigation data and up to date mapping has confirmed the presence of a number of northwest to southeast trending surface water features which have been identified to interact with the Quarry Spoil Tip in some capacity, these streams are S2 and S3.

4.2.1 Stream S2

The source of feature S2 has not been clearly identified to date, this is likely due to dense vegetation cover hindering access. It may be possible that the source has been masked by Quarry Spoil Tip material. The first point at which S2 was visually located was in the form of two underground pipes issuing a steady water flow. A well established channel was observed to flow towards the south east. The full extent of this feature was not observed due to dense vegetation.

The lower extent of feature S2 is observed again within a field to the rear of the School, as water emanating from a spring at a fence line (see Figure 2). Within the field, generally wet ground conditions and hydrophilic vegetation such as rushes were observed.

The lower extent of feature S2 is considered to comprise both overland flow and subsurface flow, with the former being more prominent following heavy rainfall. An underground plastic pipe is observed, with a steady flow of water which leads to a bath tub feature considered to act as a drinking well for grazing animals. The water flow is observed to sink into a gravel, soakaway type feature and is channelled in a formal drainage system, leading to the School.

Anecdotal evidence from the land-owners suggest that the mid portion of S2 was altered artificially to create water storage tanks, though ESP have identified no information to confirm this.

4.2.2 Stream S3

As outlined in Table 2, feature S2 was identified to emanate from a waterfall at the upper extent of Mynydd Allt-y-grug, with a clear stream channel flowing towards the south. The stream appears to sink into the ground. Springs located downslope to the southeast, are considered to be a continuation of the stream, though this has not been visually confirmed. From the springs, a distinct stream channel continues downslope to the south east, where the water enters a culvert and formal drainage system to the rear of Godre'r Graig Primary school.

Secondary features are identified, which were observed to converge with feature S3. The majority of these features were noted to emerge from the lower extents of the Quarry Spoil Tip, alongside generally wet ground conditions and hydrophilic vegetation such as rushes were observed along this boundary.

Secondary features S3_A and S3_B were observed as containing a steady water flow, whilst not water was noted in the remaining features relating to S3.

During the second site visit, where water flow had previously been recorded, this was generally observed to be flowing at a higher rate than during the visit one (following a period of more dry weather). More areas of waterlogged ground were noted during the second visit following heavier rainfall.

Based on the information to date, we consider that a number of water sources are feeding into the Quarry Spoil:

- Directly from infiltration;
- Overland flow;
- Water may be issuing out of nearby adits and into the tip;
- Water flowing into the tip from streams S2 and S3;
- Possibly from groundwater in coal mine workings and the general groundwater body with the bedrock of Mynydd Allt-y-grug.

4.3 Betterment Options

4.3.1 Primary Aim of Betterment

As discussed in Section 1.2, the objective of this assessment is to inform betterment options e.g. design of surface water drainage systems, with the aim of betterment of water flow within the Spoil Tip. The betterment options adopted should reduce the amount of water flowing into the Quarry Spoil Tip and to reduce areas of ponding and saturated ground., e.g. by providing preferential flow routes away from and around the tip and improving subsoil drainage.

4.3.2 Overview

The findings to date have identified a complex network of surface water features which are considered to directly interact with the Quarry Spoil Tip. The approaches adopted for betterment of the overall drainage system will be depended on the area of the site as discussed further in the sections below. Indicative betterment options are shown on Figure 3.

Generally we consider that a combination of existing channel improvement and the formation of a surface water interception drainage system at the base of the Quarry Spoil Tip will provide

betterment to the drainage in the area, a summary of the broad betterment options is provided below:

- Sympathetic reinstatement of features S2 and S3 so that they are channelised and any water flow is diverted from uncontrolled entering of the Quarry Spoil Tip.
- Install surface water interception drainage (AGS, 2007c – see Appendix A) channels at regular points to divert water off the tip;
- Install drainage above the tip to limit shallow groundwater and overland flow entering the tip, such as a French drain;
- Install drains into the tip to remove water at regular points, this is to decrease groundwater entering the tip from possible mine workings;
- Consider groundwater pumping via boreholes at specific points to reduce the groundwater level;
- Consider directional drilling to install subsurface drainage below the tip to provide a preferential flow; and
- All the above drainage should link into a managed outflow system.

Care should be taken during any vegetation clearance with only limited vegetation, primarily fallen branches/plant debris removed where possible. Excess removal of vegetation could impact slope stability and is generally considered as poor hillside construction practice. In addition, changes to the profile of the slope should be kept to a minimum as part of any construction works. Examples of poor and good hillside construction practices (AGS, 2007) are displayed in Appendix A. If required, a suitably qualitied engineer should be consulted.

4.3.3 Drainage Relating to Feature S2

Based on the information to date, we consider that a drainage channel/French drain (surface water interception drainage), constructed near the mapped source of S2, would allow capture shallow surface water near the base of the tip in this area. This feature will need to be separate to the other parts of the tip due to the site levels. The French drain/channel should be designed to capture water flow in the general eastern extent of the Quarry Spoil Tip, with the aim to divert and channel water flow from the Quarry Spoil Tip, into the existing S2 watercourse. In addition to the above, the following betterment measures should be considered:

- Limited vegetation clearance works to better identify the source of feature S2, particularly in the eastern extent of the Quarry Spoil.
- Sympathetic clearance of the existing S2 channel, with the aim of removing vegetation debris to improve overall flow.
- Further assessment to confirm the presence/absence of water storage tanks.
- Regular e.g. twice yearly or after significant storm events, inspection of the watercourses to ensure water flow is as intended and if required, undertake further clearance works to maintain existing channels.

The above drainage should be designed by a specialist and the effectiveness should be monitored by a series of monitoring wells or site inspections. Significant temporary works would

be required to achieve the above and some removal, or relocation of material would also likely be required.

Care should be taken not to overly straighten, or ease the flow of water in the channel, as this may increase the flow speed and possible erosional energy.

4.3.4 Drainage Relating to Feature S3

Based on the information to date, the construction of a drainage channel/French drain (surface water interception drainage) could be considered. The drain should to generally trend east to west, with the aim of capturing water flow relating to features S3-A to S3-C, and any other unidentified watercourses, in the area at the base of the tip. The drainage channel should direct the water flow into the existing S3 channel.

In addition to the above, the following betterment measures should be considered:

- Limited vegetation clearance works to better identify the mid to upper (ch. 160) of feature S3 where numerous springs were tentatively identified. If identified, the construction of a surface water interception channel in the upper extents may ensure water flow is directed into the S3 channel rather than into the Quarry Spoil Tip.
- Limited vegetation clearance works to confirm the water flow route of the upper portions of S3 (ch. 165 – 220), which to date has not been confirmed. Dependent of the findings, drainage channel construction may be required.
- A steep portion of S3 was identified (ch. 140 – 160), in this area we consider that surface water interception drainage could be constructed to ensure that no water can flow directly into the tip.
- Sympathetic clearance of the existing S3 channel, with the aim of removing vegetation debris to improve overall flow, prevent large scale blockages.
- Where significant areas of waterlogged ground is identified at the base of the Quarry Spoil Tip, the construction of surface water interception drainage in the upper extents may ensure water flow is directed into the S3 channel rather than into the Quarry Spoil Tip.
- Regular e.g. twice yearly or after significant storm events, inspection of the watercourses to ensure water flow is as intended and if required, undertake further clearance works to maintain existing channels.

The above drainage should be designed by a specialist and the effectiveness should be monitored by a series of monitoring wells or site inspections. Significant temporary works would be required to achieve the above and some removal, or relocation of material would also likely be required.

Care should be taken not to overly straighten, or ease the flow of water in the channel, as this may increase the flow speed and possible erosional energy.

4.3.5 Existing Formal Drainage

Based on site observations, the existing formal drainage network appears to be generally in good working condition. We recommend the following works be undertaken to ensure betterment of the existing system:

- Inspection of the existing drainage systems and pipework condition. If required, clearance or repair works should be undertaken to ensure proper function;
- An inspection should be undertaken following completion of the betterment works outlined above to review existing drainage function and capacity if water flow is increased as a result of the works;
- Regular e.g. twice yearly, inspection of the drainage systems to ensure water flow is as intended and if required, undertake clearance and repair works.

All inspections and assessments of the existing drainage network should be undertaken by a qualified professional.

4.4 Additional Considerations

In order to install the drainage required, access will need to be improved such that tracked vehicles can access the tip. This process will allow access to areas not previously accessible by vehicles, and once complete it would be necessary to install a greater density of boreholes to facilitate groundwater and ground movement monitoring. The boreholes will help ensure that the dewatering process is of benefit/successful.

If previously unidentified water features are identified during the works, a specialist should be consulted for further advice. ESP can provide support in this regard if required.

Depending upon the temporary works and access some reprofiling, along with netting and ground anchors could be installed.

Whilst the access is made, it would be recommended to collect a larger number of samples for geotechnical testing such that increased confidence in the material parameters could be gained, or to at least understand the wider variability of the tip such that the slope stability modelling can be confirmed.

Whilst the above will provide betterment, it still may not result in a slope that would be classified as stable in accordance with modern design standards.

5 References

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