| Neath Port Talbot Council | | Plaid Cymru | |
|---|---|---|---|
| Cllr. Steve Hunt (Leader) | cllr.s.k.hunt@npt.gov.uk | Sioned Williams MS | Sioned.Williams@Senedd.Wales |
| Hasan Hasan – Manager Engineering | h.hasan@npt.gov.uk | Adam Price MS | Adam.Price@Senedd.Wales |
| David Griffith – Head of Planning and Public Protection | d.w.griffiths@npt.gov.uk | | |

**From Tegwch Resident's Committee**


Date: 20 June 2023

# RE: 171 Graig Road, Godre'r Graig, Ystalyfera, Swansea (Formerly Godre'r Graig Infants School)

## 1.0 INTRODUCTION

On 10 January 2023 Tegwch residents committee (Tegwch) submitted a document (Tegwch, 2023) containing a large number of notes and questions on various reports prepared in the name of Neath Port Talbot Borough Council (NPTC) (See Table 2.0-1 in the for a list of the reports and published revisions in the Tegwcg 2023).

A third revision reply (Rev2) was dated 25 April 2023 (75 working days later), sent on 6 May 2023 (82 working days after the Tegwch document).

This document provides a response to the NPTC 25 April 2023 document and highlights the questions posed in the original Tegwch 2023 document that did not receive a response.

## 2.0 NPTC RESPONSE

Note on Residents' Report (Tegwch) presented in: Questions and Comments on Tip 2 Stability Reports - 171 Graig Road, Godre'r Graig, Ystalyfera, Swansea - Formerly Godre'r Graig Infants School and NPTCBC note of 25.04.2023.

Tegwch make no representation on the stability of the hillside or the tip. It is unclear who the author/s are, their qualifications or experience is in South Wales. The key points being raised in the Residents' Report appear to be:

1. Material Parameters: Over conservative parameter assumptions for the 'Reasonable Case' ground model, along with an underestimation of the positive contribution of large particles to soil shear strength.

2. Method of Analysis: Deemed unsuitability of limit equilibrium analysis and clarity on an acceptable factor of safety.

3. Impact of Rainfall: Clarity on the definition of a 1:100 year rainfall event, and how this might impact porewater pressures (correlation of rainfall to porewater pressures).

4. Remediation Options: Consideration of alternative remediation measures, including re-profiling.

5. Material Volumes: The estimated volume of the tipped material and the predicted volume of a failure.

6. Instrumentation and Slope Angles

ESP responded to the NPTCBC brief and associated time/budgetary constraints in a professional manner, considering industry standard practice and relevant guidance. Some key points that need to be considered:

- There is no such thing as perfect knowledge when it comes to geotechnical design.

- No design can have a zero probability of failure and the probability of failure increases with increasing uncertainty.

- Where the consequences of failure are significant, it is incumbent on the designer to adopt a cautious approach. The consequences of a single or chain of linked slope failures above an occupied primary school could be catastrophic. Some comments relating to the recent Coal Tip Safety (Wales) White Paper, May 2022: https://www.gov.wales/coal-tip-safety-wales-white- paper are included the end of this note for context.

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.

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. These were the options ESP was asked to explore by NPTCBC in the remediation options report.

## 2.1 Material Parameters

### 2.1.1 NPTC Response

We can never have ‘perfect’ knowledge when it comes to geotechnical design. There are two major sources of uncertainty: inherent variability due to the natural variability of geotechnical properties and a lack of knowledge; additional measurements or improved theories might assist in reducing the latter uncertainty. In all geotechnical assessments, the designer needs to deal with uncertainties, either implicitly or explicitly. Section 2.4.5.2 of BS EN 1997-1:2004 discusses the selection of characteristic values of geotechnical parameters and includes numerous references to the need to be cautious. In practice this means that where reliance on ascribed values is required suitable statistical data is required for design.

Adopted characteristic values can often be defined as less than the lowest measured value.

This may lead to a reasonable question; why hasn’t more data been acquired? This may be linked to decisions taken within NPTCBC and the previous position of any risk is considered unacceptable to the school children and staff.

As previously mentioned in our reports and subsequent correspondence, additional assessment was recommended and discussed with NPTCBC to obtain further data on the ground model and materials so that more representative material parameters could be obtained, and to understand lateral and vertical variability. This was rejected by

NPTCBC as they did not want to undertake any additional site investigation or assessment as a monitoring regime/early warning scenario was not acceptable to the authority because of:

- Site access difficulties;
- Site Topography;
- Time requirements for the results; and
- Cost.

The Resident's response states that our parameter selection was based upon the 20mm and finer soils that were tested which is incorrect. Our parameter selection was based upon field observations, descriptions, lab data and empirical relationships. The selection of data for modelling was based upon the available information considering the uncertainties.

### 2.1.2 Tegwch Reply

It is acknowledged that there will never be a perfect level of knowledge in geotechnical engineering and that is why acceptable levels of risk and Factors of Safety are stated up front. No one has suggested there should be an unachievable goal of "perfect knowledge". To date, an acceptable Factor of Safety for the hillside has not been stated, nor has a tolerance of risk.

Throughout the process there are numerous references to "*the Designer*" and *BS EN 1997-1:2004 +A1:2013 Eurocode 7: Geotechnical Design – Part 1: General Rules*. Eurocode 7 is a document for designing geotechnical structures rather than back analysing their stability based on geotechnical data. Is Eurocode 7 the most applicable text to follow for this project?

In the reports and the reply there appears to be 'cherry picking' of discrete clauses from select texts, incomplete quotes, or quotes taken out of context rather than following one standard/guideline or approach.

NPTC have to date undertaken the following over an area of about 8,500sq m:

| Investigation Tool | Number |
|---|---|
| Geophysical Resistance Profiles | 3 |
| Geophysical Seismic Profiles | 3 |
| Trial Pits | 10 |
| Windowless Samples | 6 |
| Boreholes | 5 |
| Inclinometers | 3 (1 considered unreliable) |
| Vibrating wire piezometers | 2 |
| Standpipe Piezometers | 3 |
| Large Shearbox Tests | 5 |
| Particle Size Distribution Tests | 14 |
| Atterberg Limit Test | 1 |

What additional investigation tools were, or are, requested by ESP to undertake the modelling to their satisfaction? Why were these not included in the original scope of work?

Could NPTC elaborate on what time constraints (Bullet 3 above) were imposed on the project that caused a shortfall of data collection?

Bullet 4 above suggests that cost was a contributing factor in the lack of data collection. What items were deleted from the scope?

NPTC / ESP state that the parameter selection was based on "*field observations, descriptions, lab data and empirical relationships*".

The laboratory test data is usually ranked highly in parameter selection. The laboratory data presented (ignoring the particles larger than 125mm which may have provided additional restorative forces) has a friction angle significantly higher than used in the modelling. Particle Size Distribution tests show the coarse discard as generally gravel, cobble, or larger (note if the particles greater than 125mm were sampled the percentage of finer material would likely decrease). The field logs describe the Coarse Discard as "*interlocking*". So, what "*field observations*" and "*empirical relationships*" led to the "*reasonable case*" Phi=28 and c=0 being selected for the modelling?

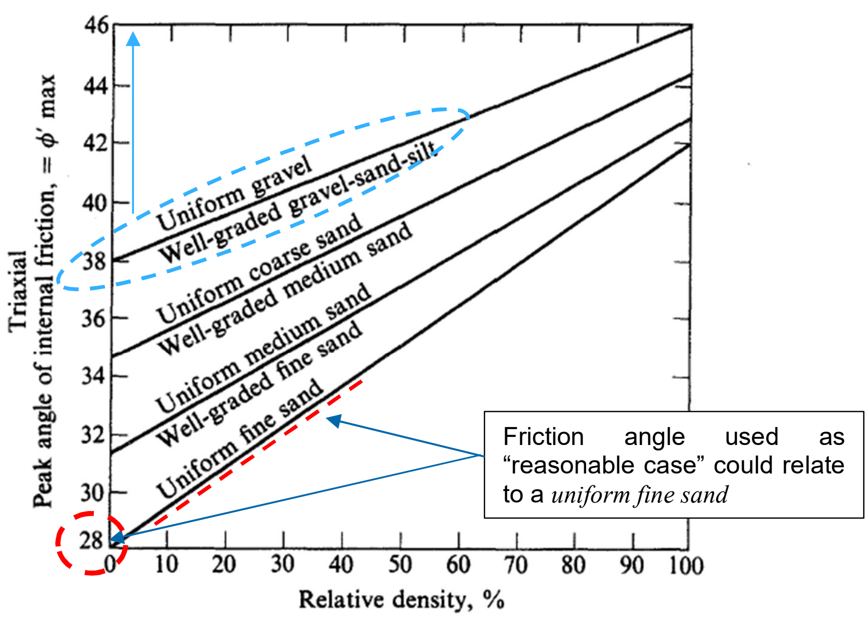
The basis of the supposition that the parameters selected for the modelling are based on published Mohr-Coulomb values. Two examples are shown below.

**Figure 2.1.2-1: Hawley and Cunning (2017) Table 5.5 – Typical shear strength parameters for soils**

**Table 5.5:** Typical shear strength parameters for soils

| Material | Unified Soil Classification System (USCS) group symbol | Cohesion (kPa) | Effective friction angle $\phi'$ (°) |
|---|---|---|---|
| Gravels, gravel with sand, alluvial deposits (high energy), well-graded sand, angular grains | GW, GP, GM, SW | 0 | 30–45 |
| Outwash (glacial), volcanic soil (lahar) | GW, GP, GM, SW, SP, SM | 0–50 | 25–40 |
| Alluvial (low energy), uniform sand, round grains | SW, SM, SP, ML | 0–25 | 15–30 |
| Glaciolacustrine | SP, SM, ML | 0–140 | 15–35 |
| Lacustrine soil (inorganic) | SP, SM, ML | 0–10 | 5–20 |
| Silty sand | SM | 0 | 30–34 |
| Till, silty clays, sand-silt mix | SM, ML | 0–200 | 34–45 |
| Clayey sands, sand-clay mix, volcanic soil (tephra) | SC, SM, ML | 0–50 | 20–35 |
| Silt (non-plastic) clayey silts | ML | 0–30 | 30–35 |
| Sandy clay, silty clay, clays (low plasticity) | CL, CL-ML | 0–20 | 18–34 |
| Clays (high plasticity), clayey silts | CH, MH | 0 | 19–28 |
| Silt loam, clay loam, silty clay loam | ML, OL, CL, MH, OH, CH | 0–20 | 18–32 |
| Lacustrine soil (organic) | OL, PT | 0–10 | 0–10 |

**Figure 2.1.2-2: Foundation Analysis and Design 5th ed. Joseph E Bowles (1997) – Figure 2-30 Relationships between angle of internal friction $\phi$ and unit weight $\gamma$ or relative density $D_r$.**




(*b*) $\phi$ vs. $D_r$. [*From Schmertmann (1978) who modified from D. M. Burmister (1948), "The Importance and Practical Use of Relative Density in Soil Mechanics", ASTM Proceedings, vol. 48.*]

We have been unable to find any comment on the spatial distribution of the laboratory tests relative to provenance, either in lateral extent or depth (TP102 showed Phi values greater than 40°. Only one sample returned a phi angle lower than 30°, and that was taken at 0.6m depth (TP101)). Would this isolated value be considered a critical factor in a rapid landslide of 500m³ or greater?

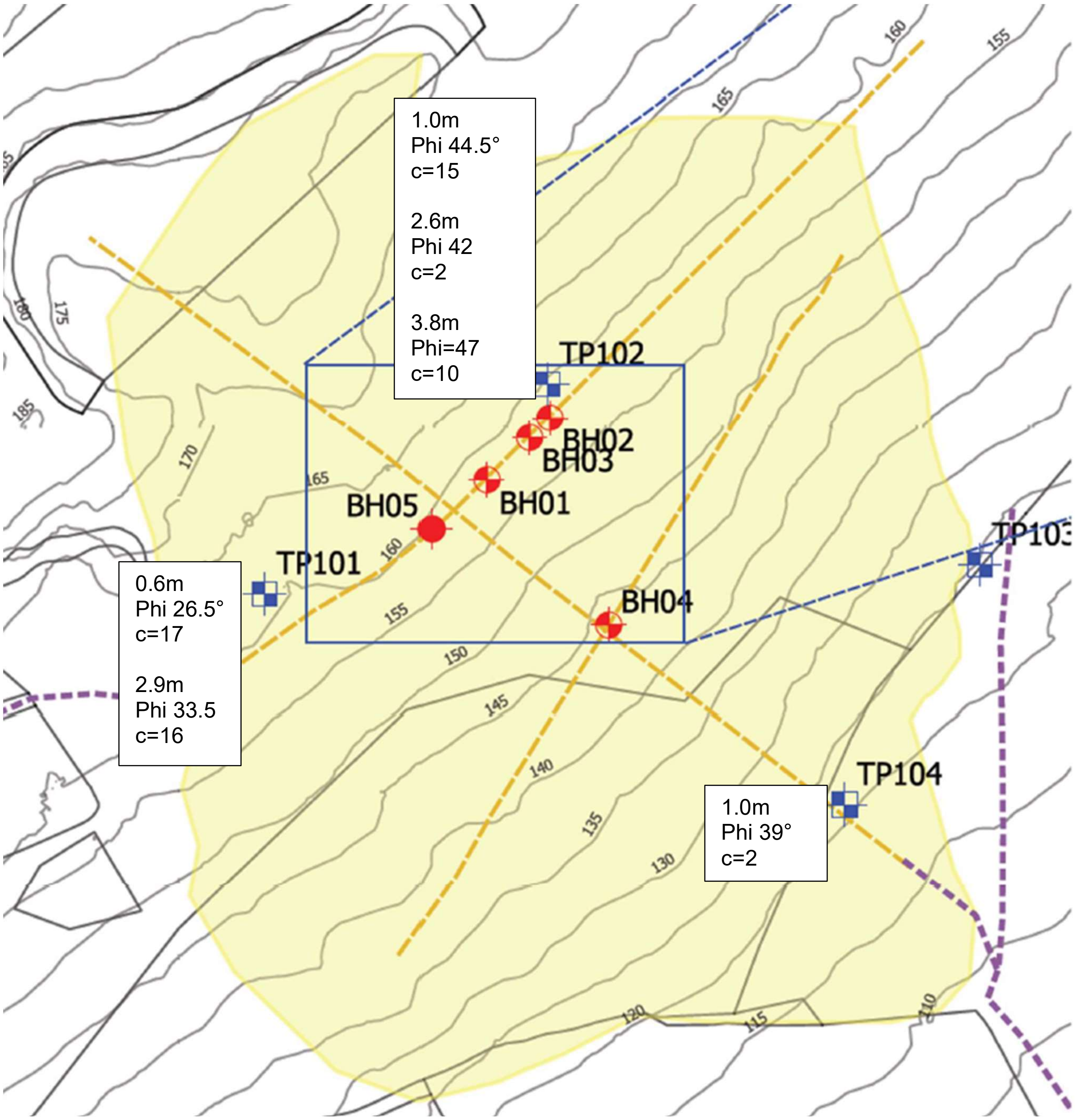



**Figure 2.1.2-1: Spatial Distribution of Shearbox Laboratory Test Data**

Does NPTC consider cohesion a valid property for boulders and cobbles (or even gravel)? If the shear box tests were to be re-analysed with cohesion = 0 then the phi angle would be increased further. There are schools of thought that cohesion will decrease to zero over decades or cohesion could be lost if there is movement in the slope.

Noting that a large shearbox was used in the laboratory testing: Why was the samples' 20mm minus fraction tested when larger particle sizes may have given a more representative estimation of tip strength and can be used in a large shearbox? Although it is unlikely that all particle sizes of 'large gravel', cobbles, or boulders would have been tested.

A slope with a Factor of Safety of 0.7 or lower cannot exist outside of a theoretical model. Why was this presented in the reports?

No in situ, laboratory, or empirical estimations of permeability have been presented. As the primary mechanism presented in the mobilisation of at least 500m$^3$ of tip material appears to be a 1:100 rain fall event, this gap in data appears to be a significant hinderance in presenting the stability of the tip.

## 2.2 Method of Analysis

### 2.2.1 NPTC Response

The suitability of adopting a limit equilibrium design approach is questioned in the Residents' Report, which suggests that they consider more advanced analytical methods should be adopted.

Limit equilibrium methods of analysing slope stability problems could be reasonably considered as the current 'industry standard' methodology in the UK. It is valid to consider more advanced analysis for a final design if the consequences of failure are significant, as would be the case if the school were to remain in place.

Given the volume and quality of available geotechnical data it is difficult to carry out a reliable Finite Element (FE) analysis. Significant assumptions would be required on the strain-dependent stiffness of the various materials identified, which would mean that any displacements predicated by an FE analysis would be subject to significant uncertainty.

It's worth noting that BS EN 1997-1:2004, 2.4.1 (2) states: "It should be considered that knowledge of the ground conditions depends on the extent and quality of the geotechnical investigations. Such knowledge and the control of workmanship are usually more significant to fulfilling the fundamental requirements than is precision in the calculation models and partial factors."

ESP and NPTCBC have discussed options for betterment, i.e., an improvement over the 'baseline' stability, rather than achieving a defined target FoS. The degree of betterment would normally be considered as part of a remediation options assessment and agreed criteria should be established that any design must satisfy involving the client in consultation with the designer and others. Minimum values should take account of both the uncertainties on parameter assessment, as well as the consequences of failure. The discussions with NPTCBC concluded that they were not willing to undertake any additional site investigations or assessments due to issues with:

- Site access difficulties;
- Site Topography;
- Time requirements for the results;
- Possibility for ongoing monitoring, or early warning system; and
- Cost.

Traditionally, for a limit equilibrium analysis, the Factor of Safety (FoS) against failure of a slope or earthworks has been considered as a target 'lump' factor, which should represent a minimum value that an analysis of failure can achieve.

When considering an acceptable FoS for the traditional 'lump' factor approach ICE (2012) [ICE Manual of Geotechnical Engineering, Vol 2, ICE Publishing, 2012], Section 69.4.1, pg. 1044, refers to Trenter (2001) [Earthworks: a Guide. London, Thomas Telford] who comments that the chosen FoS will depend on:

- Technical assessment of the geotechnical data collected.
- Judgement on the safety, environmental and economic costs of any failure.

ICE (2012) also refers to BS6031 (1981) [British Standards Institution. Code of Practice for Earthworks. BSI, BS6031], which gives minimum FoS of 1.3 - 1.4 for first time failures.

The probability of failure is never zero, and the probability of failure increases as the uncertainty increases.

### 2.2.2 Tegwch Reply

The use of LE modelling is a useful tool in the initial stability analysis of a slope. However, Limit Equilibrium modelling purely provides a summary of restorative forces over destabilising forces and presented a FoS (or AF with partial FoSs). It does not provide any commentary on how the slope will move, nor does it model how 500m$^3$ may mobilise into a rapid moving landslide that impacts the school. It is customarily a tool used in the initial stages of a decision tree. The further branches on the tree may suggest additional analysis should be undertaken.

Only one Limit Equilibrium section was presented. Other sections will likely present differing FoSs which will provide NPTC with a better understanding of the holistic tip stability; potentially with different material parameters and different slope geometry as revealed by the ground investigation data.

With the testing undertaken to date, and the repeated statements that there is a shortfall in data analysis, what additional information does NPTC require to perform modelling to show how the slope will deform over time?

NPTC state that …"*displacements predicated by an [sic] FE analysis would be subject to significant uncertainty*" Uncertainties are always present in geotechnical engineering, and especially so in slope stability back analyses. It could be argued that the LE modelling undertaken at present contains a significant amount of uncertainty through the selection of potentially overly conservate parameters as there has not been robust justification for the lower material properties presented above. With NPTC's logic presented to date it would seem that NPTC would be unhappy with undertaking of any FE modelling with geotechnical slopes as there is always uncertainty.

The reference to EC7 presented above in paragraph 4 is little perplexing as this seems to suggest that the quality of the investigation program is less than desirable and therefore not considered valid.

As there is no clear definition of what "betterment" is acceptable or required, as part of the contract how should a consultant be charged in assessing the suitability of the designs? Without a pre-defined acceptance criteria the public may leap to the assumption that the results may meet a pre-defined objective

In light of all that has happened of late, the abandonment of the building giving additional time, and the information provided via these reports we hope that NPTC will be willing to relook at providing additional site investigations and assessments. We are aware that regular access is being granted to the site. Specialist steeper slope equipment could be procured as the time requirements for results are no longer the same due to changes in priority from the school building demotion from a seat of learning. We ask that NPTC reconsider monitoring, or early warning systems and reassess costs and other options that have not been thoroughly explored.

Again, the cherry picking of standards and quotes is found to be incomplete. The quoted ICE document refers to BS6031 (1981) {Code of Practice of Earthworks} which was updated in 2009 and no longer carries the reference quoted. However, the full 1981 reference continues on and states:

"*BS6031 (1981) gives minimum factors of safety of 1.3–1.4 for first time failures, and 1.2 for failures involving ancient shear surfaces.*"

This seems to imply that the September 2016 rainfall may have caused slope movement (suggested by NPTC copied in Section 2.3.1 below). Meaning a FoS of 1.2 may be applicable?

## 2.3 Impact of Rainfall

### 2.3.1 NPTC Response

In detailed design it is necessary to provide the definition of a 'trigger event'. This will then form part of a basis of a design statement so that it is clear what assumptions have been made in relation to destabilising actions.

The Resident's Report seems to suggest the slope may have experienced a rainfall event that exceeds the notional 1 in 100 year event, but that this has not initiated a large-scale failure. There are issues with this presumption because the properties within the spoil heap could be changing with time and there are hyper- local influences such as drainage pathways and ground permeability. For example, heavy rainfall events could result in the migration of fines within the spoil, which could lead to the formation of lower permeability zones or layers, which could result in the build-up of porewater pressures in confined or semi-confined zones (and subsequent slope failure).

Antecedent rainfall and groundwater conditions are likely to be a major factor in the reaction of the slope to more extreme weather events, as we have seen in other locations in the valley. If further design is to be carried out, and if rainfall is deemed to be a significant issue, it would be prudent for meteorologist input to be included. It would also be prudent to carry out further investigations into the hydrogeology of the area on and around the site.

### 2.3.2 Tegwch Reply

NPTC seem to be unsure at which level of study the project is at. The section above interchangeably mentions the following:

- "*detailed design*",
- "*if further design is to be carried out*",
- "*it would be prudent for meteorological input*", and to
- "*undertake further hydrogeological investigations*".

However, the building has been scheduled for demolition.

Tegwch are only able to find a "notional" 1:100 rainfall event mentioned as a trigger mechanism for a rapid landslide. That rapid landslide is postulated by NPTC that debris may reach the school building. As noted in response 2 above, no rainfall magnitude has been estimated. Note there has been no linkage between a purported low Factor of Safety and a rapid landslide.

NPTC's quoted text BS6031:2009 Section 7.4.1 – General

"*When considering the deformations of earthworks, it should be appreciated that earthworks can sometimes undergo large deformations without detriment to their own serviceability, although the effect of such deformation on the shear strength might be sufficient to cause failure at the ultimate limit state. In this respect, however, it is important that consideration is given to the effect of deformations on* *structures supported by or adjacent to the earthworks, and whether or not these deformations are likely to be progressive.*"

NPTC hyperbole note that "*there are hyper-local influences such as drainage pathways and ground permeability*" and suggest that these are critical features in slope stability. However, as to-date, and leading up to the scheduled demolition of the school building, NPTC has not investigated the following:

- climatic conditions,
- in situ permeability,
- The relationship between climatic conditions and in situ permeability, or
- Permeability estimates based on empirical relationships.

NPTC have not commented on permeability throughout the project. The only comment made by NPTC is the water table rising a nominal 1m due to hyper-localised reduction of permeability, and that may trigger a failure.

NPTC appear to rely on empirical data rather than laboratory data from the site investigation, but seem to be use well established grain size - permeability relationships based on empirical data.

## 2.4 Remediation Options

### 2.4.1 NPTC Response

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.

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. These were the options ESP was asked to explore by NPTCBC in the remediation options report.

NPTCBC concluded that they were not willing to undertake any additional site investigations or assessments due to issues with:

- Site access difficulties;
- Site Topography;
- Waiting time for the result;
- Possibility for ongoing monitoring, or early warning system; and
- Cost.

As such, ESP received no further instruction to look at remedial options at the site.

Where slope re-profiling is discussed in the Residents' Report it appears to be suggested that a cut is made at the current toe of the slope in preparation for creation of a berm. This kind of approach would need to be looked at carefully to avoid inducing a slope failure. There might also be a risk of 'shifting' the problem downslope. That is, placing fill at the toe of the current slope could be applying load to top of a notional down-slope landslide, particularly if a significant berm is formed at the current toe rather than aiming for an overall reduction in the slope angle. Consideration would also need to be given to increasing stresses on natural soils and changing their loading scenario.

The resident's report is critical that ESPs assessments have not undergone a Category 3 check. Category 3 checks are commonly carried out in the later stages of engineering design for structures, but also for complex sites. They are not normally carried out on Site Investigation and Assessment reports at optioneering stages.

### 2.4.2 Tegwch Reply

A Category 3 check would resolve the concerns that the following are based on an incomplete set of data comprising the following 'leaps of faith':

- Material Parameters may be considered overly conservative.
- One 'worst case' 2D section modelled.
  - No 3D modelling undertaken even through it is mentioned in one of NPTC's quoted texts (ICE Manual).
- A notional rainfall event.
- No permeability estimates, measurements, or comments.
- No deformation analysis.
- No mass movement modelling.
- No published Factor of Safety.
- No published risk acceptance.
- Restricted options carried forward to "optioneering" stage.
- Options based upon coarse discard volume estimates that, potentially, could be over 100% greater than the volume of discard on the slope.
- Additional drainage not analysed.
- Cherry-picking discrete and partial clauses from select texts, from which further clauses appear to nullify or contradict.
- Only one tip (Tip 2) reviewed from the L44 Coal Authority Report when Tip 1 appears to be larger and steeper.

NPTC's resistance to an independent check as noted above states that:

> "*Category 3 checks are commonly carried out in the later stages of engineering design for structures, but also for complex sites. They are not normally carried out on Site Investigation and Assessment reports at optioneering stages.*"

With the school building scheduled for demolition, what later stages of the project are anticipated prior to a Category 3 check being undertaken? As a side note, Cat3 checks are undertaken on earthworks projects as a second opinion. As stated previously, Network Rail undertakes Cat3 checks regularly, even on temporary works. It would seem prudent to for additional checks to be made on this data to see if the metrics and assumptions are reasonable. There are some highly regarded professionals based in the United Kingdom who have undertaken debris flow risk assessments.

We note that there is some resistance to construction of a berm on the less steep portion of the slope due to shifting the problem down slope. However, with site preparation and processing of the fill material to remove finer grained material the 'problem' may be easily managed.

## 2.5 Material Volumes

### 2.5.1 NPTC Response

There are discrepancies between the volumes of spoil estimated by ESP and those quoted in the Residents' Report.

In the ESP Remediation Options report (ESP.7234e.04.3564) the tip volume was estimated, and stated that additional work would be needed to confirm quantities. The volume was estimated by using the mapped area of the tip and an assumed thickness of 5m based on logs and geophysics. The mapped extents were defined through a review of LiDAR data, aerial photographs, site walkovers and topographic plans and is considered reasonable for estimation purposes.

It is likely that the volume will be updated with further information; for example, is it likely to be thinner toward the edges of the tip (unknown at present). There may also be other discard material included in the volumes present (e.g., from adjacent/nearby quarried or mined ground).

Nowak and Gilbert (2015) [Earthworks: A Guide 2nd Edition, ICE Publishing, Table 9.4] suggest a bulking factor of 40% to 75% for sedimentary rock. Once the volume of the quarry void has been determined the ratio of the 'useful' volume to the discard volume will be partially a function of the end use of the quarried rock. However, all estimates of spoil volume and quarry void volume will be dependent on having sufficient reliable information to define the boundary between in situ rock and all overlying materials, this will include a reliable identification of the differentiation between in situ weathered rock and ex situ quarry discards.

Considering the current amount of data available it is unlikely that any estimates of the volumes can be fully accurate. Volume estimates should be examined for consistency and reasons for differences considered further. This may have an influence on remediation options; for example, given the consequences of failure, the principle of adopting a cautious approach should also apply to the estimated volumes used as the 'input' to estimates of possible landslide volumes.

### 2.5.2 Tegwch Reply

The Nowak and Gilbert (2015) reference does not say what the inference above postulates. NPTC appear to suggest that bulking factor of sedimentary rock may be as high as 75% (e.g., 1 cu m of rock may bulk to 1.75 cu m). This is not correct.

Earthworks: a guide (Nowak and Gilbert, 2015) Section 9.5 states:

> "*The factors shown in Table 9.4 should be used when estimating transport haulage capacities, noting that the actual factor will depend on local circumstances and could vary throughout the borrow pit or cutting*" (p163)

The text goes on to state:

> "*For most soils and rocks, the results of excavation, transport and compaction as fill is net bulking: ... and between 5% and 15% for harder rocks*" (Section 9.5, p163)

This means that 1 cu m of rock will likely ‘bulk’ up between 1.05 cu m to 1.15 cu m when in place.

Again, the reply above refers to more investigations. Is this really being considered while the school has been scheduled for demolition?

NPTC seem to be suggesting that the edges of the coarse discard may be thinner than the middle. Is a blunt edge of tip a realistic landform?

As the purported tip volume (>87,000 $m^3$) plays a significant factor in enabling removal/betterment work, the assessment of cost options are also equally questionable. We refer NPTC to Tables 3.13-1 (no thickness of coarse discard greater than 2.9 m and Table 3.13-3 Borehole Made Ground thickness. These data have been presented in Figure 2.5-2 below. The thickness of the coarse discard are presented adjacent to intrusive investigation locations (trial pits and borehole data). It appears that the thickness should be significantly less than the 5m across the mapped extents of the tip.

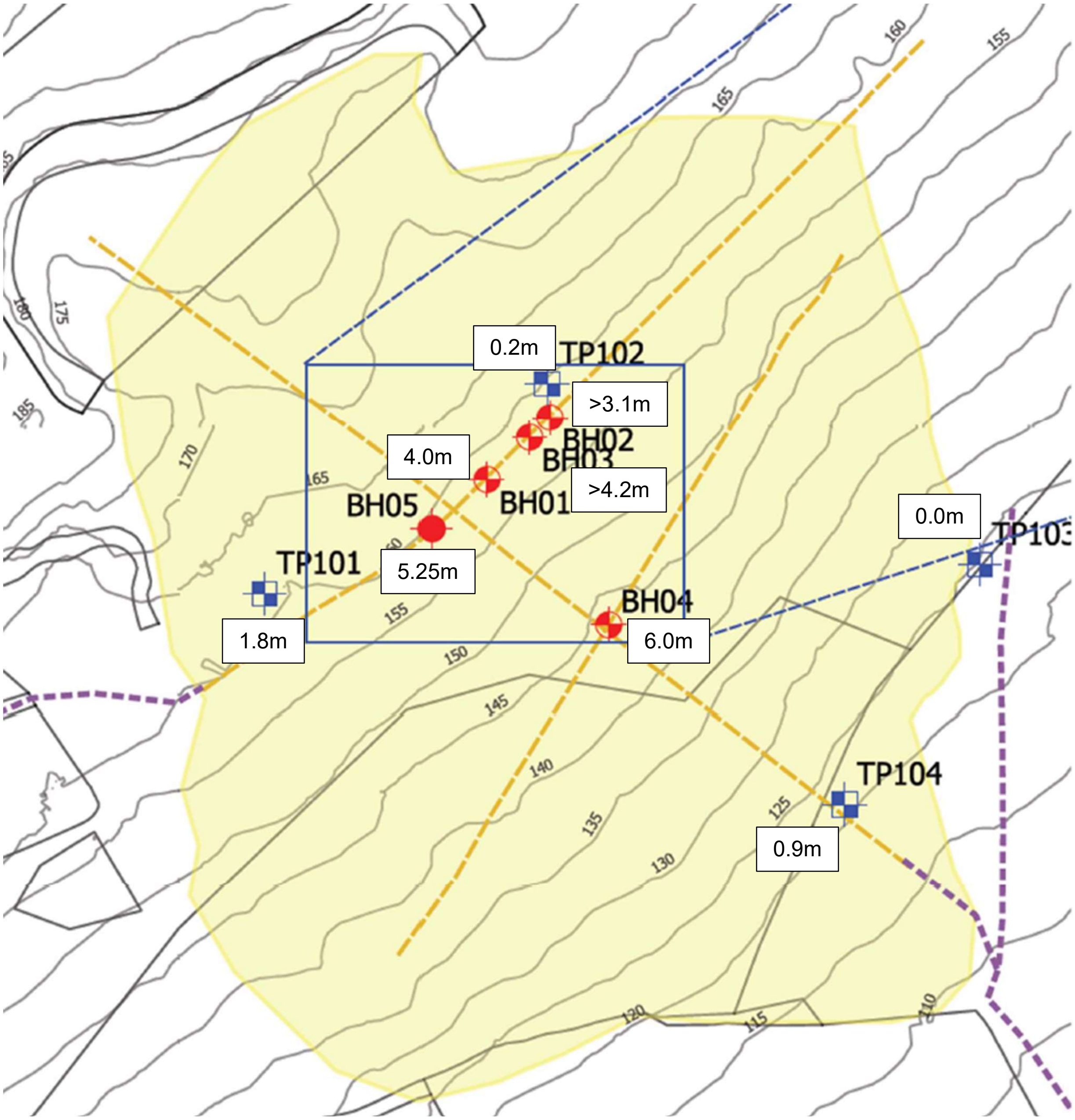



**Figure 2.5.2 – Made Ground Depths**

Using basic averages (mean) gives a thickness of 3.6 (assuming depth of 5.5m for BH02 and BH03) this then tapers to the edges (factor of 0.5) may present average thickness of 1.8 m.

The deflection in contours suggest a smaller tip outline.

## 2.6 Instrumentation and Slope Angles

### 2.6.1 NPTC Response

Three inclinometers were installed in the Quarry Spoil Tip, these were in BH01, BH04 and BH05. They were installed in general accordance with requirements of BS5930. The inclinometers are secured within the borehole with a cementitious grout annulus so that they mimic the surrounding ground conditions and thus be able to provide representation of ground movement.

Previous ESP reports and information issued has stated that the inclinometers from BH01 and BH05 have measured downward movement of the tip, in the region of 20mm and 15mm respectively.

The data obtained from BH04 is not as would be expected from a fully functioning inclinometer, in that there is movement being recorded at the base of the inclinometer. As previously stated in our reports, it is considered that this inclinometer base is possibly moving with the surrounding soils, which may explain the data being recorded. Due to this, the data from BH04 has not been used in our assessment. It is worth noting that the graph shows a relative downward movement of the upper horizons.

The Resident's report appears to suggest that the tip generally measures some 27°. This is not accurate and is a simplification of the tip morphology. We have previously provided a geomorphological map of the tip in our report ref. 7234e.02.3302; the geomorphological mapping shows discrete areas of the tip that are steeper and shallower, as could be expected from a man-made topography.

### 2.6.2 Tegwch Reply

Inclinometer BH01 shows about 5 mm of movement between installation (29/11/2019) and 15/6/2020 and then a further 8mm (total ~13mm)

Inclinometer BH05 shows about 6 mm of movement between installation (29/11/2019) and 15/6/2020 and then a further 11mm (total ~17mm)

To put this into perspective this is about the size of a medium piece of gravel. This is still within the borehole wall that may have displaced a cobble or boulder while the borehole was being drilled.

The practice of considering "effective slope angle" is in line with NPTC's text ICE Geotechnical Engineering Manual Vol1 – Simplifying geometry is standard practice in Limit Equilibrium modelling. Small rock faces give an indication at an angle the slope can stand up (in Tip 2's case for many decades) without failing. If the Phi=28° was an appropriate parameter these escarpments and smaller faces would have failed, especially with the historic rainfall events.

The most recent inclinometer readings BH01 and BH05 apparently show negligible movement between the last three readings and that 'movement' appears to be within the reading tolerance of the inclinometer probe.

## 2.7 Coal Tip Safety

### 2.7.1 NPTC Response

Coal Tip Safety (Wales) White Paper (May 2022): https://www.gov.wales/coal-tip-safety- wales-white-paper
Welsh Government proposals aim to introduce a consistent approach to the management, monitoring, and oversight of disused coal tips in Wales. The aim being to create a new legislative management regime for monitoring and maintaining disused coal tips and the establishment of a new public body to ensure compliance and consistent delivery.

Proposals in the consultation document focus on disused coal tips; however, there is discussion of the extent of non-coal tips with a view to developing the framework to apply equally to both coal and non-coal tips, enabling the phasing in of other spoil tips into the regime over time.

It should be noted that the behaviours of non-coal tips are likely to differ to coal tips in terms of the geotechnical properties of the materials, the types of failures that could occur, event frequency and mass mobility.

Brief relevant excerpts of the white paper are presented below verbatim:

- "4.18. It is proposed that receptors are classified under 5 key groups (1. people/communities, 2. property, 3. infrastructure, 4, ecosystems/environment, and 5. culturally sensitive/significant sites) with 4 Receptor Levels (1. low. 2. medium-low, 3. medium-high, 4. high), as detailed below and in Table 4. We propose risk to life is always scored as a '4' – high priority, irrespective of receptor group. Tiers 1 to 3 are to be considered where the consequence has the potential to cause injury or impact condition, safe operational performance or serviceability."

- "4.20. The hazard level is obtained by multiplying the likelihood of the hazard against the receptor level as outlined in Table 2. Table 3 provides a proposed hazard level key."

**Table 2: Hazard Level Matrices**

| | | Likelihood | | | | |
|---|---|---|---|---|---|---|
| | | Highly Probable | Probable | Possible | Unlikely | Rare |
| | | 5 | 4 | 3 | 2 | 1 |
| Receptor Level | 4 | 20 | 16 | 12 | 8 | 4 |
| | 3 | 15 | 12 | 9 | 6 | 3 |
| | 2 | 10 | 8 | 6 | 4 | 2 |
| | 1 | 5 | 4 | 3 | 2 | 1 |

**Table 3: Hazard Level Key**

| Hazard Level | |
|---|---|
| Severe | 15–20 |
| Major | 7–14 |
| Moderate | 4–6 |
| Minor | 1–3 |

The Welsh Government approach will require development to refine understanding/meaning of the terms likelihood and hazard levels. We expect more guidance will be developed with example scenarios with refinement of the nomenclature and definition of terms (e.g., hazard, probability, and risk).

Initial consideration of the white paper approach is provided below:

- The risk-based approach discussed in the Hazard Assessment section of the document presents a rational framework for assessing the hazard level at Godre'r Graig. It is likely that this framework will be extended to non-coal tips in the future.

- The Coal Authority previously note that "A major failure of the quarry spoil could potentially reach Godre'r Graig School." and this aligns with the ESP assessments carried out to date.

- If the school remains in place and occupied then the Receptor Level (Table 2, Hazard Level Matrices) could always be Level 4.

- With no changes/modification to the slope, the Likelihood is at best going to be Possible (but could conceivably be considered higher), meaning the Hazard Level (Table 3) is going to be at least 'Major Hazard'. This is also the case if a failure is considered 'unlikely' and perhaps underlines the sensitivity of the Godre'graig school scenario.

- If the Likelihood of the occurrence of a Ground Movement/Instability hazard could be reduced to

'Rare', a Moderate Hazard Level could be considered.

NPTCBC and stakeholders may view an engineered solution presents a Moderate Hazard level. This needs to be framed considering the potential impacts on the downslope school. As discussed earlier: "Where the consequences of failure are significant, it is incumbent on the designer to adopt a cautious approach.

The consequences of a single or chain of linked slope failures above an occupied primary school could be catastrophic."

### 2.7.2 Tegwch Response

It is noted that this is a White Paper and has not been adopted for coal tips, let alone NPTC's inference that the paper in its current form is applicable for sandstone discard. NPTC state that the properties are likely to differ but offer no commentary on how these properties will affect the mobilisation of the material.

The above paragraph is a good example of 'cherry picking' standards or clauses. ESP.7234e.7372e.3451.Rev1 Table 1 in Section 4.1 shows the risk as Low to Very Low (depending on travel angle to element at risk). Note that this "travel angle" would be assessed in the rapid mass movement modelling work.

We note that NPTC are selectively quoting the Coal Authority's L44 report in bullet 2 above. The full quote from Report L44 for Site 2 is:

> "*A major failure of the quarry spoil could potentially reach Godre'r Graig School.* ***Although unlikely****, a slope stability analysis based on available information supported by ground investigation data would be beneficial to assess the extent and likelihood of such a failure.*"
>
> Emphasis added in underlining and bold.

This would change the Hazard Level. However, this is the initial stages of a site-specific assessment which NPTC have financed over £130,000. If the initial stages of modelling suggest that the Factors of Safety lead to an acceptable risk tolerance then the studies end there. Yet there has not been deformation modelling or rapid mass movement modelling to show whether an element is at risk.

## 3.0 UNADDRESSED QUESTIONS IN THE ORIGINAL NOTES DOCUMENT

The following are a series of questions from the Tegwch 2023 document that appear not to have received responses. We have reordered the questions for ease of referencing a response.

1. On what basis was the decision to close and demolish the school based upon? NPTC's consultant states that the "*reasonable case*" properties were too low.

## 3.1 Report Revisions

1. Can Tegwch review the previous revisions of the reports and understand why the report revisions were requested and by whom? See Table 2.0-1 Tegwch 2023 document.

## 3.2 Ground Investigation / Data Collection

1. Were the samples presented for particle size distribution tests representative in volume of sample based on particle sizes encountered as per BS5930(2015) Table 4?
2. What frequency of large gravel, cobble, and bolder particle sizes were in the trial pits? Would this increase the phi parameter?
3. Can NPTC confirm whether the coarse discard was an interlocking deposit or whether the matrix was extensive?
4. What is the magnitude of rain fall in a 1:100 year rain fall event?
5. Why was a tracer dye programme not undertaken to estimate flows?
6. Why was meteorological data not linked to the piezometer information?
7. How close to a 1:100 rainfall event has there been in the valley? Either since records began or since the study started.
8. Why did BH02 and BH03 not bottom out the coarse discard stratum?

## 3.3 Project Acceptance Criteria

1. What does NPTC use as an acceptable Factor of Safety for this tip? We don't think it is presented in the reports.
2. What is NPTC's acceptance of risk? Does this fit on to Whitman's F-N plot? Note that Whitman's work has been revised and improved many times since its inception. [*R.V. Whitman, 1984, Evaluating calculated risk in geotechnical engineering. J. Geot. Engineering, 110, 2*]
3. The 1:100 rainfall event; is this a tip lifetime probability or an annual probability?
4. What is the cause of a >500m$^3$ rapidly moving landslide other than a "*simple arbitrary 1m rise in ground water*"? The cause of the rise in ground water has not been presented as yet.
5. The Mechanism presented in the ESP decision tree appears to be:
    a. 1:100 rainfall event.
    b. Water table rises 1 m.
    c. Rise in water table destabilises the slope.
    d. The slope destabilisation causes the slope to deform through excess pore pressures building in the Coarse Discard stratum.
    e. The Coarse Discard Stratum becomes a rapidly moving landslide of at least 500m$^3$.
    f. The topography of the slope causes the rapidly moving landslide to travel towards the school building and impacts the school property (assuming energy is maintained in the movement).

6. Can NPTC confirm this mechanism presented in 3.3.5 is correct?

## 3.4 Material / Modelling Parameters

1. What has led NPTC to select Phi = 28° and c=0 kPa as "reasonable case" properties when the geotechnical tests show significantly higher values.

    a. This is not considering the "*predominantly coarse*" "*interlocking particles*" were not tested (in some samples over 60% was not tested). The tested values also included cohesion. Removing cohesion in a coarse deposit is likely to cause the phi angle to increase further. What engineering judgement has led to the perceived over conservatism?

2. Why was the angularity of the gravels not included in the estimate of material properties?

3. Does NPTC believe that the shearbox tests undertaken are for the deposit or the matrix in between the larger particles (that were not collected or tested)?

    a. What is the governing element in the Coarse Discard?

4. What was the rationale for not undertaking the tests in item 3.9.1 below during the initial phase?

5. How confident is NPTC with the geotechnical properties of the glacial diamicton stratum?

    a. This stratum appears to be governing the hillside as the slip surface contours shown do not deflect at the change of stratum.

    b. Could the properties of the diamicton selected for the analysis be too similar to the coarse discard?

    c. See 3.6.4 below.

6. When NPTC's consultant states that "*The site walkover, historical mapping and aerial photographic review show no sign of instability predicted by the modelling. It is therefore likely that the Reasonable Case Material Parameters adopted are too low as signs of movement would likely be visible at the Quarry Spoil Tip.*" Why were these figures published in an appendix?

    a. Can Tegwch review these figures?

7. Does NPTC consider the mechanism of end tipping would have given a deposit with homogeneous properties?

8. With the Diamicton's Liquid Limit being 49% and moisture content at reported at 32%, does NPTC the water table seems reasonable for the modelling? What were the Atterberg Limits of the Diamicton used for in the analyses?

9. What does the apparent minimal strain softening of the shear box test results suggest to the stability of the hillside? Note that this is only the 20mm minus fraction of the coarse discard.

10. Why were in situ (or ex-situ) permeability tests not performed?

11. With the hyperbolic 'hyper localized pathways opened and closed in micro deformations' changing the slope does the notion of fine-grained material being washed out over the years reduce the likelihood of pore-pressures developing in the tip?

12. How will pore pressures develop in the coarse discard?

13. How laterally extensive are the postulated zones of lower (or higher) permeability? Were these noted in the trial pits or borehole logs? Please can NPTC provide a reference for this? NPTC seem to believe these are "*hyper-localised*" in some of the responses in 3.4.11 above.

14. What is the assumed permeability of the tip? We understand a permeability estimate must have been developed to assist with the rise of the water table by a metre.

15. How thick and extensive do the "*Smaller individual/impersistent layers*" need to be before they are a critical feature? $D_{50}$, $D_{75}$, or other metric?

16. The groundwater elevations shown Tegwch 2023's Table 3.7.1 do not appear to show significant rise following periods of heavy rainfall. What does this suggest in regard to the tip's permeability?

17. Can NPTC provide comment on the likely velocity sorting of larger material towards the toe and what this usually means to the phi angles of a deposit?

## 3.5 Modelling

1. How would the unburdened slope's Factor of Safety change in the purported nominal 1 m rise of the water table in a 1:100 year event?

2. How does the factor of safety of the section compare to the adjacent slope? Is it possible for the natural slope to achieve the (unpublished) acceptable Factor of Safety?

    a. If so, what are the consequences for the additional dwellings along Graig Road?

3. Does NPTC or their consultant believe that a slope can exist with a Factor of Safety below 1.0 outside of a computational model?

    a. What Factor of Safety is assumed before the slope will start to show signs of distress and movement are observed?

4. The contours of the Factors of Safety show high gradients at the edges of the Limit Equilibrium Modelling. Does NPTC think that 'edge effects' of the modelling are affecting the results? Note that in the graphic showing the "reasonable case" LE model a point neat the downslope 'exit' window has a FoS between 1.0 and 1.25.

5. Relatively flat ground is shown towards the quarry (upper slope) in the "*reasonable case*" Limit Equilibrium model. This model shows FoSs lower than 0.85 and 1.25 towards the crest of the slope. Is this correct?

6. Would a stress dependent model be more appropriate for modelling the large particles encountered? (Leps, 1970 - Review of Shearing Strength of Rockfill, Journal of the Soil Mechanics and Foundations Division Volume 96, Issue 4, https://doi.org/10.1061/JSFEAQ.0001433). Tegwch notes that these rock tips similar to this were the basis for Leps' work.

7. Were back analyses undertaken to see what parameters were reasonable for the slope? Were these parameters close to the laboratory data? What was the outcome of the back analysis?

8. Will 3D limit equilibrium modelling be undertaken as mentioned in the ICE text quoted?

9. Why was one phi & c used for the whole tip when the testing performed shows significant variability in these essential properties.

10. Why was only one 2D slice modelled when additional slices may have represented the hillside better. Note that closed form calculations may have given a different hillside FoS.

11. What inferences does NPTC make from the Atterberg limit test performed?

12. Why are NPTC focusing on small (likely single digits) volume failures with the locally steeper slope angles when the decision tree presented shows a 500m$^3$ rapid landslide appears to be the issue that closed the school? The "effective slope" angle is about 27° in the direction towards the former school building? Would a 3D LE model suggest the failure may trend towards a different receptor other than the school building?

13. Does the failure surfaces shown in the model reflect the 500m$^3$ failure of a predominantly coarse-grained deposit failure surface?

14. What is the mechanism where a slope deformation of 500m$^3$ will rapidly mobilise and flow into the former school property? Note that the three-dimensional trajectory has not been presented. Note that unconfined mass movement events usually lose energy rapidly as the movement spreads and the spreading of the flow causes loss of energy.

15. We hear the resistance of the NPTC's consultant to undertake Finite Element (or other deformation) modelling. What additional data would NPTC require to model how the slope will deform over time? We note that slope deformation modelling can be undertaken with less data than obtained so far. Would the cost of this data collection be less than the demolition and unpublished re-establishment costs of the site?

16. Rapid landslide modelling, RAMMS or DAN/W modelling (or other software), will show how a mass movement event may travel. Why was this not undertaken?

17. How will the answer of 3.2.4 be used to demonstrate that that volume of rainfall will cause the water table to rise a "nominal metre" in the coarse discard stratum?

18. How will the 500m$^3$ of material become fluidised?

19. How realistic is the LE model water table to the piezometric data? And how is this extrapolated across the tip in three-dimensions?

20. BH05 shows a 400mm thick cobble layer, is this not considered a good drainage layer?

21. How long should the water table be a "nominal 1 m above background" for before a failure may occur?

22. Why was only one plane (worst conditions) modelled? Note: additional sections can only add minutes to the simplistic modelling approach taken?

23. Why was a simple Computer Aided Design 3D model not developed for the volume of the coarse discard strata? The boundary was mapped and borehole and trial pit records show the upper and lower horizons. It seems like the a notional 87,350 m$^3$ is a significant factor in the remedial options (especially with the incorrect bulking references provided and the notion that 10s of thousands of cubic metres of spoil were brough to the top of this slope to be discarded).

## 3.6 References

1. There appears to be considerable discrepancies between some of the standards / texts discretely quoted. Which is the governing text and why was that text selected?

2. What was the "Stroud 1975" reference for the selection of the properties?

3. What was the BS8004 reference (Code of Practice for foundations) was used to select the parameters?

4. What reference in CIRIA C504 was used to select the parameters of the diamicton?

5. The references provided to the excavation volumes and bulking factors are incorrect (Section 2.5.1 above). Please revise and resubmit this section.

## 3.7 Discarded material

1. Please provide commentary on what size of material would likely have been discarded from the quarry workings.

2. NPTC appear to suggest that additional material (potentially many 10's of thousands of cubic metres were brought to the tip from other sites when it was customary to tip as close to the adit or quarry as practicable (as the original quarry site). Can NPTC supply case studies or references this was the normal operating procedure at the time of the quarrying / work being conducted?

## 3.8 Instrumentation

1. Does the incremental movement suggest that the tip is still moving or accelerating as based on Fukuzono (*1985 – A new method for predicting the failure time of a slope*) and various improvements to the methodology over the past 35 years. Note the comment "*movement information from inclinometers (at present) not representative of large scale instability*".

2. Can NPTC provide a same scale piezometric elevation and depth plots overlaid with rainfall and other climatic data for the site?

3. Please provide commentary on the gradient of the piezometric plots and does that link with the empirical permeability relationships of the coarse discard?

4. What does NPTC mean by a "*masked secondary influence*" when referring to the gradient of the piezometric surfaces?

5. What is NPTC's settling in tolerance of the inclinometers?

6. Why does NPTC's consultant state that "*20 mm of movement was settling in which is common*" in one report and then consider the tip "*actively unstable*" in a subsequent report when less movement was noted?

## 3.9 Future Investigations

1. What other testing is NPTC scheduled to undertake "*extensive geotechnical testing*" to avoid "*a relatively limited data set*"?

## 3.10 Remedial Options

1. Why were the remedial options restricted to only three options?

2. Why was additional drainage not considered as a viable remedial option? Note that excess water in the coarse discard is the only presented mechanism for triggering a 500m$^3$ mass movement event.

3. Why was soil nailing not considered a cheaper feasible alternative remedial or betterment work? Combined with drainage that could be installed synchronously.

4. Why was a Menzimuck excavator not used to undertake test pits where the Consultant requested them?
5. What was the estimate of the reconstruction work, and should this be considered prior to demolition of the old school building?
6. If the volume of the tip is found to be significantly less than the 87,350m$^3$ would the cost of Remedial Option 1 reduce, as would Remedial Option 1's enabling and supervision works?
7. Option 1's access route seems tortuous, why was a 'bulldozer push down' from the crest to the back of the school not explored further?

## 3.11 General commentary

1. Is the notion of the slope being "*oversteep*" still valid? Tegwch notes there are drivable slopes in Ffordd Pen Llech, Harlech that is over 20° and likely localised steeper portions.
2. Is NPTC's decision tree and it's 'branches' presented still valid? Can NPTC provide any references other than "engineering judgement" for any of the decision tree probabilities as these do not seem reliable or verifiable?
3. Does the health of the vegetation on the slope and shape of the trees suggest that the slope is "*actively unstable*"?
4. What causal factors were used to demonstrate that the slope is "Marginally stable" (Popescu 1994) as referenced by NPTC?
5. How will adits affect the water table or the permeability? As such does the water table seem reasonable?
6. If the deformation of the slope is such that a failure is plausible, based on a given rainfall magnitude, and that the deformation is rapid and that the flow path could connect with the former school building would the school building be occupied during such an event as these rain fall events usually give more than 4 hour's notice.
7. Why was the tip material not mobilised in the 2016 rainfall event when many other larger particles were? This assumption that the >50mm/hr is at or above a 1:100 rainfaill event magnitude.
8. Why was the focus of the report on Tip 2 when Tip 1 appears to be larger and steeper and is closer to residential dwellings?
9. Could the Coal Authority provide commentary on the quote used from report L44 where it is stated that a landslide reaching the school building is "unlikely" as this is being used in the matrix regarding **coal spoil tip** risk assessments.

## 3.12 Independent Check

With purported estimate of costs upwards of £6M, why is there such resistance to an independent check of the assumptions, modelling, and risk acceptance not performed?

1. Why is NPTC so vehemently resisting an independent expert of modelling and risk assessments of rapid landslides reviewing the data and assumptions provided in these reports? This would use the same data obtained in the investigation programme and may resolve the contention about overcautiousness of the properties and appropriateness of the analyses undertaken to date.