Appendix C

Geology, Geotechnical and Hydrology

Ty Mawr West Quarry

Geotechnical Review of Proposed Development- Eastern Quarries (October 2010)

Prepared for: Ty Mawr West Limited

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Job Number: 10-312

Report Number: 10-312-R-001

Ty Mawr West Limited

Ty Mawr West Quarry

Geotechnical Review of Proposed Development- Eastern Quarries (October 2010)

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CONTENTS

EXECUTIVE SUMMARY

On behalf of Ty Mawr West Limited, Key GeoSolutions Ltd (KGS) have been appointed to undertake a geological/geotechnical assessment of the proposed activities within the Eastern excavation within Ty Mawr West Quarry

Location

The National Grid Reference of the Ty Mawr West Quarry is 249636mE, 352410mN.

- Eastern excavation 249745mE, 352370mN

Site Description

Ty Mawr Quarry, nr Penygroes is operated by Ty Mawr West Limited.

The site currently recovers slate of Cambrian age from existing tips on site.

The quarry operator is currently intending to apply for planning permission to extract slate rock from the eastern part of the site.

Conclusion of Geotechnical Inspection

The most likely mechanisms of instability associated with the faces within the Eastern Quarries will involve toppling failure and general rockfall. However, suitable working methods have been proposed within this report to manage these potential hazards when development commences.

It is believed that removal of the rock mass joining East Blue and East Green quarries will not impact significantly on the groundwater regime of the site, due to the hydraulically isolated nature of the material from its surroundings.

Date of next Geotechnical Assessment / Appraisal

In accordance with the requirements of Regulation 33 of the Quarries Regulations 1999, a Geotechnical Assessment of the Eastern excavation at Ty Mawr West Quarry should be undertaken prior to the start of mineral extraction.

1.0 INTRODUCTION

On behalf of Ty Mawr West Limited, Key GeoSolutions Ltd (KGS) have been appointed to undertake a geological/geotechnical assessment of the proposed activities within the eastern excavation area at Ty Mawr West Quarry.

The purpose was to review ground conditions within the area of the proposed development and provide recommendations regarding that development.

In particular, the report serves to provide the following:

- A preliminary geological assessment to establish the extent, type and quality of mineral to be won by the proposed development (see Section 3.1).
- A preliminary geotechnical assessment relating to the likely stability of the ground to be worked (see Section 3.3 & 3.4)
- A preliminary assessment of the impact of the development on the hydrogeology of the area (see Section 3.2 & 4.2).
- A preliminary assessment of the impact of the development on surface water flow and land drainage implications (see Section 3.2 & 4.2).

The report will recommend any remedial works necessary and give advice on the Excavation and Tips Rules as appropriate to ensure that the risk associated with those hazards identified is lowered to an acceptable level.

There are no records of any previous geotechnical reports having been undertaken for the Ty Mawr West Quarries.

The information available for review as part of the current assessment is limited to a number of small pieces of historical geological mapping which shows the general sequence and ground conditions present at the quarry. This information was provided by Dr. G.P. Jones, Mineral Planning Agent to Ty Mawr West Ltd. Dr. Jones and Mr. E. Jones of Ty Mawr West Ltd. accompanied KGS during the geotechnical inspection and were able to provide information relating to previous workings and historical slope failures at the quarry – reference to this advice is made within the current report.

The survey detail for the quarries, as provided by Ty Mawr West Ltd, is presented on Drawing No. 10-312-D-001; the drawing has been annotated to show the main points of interest and localities referred to within this report.

2.0 SITE OVERVIEW

2.1 Location and Quarry Operations

Ty Mawr West Quarry is operated by Ty Mawr West Limited; the National Grid Reference of the quarry is 249636mE, 352410mN.

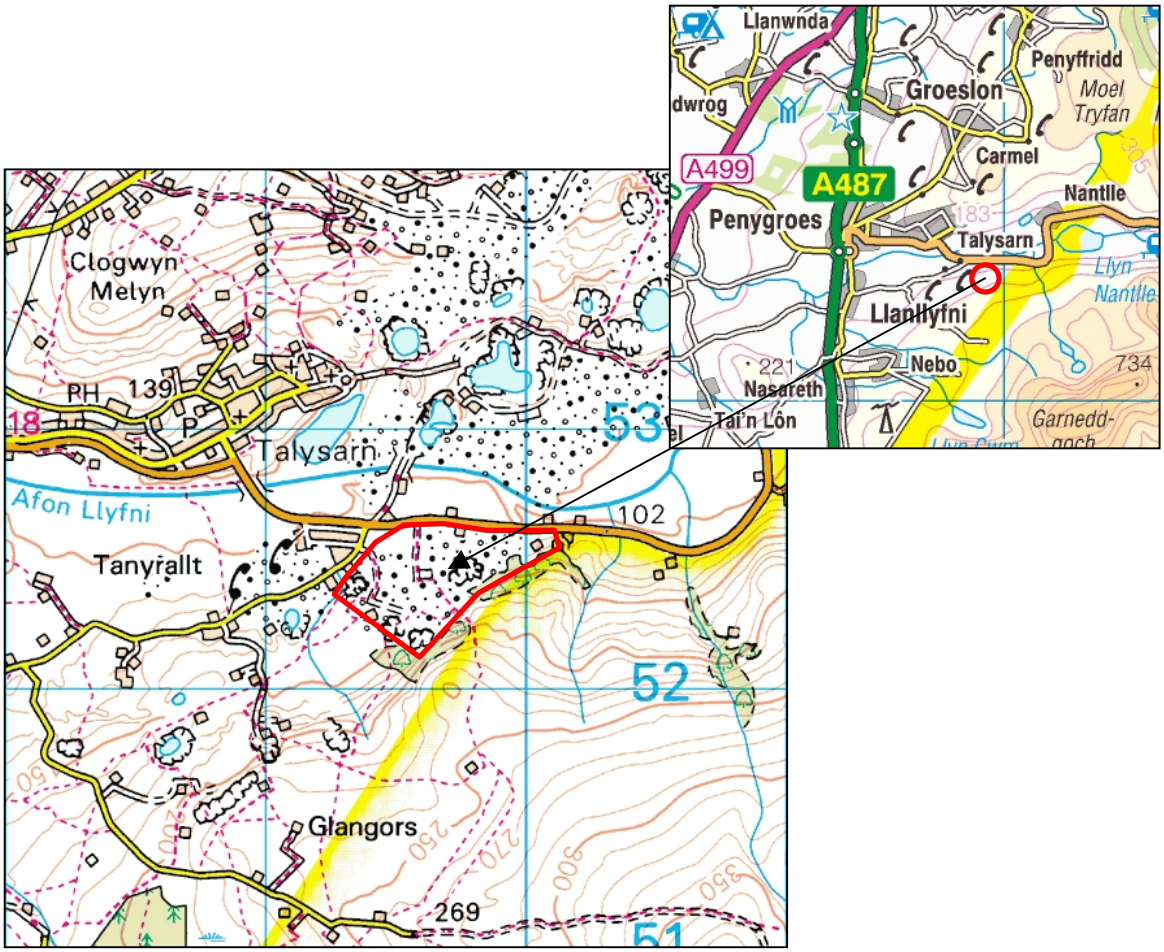


Figure A. *Site location plan*

(Figure not to scale. Based on Ordnance Survey mapping with permission of the controller of Her Majesty's Stationery Office. Crown Copyright Licence No.100045347)

The quarry is located to the south of the B4418, approximately 1km south east of Talysarn village and 2.8km to the east of Penygroes. The site is situated adjacent to the boundary with the Snowdonia National Park and occupies an area of approximately 7.8 hectares. The Eastern Quarry excavation is approximately 150m in length (N-S) and on average 50m wide (E-W), and includes two separate excavations; 'East Blue Quarry' and 'East Green Quarry' which are joined by a narrow cutting approximately 30m in length and 4m wide (Photo 1). Face heights within the East Blue Quarry, as interpreted from the latest survey, are estimated to be in the range of 8 to 20m in height, however, the void has been largely infilled in the past with quarry waste, resulting in partial backfilling of the majority of faces exposed within the excavation (Photo 2).

According to the topographical survey the faces within the East Green Quarry consist a single face approximately 25m (max.) in height.

It is believed that quarrying operations began at the site around the 1800s to supply local demands, with commercial quarrying starting later.

Towards the end of the 19th century, ownership of Ty Mawr West had passed through several hands until 1908, when 'Welsh Green Slate Ltd' took over. In 1932, the quarry was purchased by Dorothea Quarry, however until recently little quarrying has taken place at Ty Mawr West.

Recent works have generally involved the re-processing of existing slate tips within the quarry; no extraction of ‘virgin’ ground is presently taking place.

The weighbridge and site offices are located near the quarry entrance at the north-eastern limit of the site.

3.0 GEOLOGY, HYDROGEOLOGY & GEOTECHNICAL STRUCTURE

3.1 Geology

The area in the vicinity of the Ty Mawr West Quarry is underlain by Slate deposits of Cambrian Age.

The Nantlle Valley is part of the long belt of Cambrian slate formed about 500 million years ago. This stretches from the Nant Ffrancon valley in the East to the Nantlle valley in the West. In the East the slate was won by open quarries using the gallery method, while at the West end, the slate beds were found beneath the floor of the valley.

The slate beds of the Caernarfon district stretch from the area of Bethesda via Llanberis, Moel Tryfan and Nantlle to Penygroes. These deposits were formed during the Palaeozoic Era, at a time, when what we today know as North Wales was buried beneath the sea, with mud, pebbles and sand collecting on the sea bed at depths of around 1,500m. The relatively soft slates located within Ty Mawr Quarry, which form part of the larger Nantle slate belt, were exposed to intense lateral pressures during the Caledonia orogeny which imposed a secondary lamination process to the slate producing a more 'slatey' cleavage.

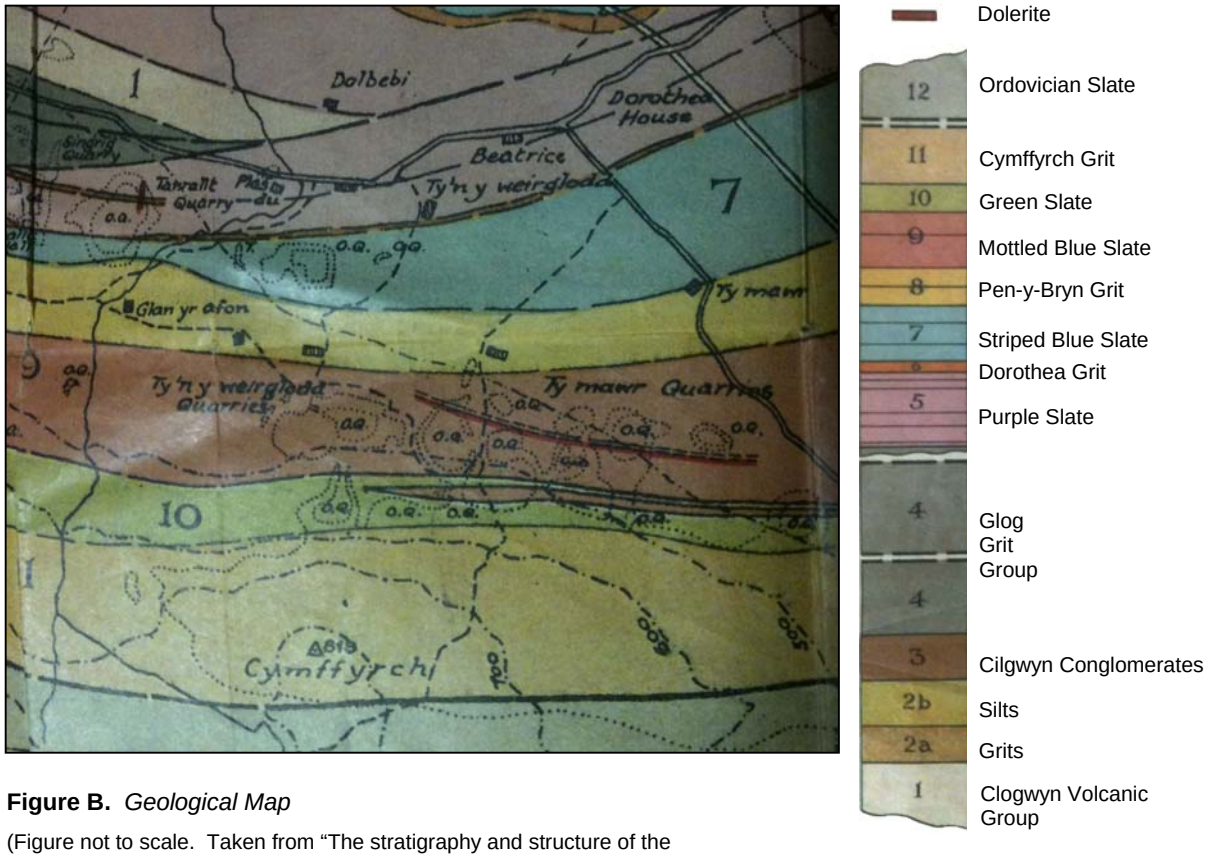


Figure B. *Geological Map*

(Figure not to scale. Taken from "The stratigraphy and structure of the Cambrian Slate Belt of Nantlle (Caernarvonshire)" by T.O Morris & G.G. Fearnsides.

The geology of the rock exposed within the Eastern Quarry at Ty Mawr West is complex. Two main sub groups of the Nantle slate belt have been identified; the Mottled Blue Slate Group (Gwely Llwyd-las Ysnodennog) and the Green Slate Group (Gwely Llwyd). The Blue slate group is exposed within the Blue East excavation, and represents blue-purple slate with cleavage faces that are often blotched with green. KGS are informed that the blue slate is of poorer quality than the other slate seams, hence, the East Blue excavation is now partially backfilled, however, it is thought to have applications as 'dimension stone'. The average local dip of the Blue Slate Group is 70° to the south-east and in places vertical.

The Green Slate group, exposed within the East Green Quarry, consists of a more coarser, silty type of sediment. The green slate is particularly sought after, due to its colour and rarity within local quarries.

The boundary between the Blue and Green Slate groups was identified by KGS during the site visit and lies approximately 10m along the cutting between the two excavations. The transition zone between the two slate sub groups dips at approximately 50° to 60° (as observed) towards the south south-east (although this is possibly locally disturbed by recent ground movements).

3.2 Hydrogeology

The data search undertaken as part of the current assessment has not revealed any information about the groundwater regime for the site.

Details provided by Ty Mawr West Ltd. refer to the presence of deep water-outlet tunnels located in the vicinity of the base of the old and infilled quarry pits. KGS are advised that these show no signs of contamination from the operational crushing plant on site.

KGS can confirm that no water bodies were present on site, and during the site inspection minor areas of 'boggy' ground were noted between the two excavations, this is believed to be the results of rainwater run-off.

It is advised that surface water in the proposed development area drains northwards through a drainage channel to the north of the void (see Drawing No. 10-312-D-001).

3.3 Geotechnical Structure

The geotechnical structure within the Eastern Quarry at Ty Mawr West is complex and highly variable.

Structure is generally dominated by well-developed, steeply inclined to sub vertical joint planes and cleavages, with the dominant sets exposed within the East Blue Quarry and cutting to the East Green Quarry summarised on the stereoplot below.

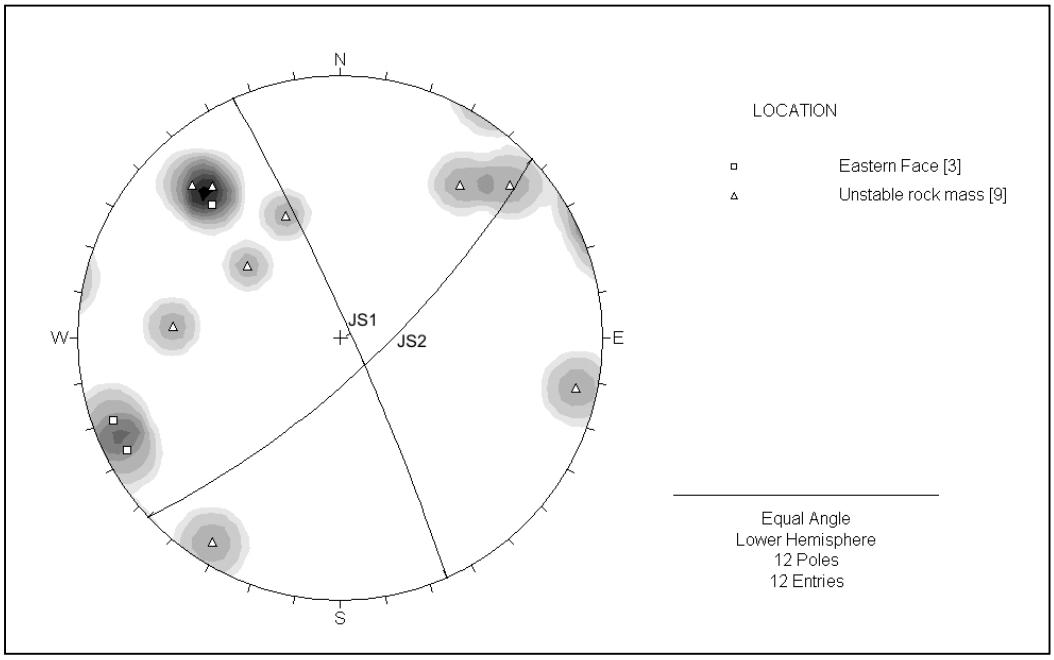


Figure C. *Stereoplot summarising principal discontinuity sets at Pant Quarry*

Discontinuity Type	Average Dip	Dip Direction
Joint Set 1*	85°	066°
Joint Set 2	74°	137°

* Note: Joint Sets A and B commonly overturned

All faces within the East Green Quarry were inaccessible at the time of the recent inspection. As a consequence, the structure of the rock mass in these areas cannot be ascertained.

Recent inspection has, however, identified the presence of two dominant joint sets within the East Blue Quarry, which are steeply inclined to sub-vertical and approximately perpendicular to each other, trending approximately NNW-SSE and SW-NE. The joint sets are locally overturned.

The portion of rock mass which separates the East Blue an East Green excavations (Photo 3), displays sections of disturbed, unstable ground. Here, the dip of the joint set varies from 48° (northern slope) to 85° (southern slope) (Photos 4 & 5) the joint sets typically appear to dip to the south and south-east.

3.4 Slope Stability and Potential Failure Mechanisms

As part of this assessment, attention has been paid to reviewing the likely stability of the individual quarry faces which will result from the removal of the rock mass between the two quarry voids.

The current condition of the eastern faces is shown in Photo 6.

This assessment will focus on faces formed along the eastern margin of the site, with the following assumptions have been applied:

- Maximum face height of 6m
- Face gradient of 70° (from horizontal; i.e. 20° vertical inclination).

A kinematic stability assessment of the eastern rock faces at Ty Mawr West (Eastern Quarry) was undertaken as part of the current assessment. The following provides a summary of the potential failure mechanisms associated with those faces.

"Kinematics" refers to the ability of blocks to move (without reference to the forces that cause them to move). Therefore, the kinematic approach to rock slope stability analysis deals mainly with directionality (dip and dip direction) of discontinuities within a rock mass to predict the mechanism and likelihood of potential failures.

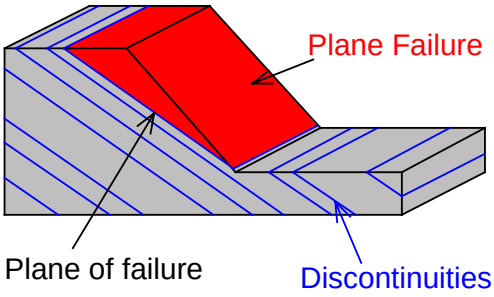
When considering the stability of rock slopes, there are three principal failure mechanisms that are addressed:

i. Plane failure
ii. Wedge failure
iii. Toppling failure

Plane Failure

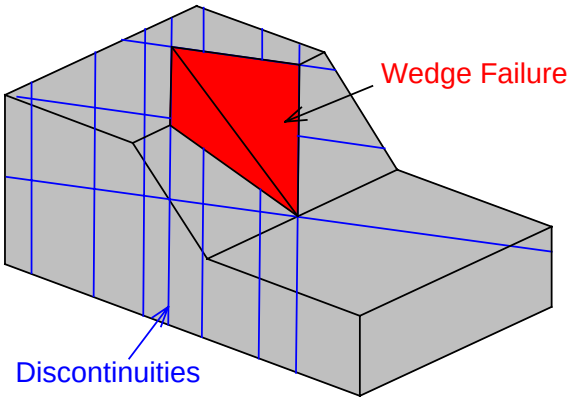
Plane failure occurs when a block of rock slides along a planar surface, usually a discontinuity plane. For plane failure to occur the discontinuities within the rock must:

- have a lower angle of dip than that of the slope face.
- have a dip greater than the angle of friction.
- have a strike parallel, or within +20º or -20º of the strike of the slope face.
- be positioned behind the face, but must 'daylight' in the face surface at some point.



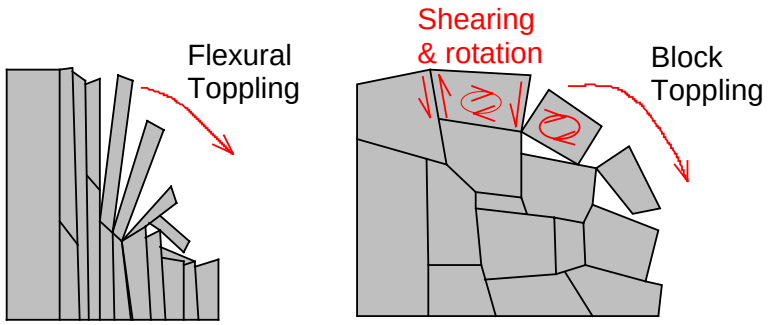
Wedge Failure

Wedge failures occur due to sliding of a block of rock along at least two intersecting discontinuity planes. As with plane failure, it is necessary for the discontinuities to 'daylight' in the slope face and for the dip of the intersection to be greater than the angle of friction.



Toppling Failure differs from planar failure, in that, the blocks of rock do not slide over a discontinuity plane, instead they rotate about a fixed axis. Toppling is a very common form of slope failure, forming relatively small failure blocks, which tend to build up at the base of the slope as scree. The conditions required for toppling failure to occur are:

- The centre of gravity of the toppling block must lie in front of the base of the block, as shown below, in order to initiate rotation.
- The discontinuities should be steeply inclined and sufficiently open to allow separation of a block from the main intact rock.
- The block must have a relatively low width to height ratio, less than around two.



In addition to the potentially large-scale failure mechanisms discussed above, small-scale failures can occur; these are generally termed **rockfall*** (or ravelling or spalling). Rockfalls involve generally random collapses of blocks of rock, occurring in fractured loose rock masses, and can be triggered by numerous mechanisms including water ingress, freeze-thaw events and fracture dilation caused by vegetation and root growth.

Given the condition and structure of the majority of faces exposed within Ty Mawr West (Eastern Excavation), the most likely mechanisms of instability will involve **toppling failure** and general **rockfall**.

***** Whilst toppling failure and rockfall mechanisms have been identified as potential modes of failure at Ty Mawr Quarry, Factors of Safety cannot be readily calculated for such events as shear strength parameters along the particular failure surface cannot be defined (after Hoek, E. and Bray, J. "*Rock Slope Engineering. Revised Third Edition*". The Institute of Mining and Metallurgy, London. 1981). In such cases, it is usual to apply an observational approach to monitoring slope stability and managing the risks associated with such excavations.

Provided individual faces are limited to a maximum height of 6m, intermediate benches of 3m are maintained between individual faces and faces are inclined at 70° (from horizontal) or shallower, it is considered that the potential failure hazards associated with the intended development will be manageable.

4.0 QUARRY DESIGN

4.1 Eastern Quarry – Proposed Design Parameters and Quarry Development

When excavation recommences at Ty Mawr West, it is intended to develop the existing mass of rock between the East Blue and East Green excavations (see Figure D below).

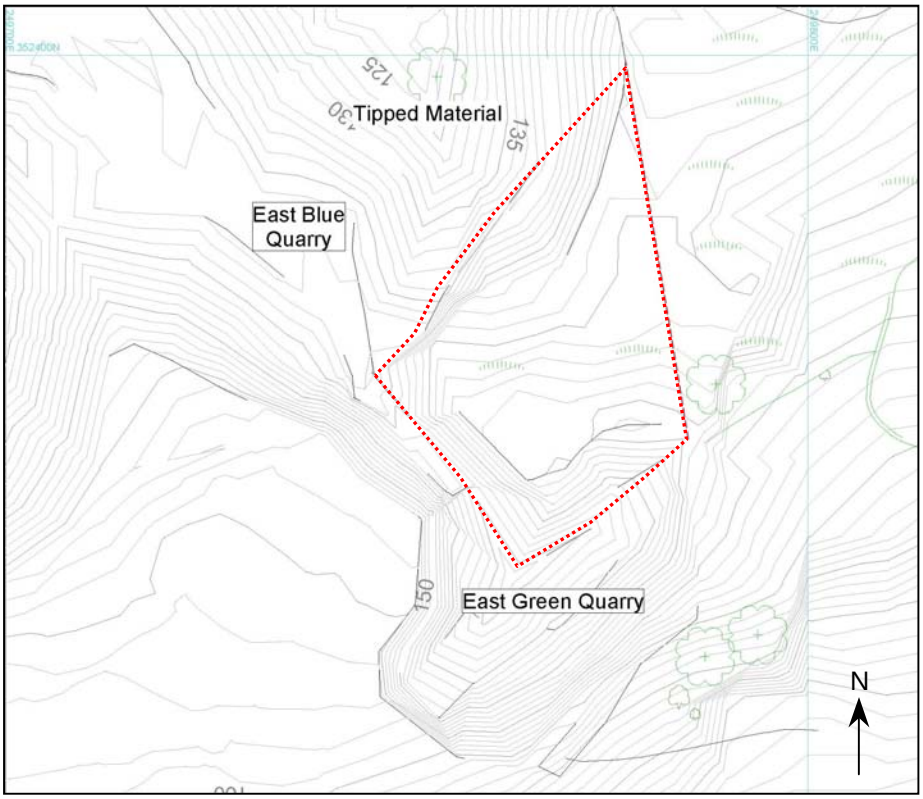


Figure D. *Eastern Quarries*

Inspection of the rock mass which separates the two quarries indicates potential for toppling failures and rockfall. This has been exacerbated by the apparent failure/slumping of the rock mass between the two quarries, leading to toppling of the slate beds towards the northwest (Photo 4).

Drawing No. 10-312-D-002 shows the suggested development phases for the area separating the two quarries. It is recommended that all resultant faces created during the removal of the rock mass should adopt the following parameters.

- Maximum face height - 6m
- Maximum face inclination - 70°
- Minimum final bench width - 3m

It is stressed that this design assumes that faces are fully stabilised and dressed of all loose,

potentially unstable blocks following excavation. Should any potentially unstable or otherwise hazardous blocks be left on the face then the intermediate bench width may require to be increased.

The following details the proposed method to work faces of up to 6m in height within Ty Mawr West;

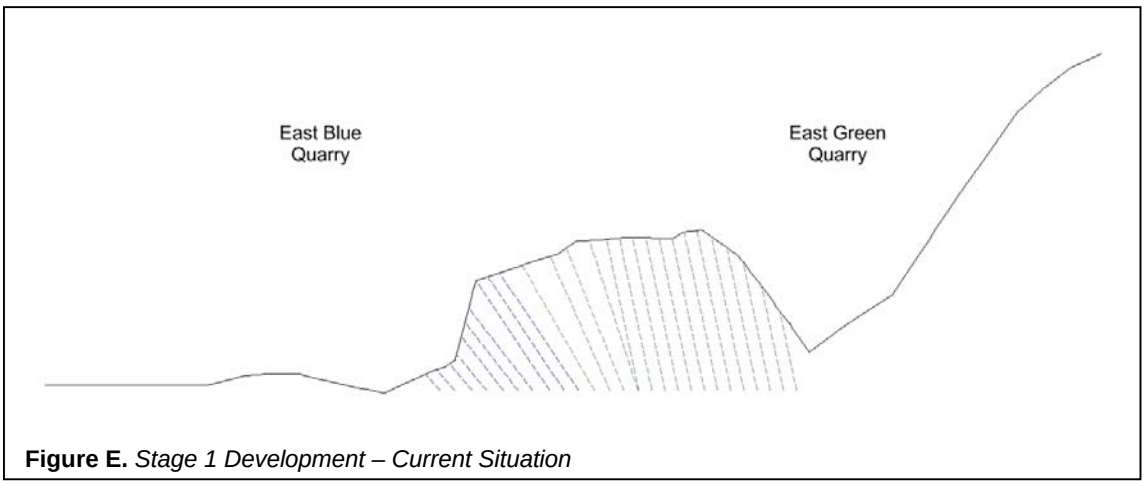


Figure E. *Stage 1 Development – Current Situation*

Currently, there is potential for toppling and rockfall failures within the East Blue Quarry, mainly associated with the 'slumped' rock mass forming the southern side of excavation.

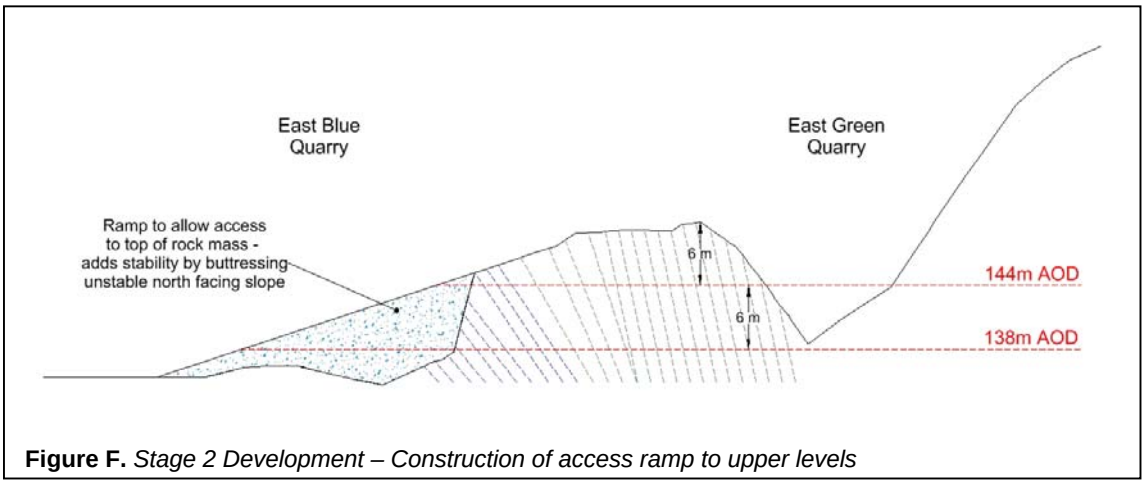


Figure F. *Stage 2 Development – Construction of access ramp to upper levels*

Prior to excavation of material, a suitable ramp will need to be constructed to enable access onto the 150m AOD level. This should be undertaken following a risk assessment, Safe System of Work (SSOW) and installation of suitable edge protection. The ramp will act like a buttress against the unstable north-facing slope, temporarily removing the risk of toppling and rockfall potential from this area.

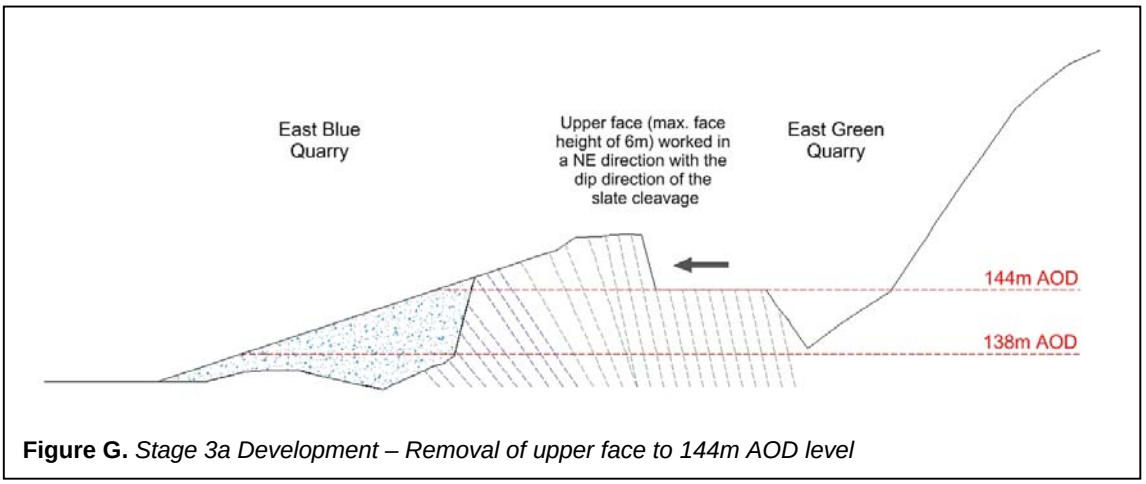


Figure G. *Stage 3a Development – Removal of upper face to 144m AOD level*

An excavator will then work from the c.150m AOD level and create a platform on the 144m AOD level, from which the remaining upper levels will be removed in a south-east to north-west direction, in conjunction with the dominant dip of the slate cleavage. Again, a risk assessment, SSOW and installation of suitable edge protection will need to be place prior to excavation of material.

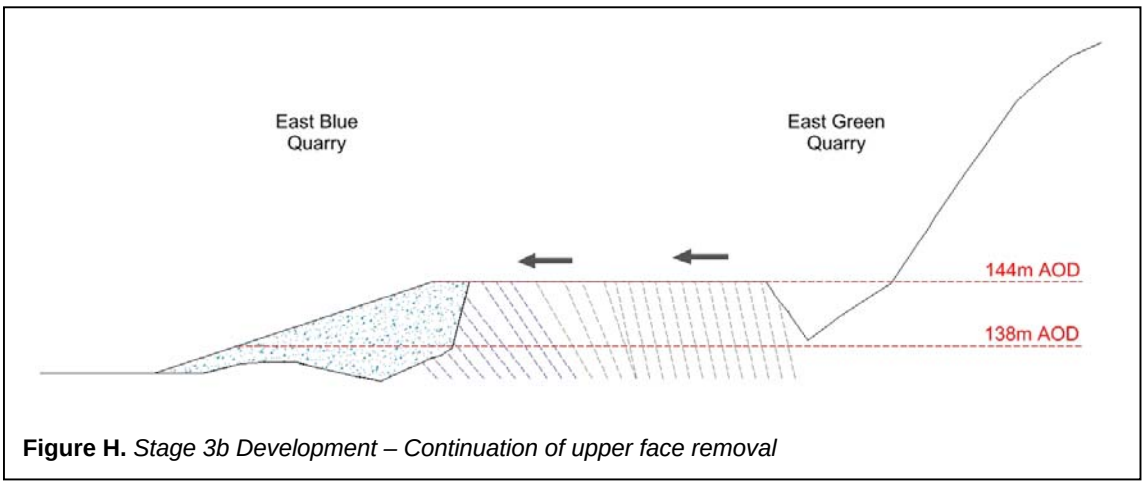


Figure H. *Stage 3b Development – Continuation of upper face removal*

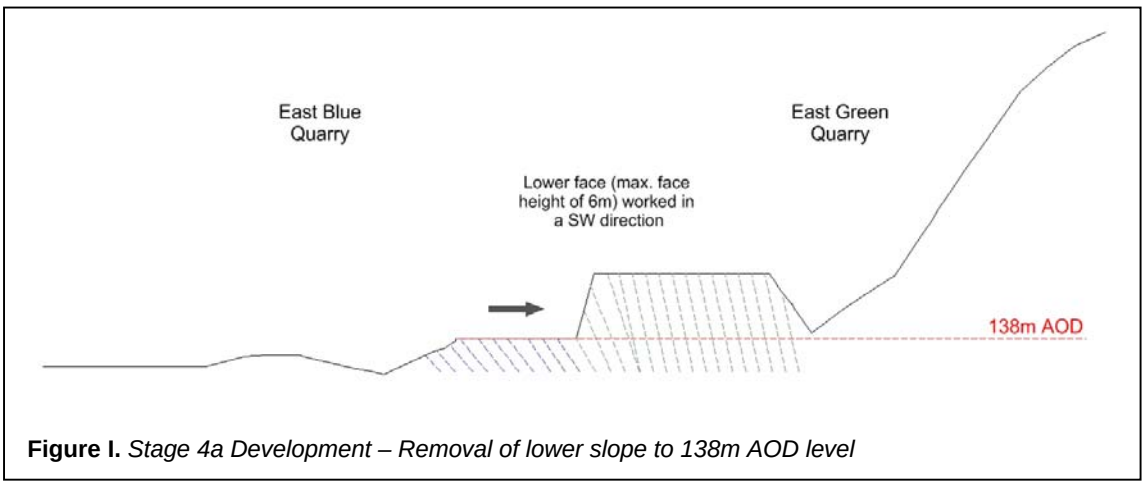


Figure I. *Stage 4a Development – Removal of lower slope to 138m AOD level*

After the upper slope has been fully removed, the access ramp and lower level will be removed by an excavator in a south-easterly direction. The face height should not exceed 6m and suitable working methods (Excavation Rules) should be followed to ensure the safety of the excavator during loading.

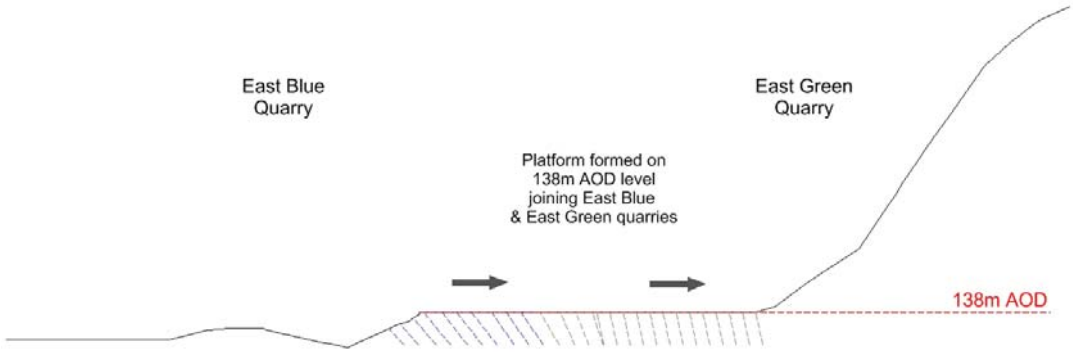


Figure J. *Stage 4b Development – Continuation of lower face removal*

The following provides an estimation of the volumes of virgin slate recoverable to an elevation of 138m AOD (no estimation is provided in respect of the volumes of tipped material that will be removed).

- Total mineral = **c. 7,500m³**

- of which:
  c. 4,500m³ 'green' slate
  & c. 3,000m³ 'blue' slate

It is estimated that an additional **10,000m³** of slate could be extracted by development of the excavation to an elevation of 125m AOD. This development would require the removal of existing tipped slate.

A scheme of works and further geotechnical assessment will be required prior to development below the 138m AOD level (in accordance with Regulation 33 of the Quarries Regulations 1999).

4.2 Hydrological and Hydrogeological Implications of Proposed Development

The area of proposed development is effectively 'cut-off' from its surroundings, only joined along its eastern margin. The rock mass is thought to be 'hydraulically isolated' from the surrounding rock mass and therefore removal of the rock should not impact on the surrounding groundwater regime. It is expected that a slight increase in surface run off may occur through the base of the

two quarries once joined, however this will continue to be diverted out of the excavations through the existing drainage channel to the north of the void (see Drawing No. 10-312-D-001).

5.0 SUMMARY

On behalf of Ty Mawr West Limited, Key GeoSolutions Ltd (KGS) have been appointed to undertake a geological/geotechnical assessment of the proposed activities within the Eastern excavation area in Ty Mawr West Quarry

It is concluded that, given the condition and structure of the majority of faces exposed within Ty Mawr West (Eastern Excavation), the most likely mechanisms of instability will involve toppling failure and general rockfall. However, working methods have been proposed within this report that will serve to minimise the risks associated with the potential hazards when development commences (see Section 4.0).

It is believed that removal of the rock mass joining East Blue and East Green quarries will not impact significantly on the groundwater regime of the site, due to it being largely isolated from the adjacent ground.

Prior to development, a full Geotechnical Assessment (in accordance with Regulation 33 of the Quarries Regulations 1999) of the excavation areas within the Eastern Quarry at Ty Mawr West will be required.

PHOTOGRAPHS

Photo 1. View of narrow cutting leading to East Green Quarry.

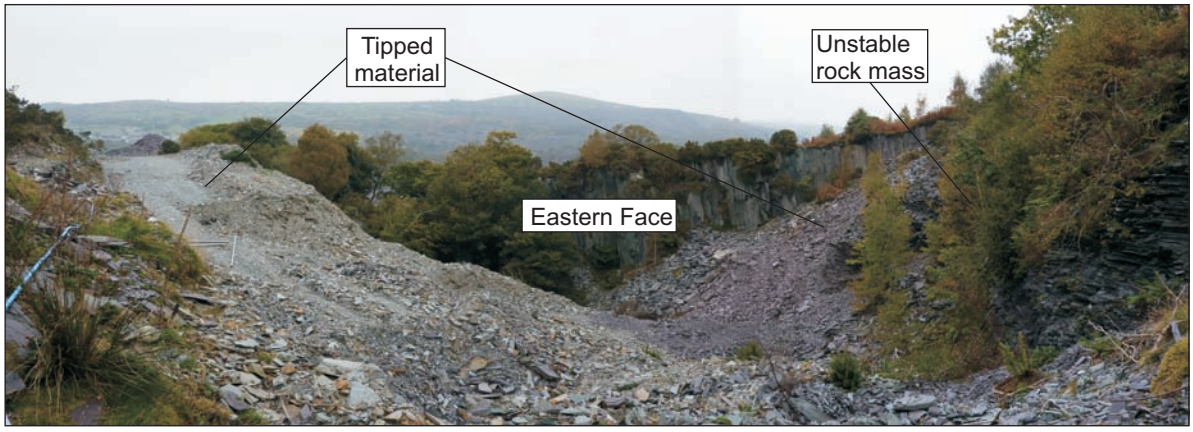


Photo 2. View of East Blue Quarry, view looking East..

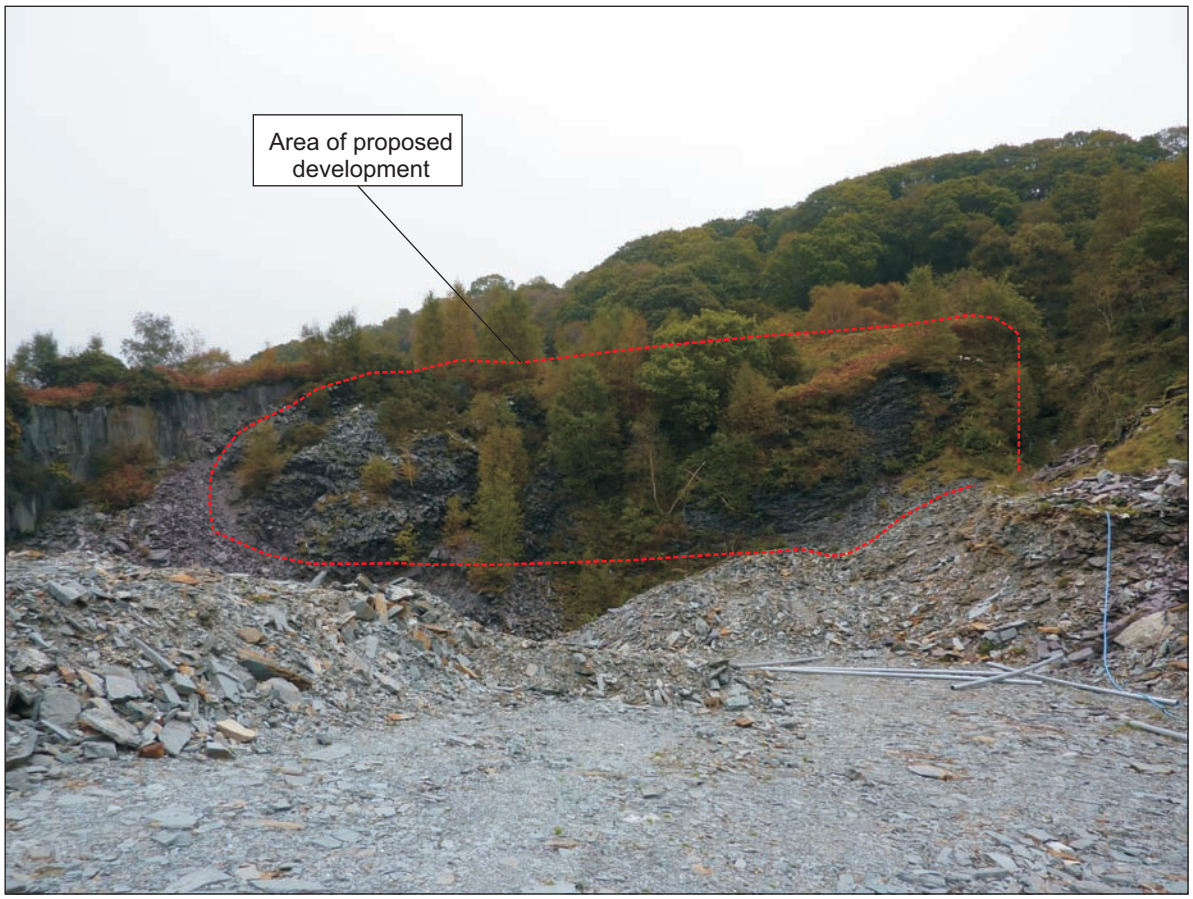


Photo 3. View of rockmass between the two quarry excavations, view looking south.

Photo 4. Front of rock mass, East Blue Quarry.

Photo 5. View near to back of rock mass, taken in cutting through to East Green Quarry.

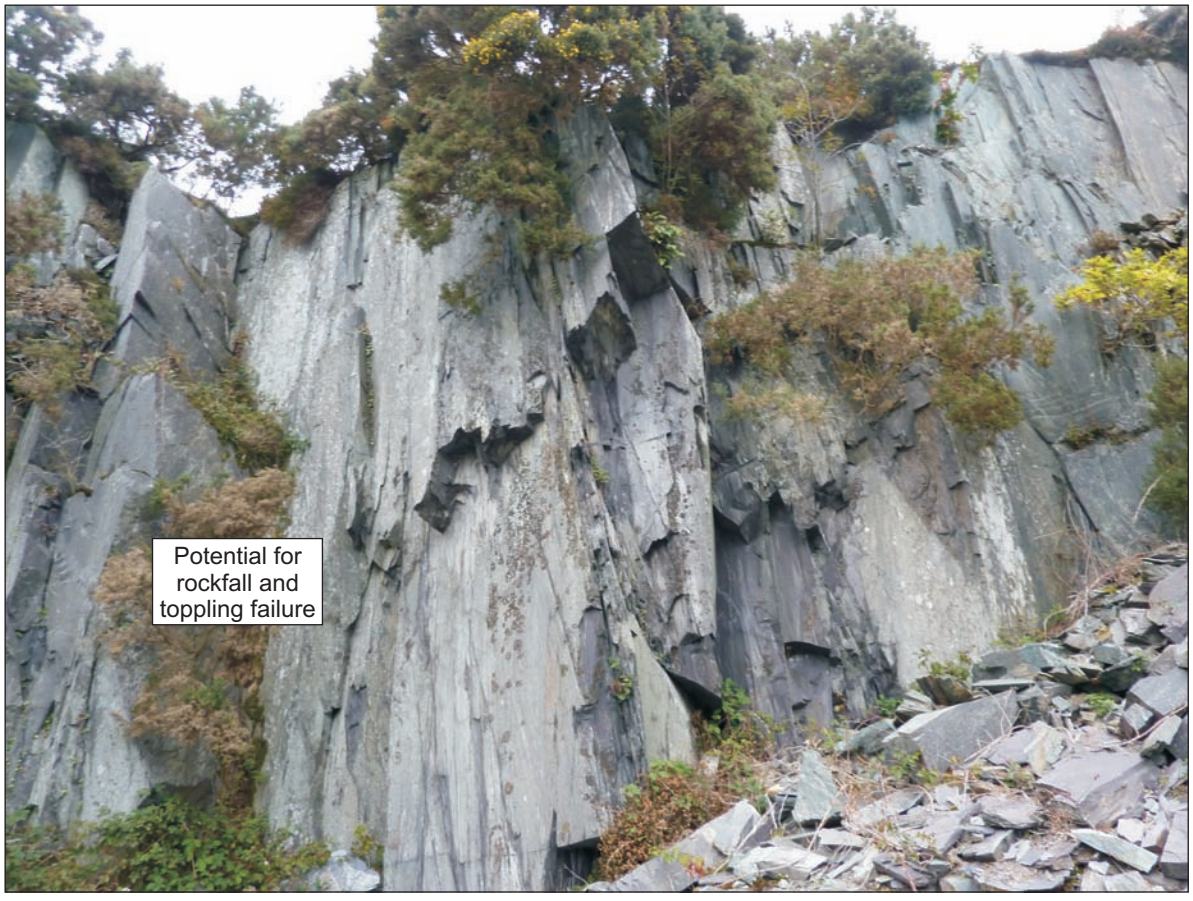
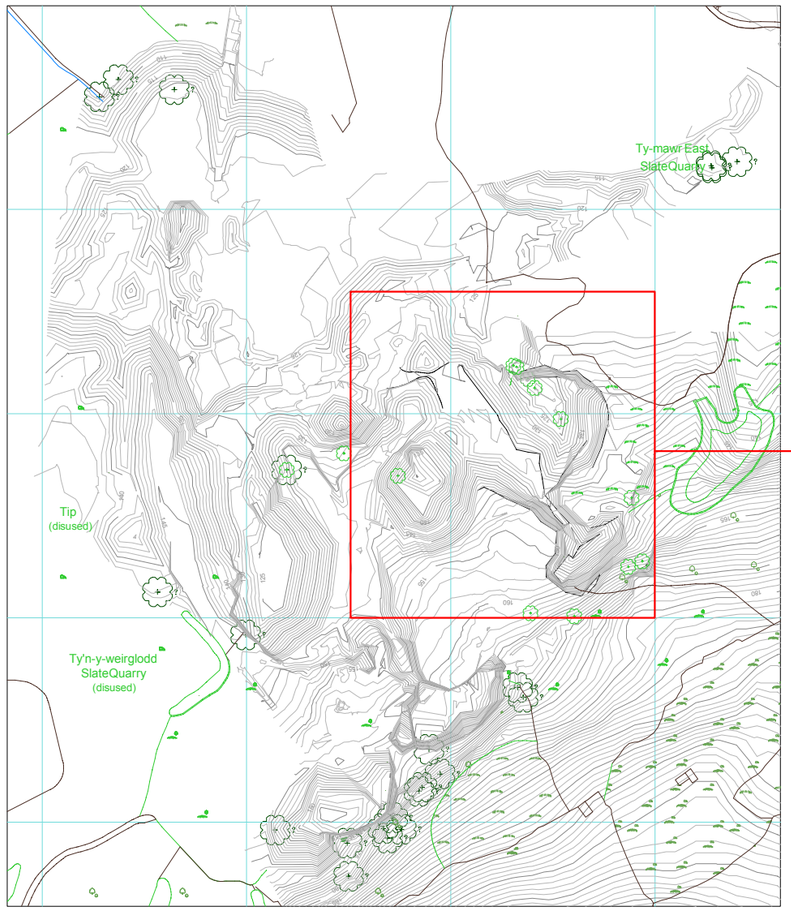


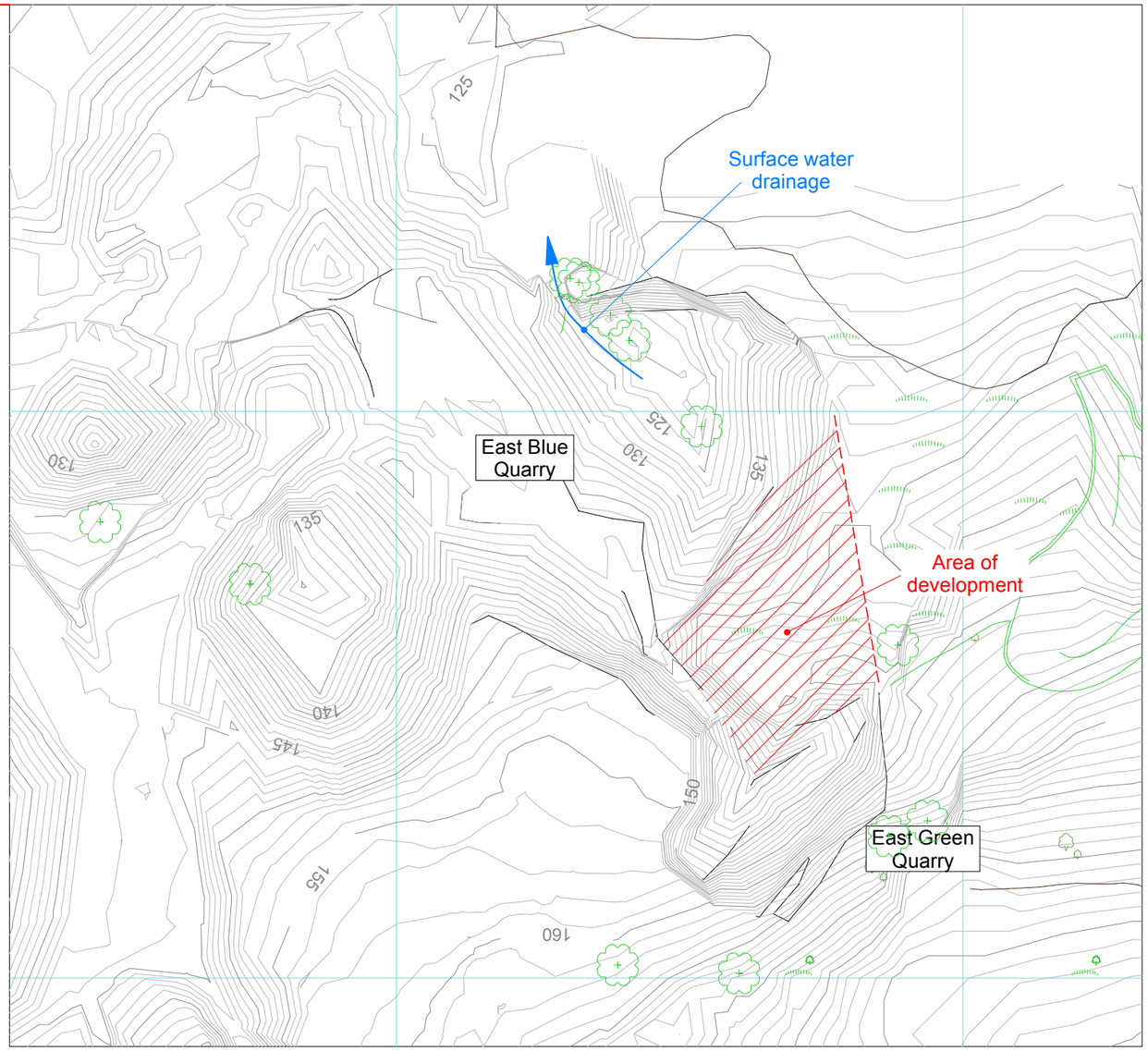
Photo 6. View of Eastern Faces, East Blue Quarry.

DRAWINGS



Topographical Survey (dated May 2008)

Plan Scale 1:3000



View of Eastern Quarry voids (dated May 2008)

Plan Scale 1:1000

LSS Model used to create plot: ****MODEL DETAIL****

Rev	Revision Detail	Drawn	Date

CLIENT:

Ty Mawr West Limited

PROJECT: Ty Mawr West Quarry

TITLE: Site Location Plan

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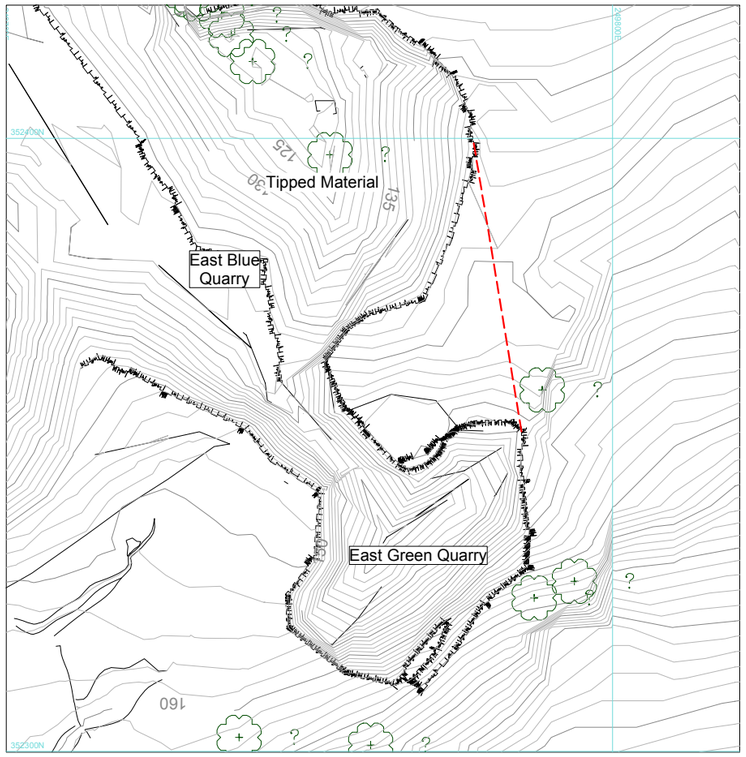
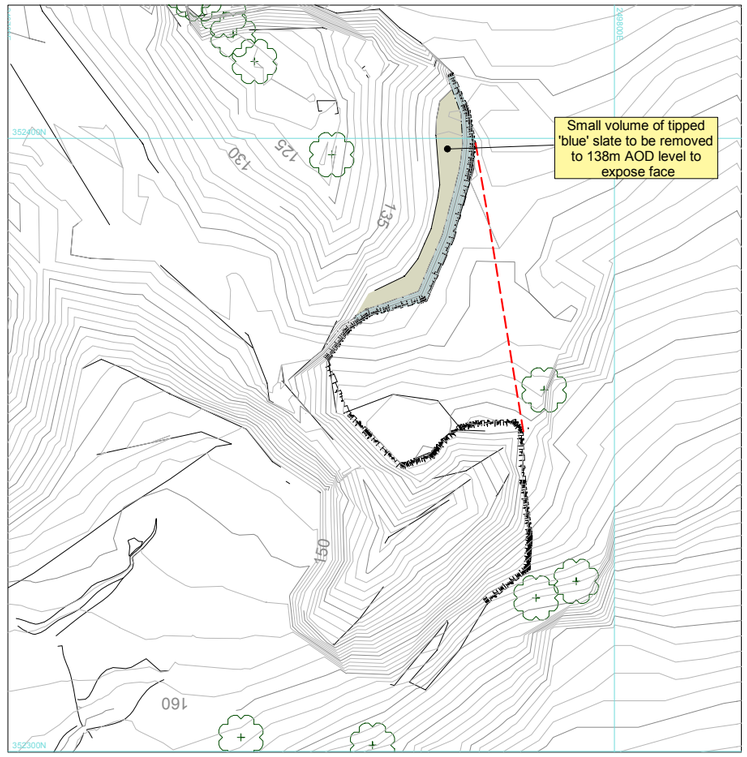
Drawn	Checked	Date	Scale @ A3
S Gibb	JA	Oct '10	as shown

Drawing No. **10-312-D-001**

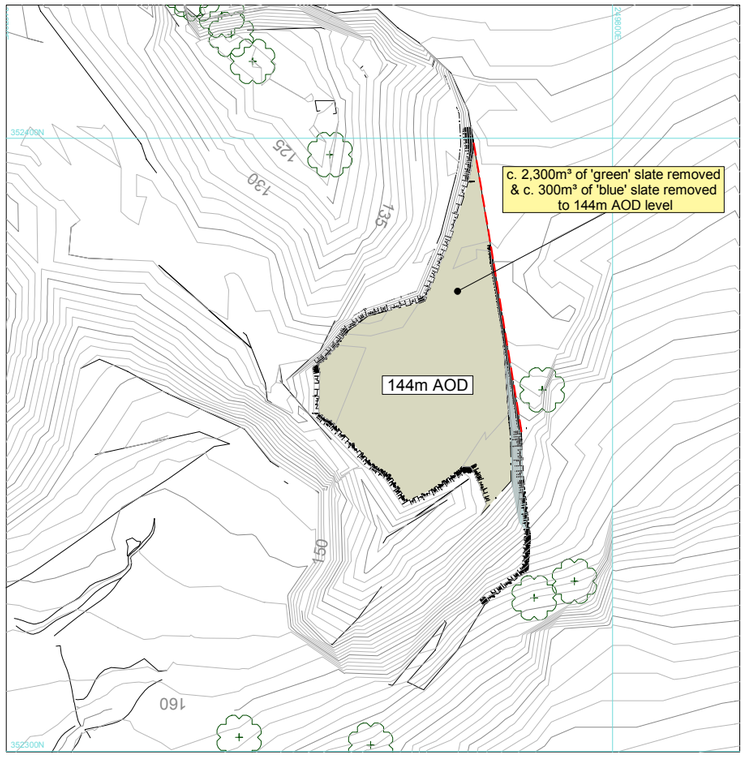
Revision



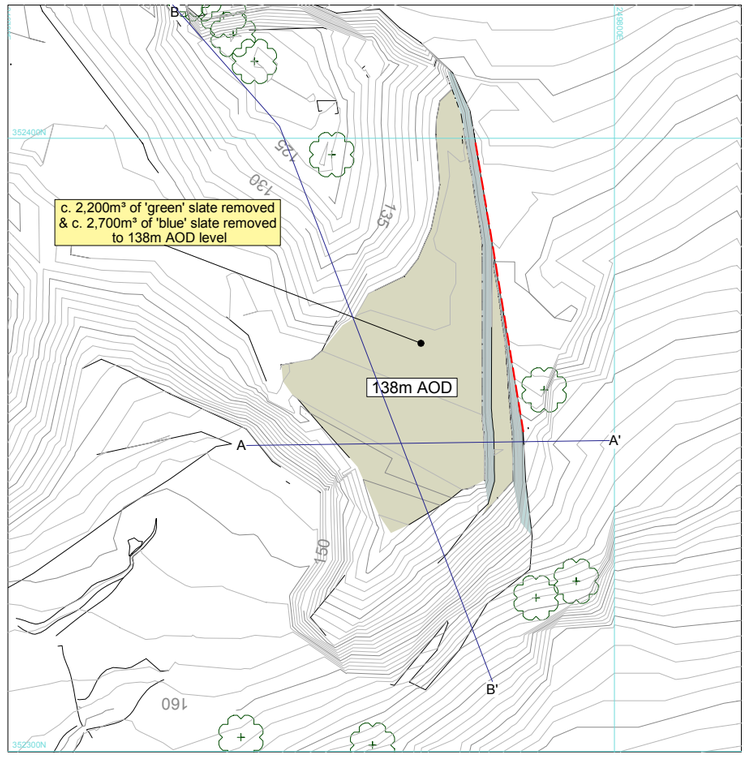
Topographical Survey (dated May 2008)



Removal of tipped material to 138m AOD level



Development of face to 144m AOD level



Development of face to 138m AOD level

The following provides an estimation of the volumes of virgin slate recoverable by the proposed development (no estimation is provided in respect of the volumes of tipped material that will be removed).

Total mineral =
c. 7,500m³

of which:
c. 4,500m³ 'green' slate
& c. 3,000m³ 'blue' slate

It is estimated that an additional 10,000m³ of slate could be extracted by development of the excavation to an elevation of 125m AOD.

This would need to be subject to prior assessment of the stability of the southern slopes and does not allow for removal of existing tipped slate that would be necessary to allow the development to take place.

N

LSS Model used to create plot: ****MODEL DETAIL****

Rev	Revision Detail	Drawn	Date

CLIENT:

Ty Mawr West Limited

PROJECT: Ty Mawr West Quarry

TITLE: Quarry Development Plan

Key GeoSolutions Ltd
Nova House
Audley Avenue Enterprise Park
Newport
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Drawn	Checked	Date	Scale @ A3
S Gibb	JA	Oct '10	1:1000

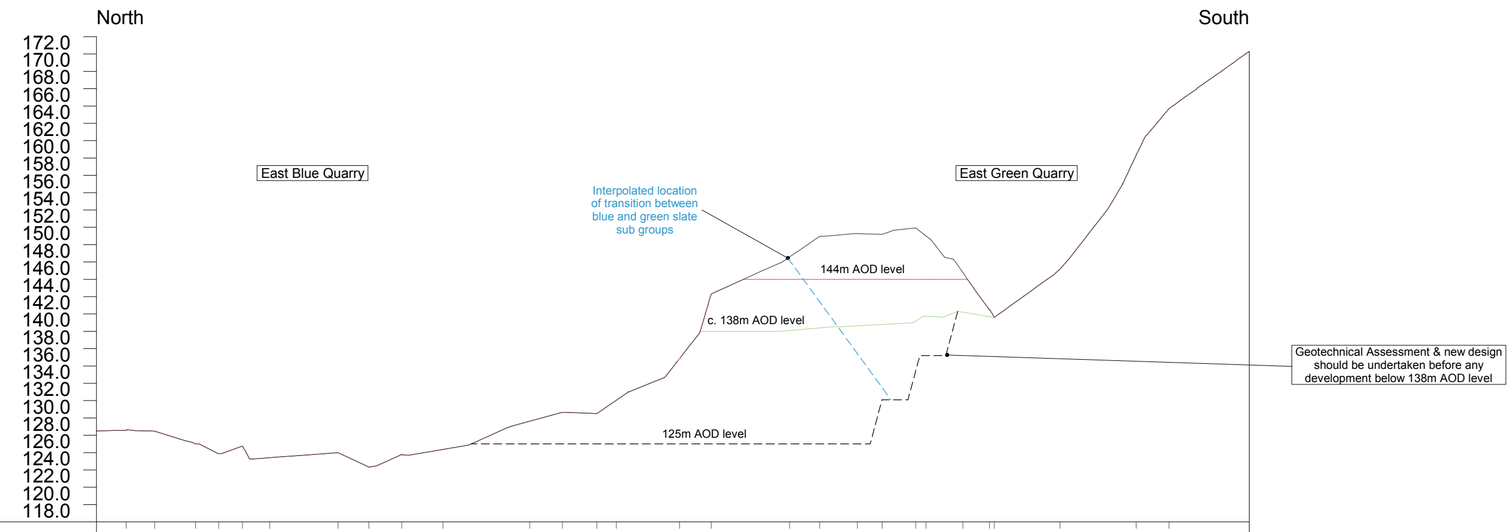
Drawing No. **10-312-D-002**

Revision

Datum 132.0

Topographical Survey (dated May 2008)	153.31	153.22	142.35	140.66	146.66	149.00	149.68	149.00	148.57	150.90	154.78	157.25
Design to 144m AOD level	153.31	153.22	142.35	140.66	144.00	144.00	144.00	144.00	144.00	144.00	144.00	144.00	150.00	154.78	157.25
Design to 138m AOD level	153.31	153.22	142.35	140.66	139.75	138.63	138.00	144.00	144.00	144.00	150.00	154.78	157.25
Longsection Chainage (m)	0.0	10.0	20.0	30.0	40.0	50.0

Section A - A'



Datum 116.0

Topographical Survey (dated May 2008)	126.50	126.55	126.47	125.00	123.87	124.75	123.42	124.00	122.34	123.77	124.37	127.62	128.65	128.50	130.03	134.13	142.31	146.58	148.96	149.28	149.19	149.92	149.00	144.78	140.47	139.60	145.17	158.28	163.71	170.30
Design to 144m AOD level	126.50	126.55	126.47	125.00	123.87	124.75	123.42	124.00	122.34	123.77	124.37	127.62	128.65	128.50	130.03	142.15	142.31	144.00	144.00	144.00	144.00	144.00	144.00	144.00	144.00	140.47	145.17	158.28	163.71	170.30
Design to 138m AOD level	126.50	126.55	126.47	125.00	123.87	124.75	123.42	124.00	122.34	123.77	124.37	127.62	128.65	128.50	130.03	138.00	138.00	138.00	138.51	138.76	139.75	139.61	140.20	139.60	145.17	158.28	163.71	170.30
Longsection Chainage (m)	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0	110.0	120.0	130.0

Section B - B'

LSS Model used to create plot: ****MODEL DETAIL****

Rev	Revision Detail	Drawn	Date

CLIENT:

Ty Mawr West Limited

PROJECT: Ty Mawr West Quarries

TITLE: Eastern Quarries - Cross Sections

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Drawn	Checked	Date	Scale @ A2
S Gibb	JA	Nov '10	1:500

Drawing No. **10-312-D-003**

Revision **A**