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INTRODUCTION

Envireau Water has been instructed by Breendon Trading Limited to prepare a Hydrogeological Risk Assessment (HRA) and Flood Consequences Assessment (FCA) as part of the EIA to support a planning application. As noted from Chapters 1 and 3 above, the planning application is for a small lateral extension to the slate workings at Penrhyn Quarry.

- 9.1 The proposed extension is contiguous with and located at the north-western corner of the existing quarry. Notably, the extension would be wholly within the confines of the area covered by planning permission C12/0874/16/MW (dated 18 December 2012) granted for a “*proposed extension and realignment of slate extraction operations with a progressive scheme of restoration*”.
- 9.2 The proposed extension would be worked in an identical fashion to the current workings, for which a comprehensive working scheme was approved in 2017 as part of a review under the Environment Act 1995 (the ‘Review of Mineral Permissions (ROMP) review’ planning application ref. C16/1164/16/MW). The extension would form a logical progression from the previous extension to the workings (planning permission ref. C12/0874/16/MW), expanding the workings along the north-western side of the quarry.
- 9.3 The basis of this assessment is a hydrological and hydrogeological appraisal of the proposed extension area for the dewatering operations, giving consideration to potential impacts to water dependent environmentally sensitive features. This report also includes a flood consequence assessment relating to the proposed extension area.

METHODOLOGY

Report Context

- 9.4 The report combines published regional and local data and the results of intrusive site investigations, and comprises the following:
 - A review of the baseline hydrology, geology and hydrogeology around the proposed extension.
 - Identification of surface water and groundwater features in proximity to the proposed extension.
 - The proposed development plan and proposals for water management and drainage throughout the proposed extension within the context of the quarry.
 - A Hydrogeological Risk Assessment (HRA) following the principals outlined in the technical framework for groundwater risk assessment set out in Groundwater protection: Principles

and practice (GP3) [Ref. 3] and the risk assessment methodology set out in DEFRA's Green Leaves III (GL III) [Ref. 4]; together with proposals to mitigate hydrogeological risk, where required; and

- A Flood Consequences Assessment (FCA) prepared in accordance with the Technical Advice Note (TAN) 15: development and flood risk dated July 2004 [Ref. 5].

Data Sources

9.5 The following data sources were used in this assessment:

Natural Resources Wales

- Licensed and deregulated water abstractions.
- TAN 15: Development and Flood Risk – Development Advice Maps.
- Surface Water Flood Risk Maps.
- Groundwater Source Protection Zones (SPZs).
- Discharge permits.
- Landfill sites.

Ordnance Survey

- OS Explorer Maps 1:25,000 and 1:50,000 scale.

British Geological Survey

- Geological map, 1:50,000 scale, Sheet 106 (Bangor);
- Onshore GeoIndex;
- Borehole and water well records; and
- Physical properties of major and minor aquifers in England and Wales.

Natural England

- MAGIC Map application (Protected sites and water dependent features).

Gwynedd Council

- Registered Private Water Supplies (PWS).

Centre for Ecology and Hydrology

- Flood Estimation Handbook (FEH) Web-Service.

SLR Consulting Ltd/GWP Consultants Ltd

- Topographical data for Penrhyn Quarry and the proposed extension area;
- Site investigation reports and development plans.

Envireau Water

- Hydrology, Hydrogeology, Water Quality and Flood Risk: Proposed realignment of Quarry Workings at Penrhyn Quarry, Bethesda in order to Optimise Recovery of High Quality Slate (Ref: C:\TLM\WS Penrhyn (6124)\Chwarel Penrhyn r8 final.doc) Envireau Water November 2011, in support of planning application Ref: C12/0874/16/MW [Ref. 1].
- Review of Old Mineral Permissions at Penrhyn Quarry, Bethesda, Gwynedd: Hydrogeology, Hydrology, Water Quality, Drainage and Flood Risk [ref. P:\WS Penrhyn HIA (1736)\ROMP HIA r3.docx by Envireau Water and dated May 2015] [Ref. 2].

Assessment Methods

- 9.6 Current hydrological and hydrogeological conditions have been established through a desk study assessment which is supported by previous site surveys, investigations and reporting for the quarry developments (see Ref. 1 & 2].
- 9.7 An assessment has been undertaken on the significance of the likely direct or indirect impacts on features of ecological, hydrological or geological importance; including the potential impacts on ground and surface waters; any local spring systems; water quality; and any sources of potable supply/licensed abstractions.
- 9.8 It is important to put this assessment into the context of the current operations, where the extraction of slate has been undertaken in various stages since at least the nineteenth century. The extraction of slate and associated operations at the proposed extension will be analogous to the current working practices at the quarry.
- 9.9 In addition to the above, potential impacts have been assessed in this report using a Source-Pathway-Receptor (S-P-R) methodology. Where S-P-R linkages have been identified, the sensitivity of the receptor, magnitude of impact and significance of effect has been considered in order to assess the overall impact of the proposed extension of Penrhyn Quarry and associated slate workings.
- 9.10 Mitigation measures have been considered as part of the assessment.

SITE SETTING AND DESCRIPTION

- 9.11 This section describes the existing physical and hydrogeological characteristics of the land within and surrounding Penrhyn Quarry.

Location

- 9.12 Penrhyn Quarry is located approximately 2km south of Bethesda, Gwynedd within the Snowdonia region of North Wales (Figure 1). The quarry is centred on National Grid Reference (NGR) SH 619 648. The settlements of Mynydd Llandegai, Bryn Eglwys, Coed y Parc and Braichmelyn are situated to the north of the quarry, with the Afon Ogwen lying to the east and the mountains of the Glyder Ridge to the south.
- 9.13 The proposed extension is located at the north-western corner of the quarry workings (approximate centre at NGR SH 6089 6388).

Current Quarry Workings and Proposed Extension

- 9.14 Penrhyn Quarry currently extends over an area of some 318ha, the majority of which has been disturbed to some degree by quarrying or associated activities. The main elements of Penrhyn Quarry consist of the old North Quarry (now worked out and flooded); the existing permitted extraction area in the South Quarry; the slate waste tips; the processing area, aggregate processing plant and the administration offices (Figure 2).
- 9.15 The northern and eastern limits of the quarry are covered in the main by a series of slate waste tips, many of which are very old and reflect the primary means of slate waste disposal in the nineteenth century. The more recent slate waste tips are located on the north-western limits of the quarry and within the current quarry working area (at its northern end). The current quarry workings are located in the South Quarry and are generally advancing in a south-westerly direction.
- 9.16 The proposed extension encompasses a small, ~2.6ha plot of land located wholly within the confines of the area covered by planning permission ref. C12/0874/16/MW. Margins to the north-western and south-western boundaries of the proposed extension would be provided and therefore the extraction from the proposed extension would be ~ 1.6ha in extent. The proposed extension effectively 'squares off' the quarry workings by re-aligning the north-western boundary of the working area to create a straighter edge.
- 9.17 The proposed extension is bounded to the south and east by the existing and future quarry working area; with areas of open heathland/bog (Gwaen Gynfi) forming the northern and western boundaries. A 'leat' (interceptor and recharge channel), constructed in 2014, runs along part of the southern, northern and western quarry boundary, and will remain in place as part of the proposed extension.

Topography

- 9.18 Penrhyn Quarry is located on an exposed northern flank of a south east to north west trending mountain ridge in north Snowdonia. From this flank, the land gradually falls towards Bangor some 9km north west of the site and to the estuary on the Menai Straits to the north of the site.
- 9.19 At the southern, highest boundary of the quarry, the ground elevation is approximately 430m AOD, and drops to approximately 170m AOD at the quarry processing area dropping further to circa. 150m AOD at the main road (B4409) at the quarry entrance. The base of the South Quarry is currently at an elevation of 250m AOD, with a sump level of 240m AOD, whilst the rim reaches around 400m to 440m AOD on the south-eastern side and between 365m and 315m AOD on the north-western side.
- 9.20 The proposed extension ranges in elevation from approximately 385m AOD at the south-western boundary to approximately 355m AOD at the northern boundary.

Soils

- 9.21 The soil type at the proposed extension area (taken from the LandIS Soilscales website, developed by Cranfield University accessed on 20/05/2019 [Ref. 6]) are described as:
- 'Slowly permeable and wet very acid, upland soils with peaty surface'*
- 9.22 These soils drain to the local stream network. The main water protection risks are associated with increased overland runoff and erosion from compacted, over grazed and poached lands.

Hydrology

- 9.23 The hydrological features relevant to the Site are summarised below and presented on Figure 3.

Watercourses and Waterbodies

- 9.24 The principal watercourse adjacent to Penrhyn Quarry is the Afon Ogwen which flows in a north-westerly direction, to the east of the quarry. The Ogwen has a catchment area of approximately 32km² up to where it borders the quarry, comprising predominately upland mountainous terrain. Immediately adjacent to the quarry boundary at the location of the old quarry void, the elevation of the Afon Ogwen ranges from 160 to 145m AOD falling steeply towards Bethesda where it reaches an elevation of 110m AOD. At Bethesda, the Afon Caseg and the Afon Llafar converge with the Afon Ogwen before discharging some 7km downstream, to the Menai Strait on the eastern side of Bangor, Gwynedd.
- 9.25 Several other minor watercourses are located to the south-west of the quarry, close to the proposed extension. A watercourse rises approximately 200m to the south of the western boundary of the proposed extension at an elevation of circa. 400m AOD. The watercourse flows southwards and approximately 100m adjacent to the western boundary of the proposed extension, where the watercourse is small and often difficult to distinguish within the surrounding heathland and peat deposits.

- 9.26 Observations at the quarry by Welsh Slate Ltd have shown the watercourse experiences rapid, high flows following heavy rain, due to the upland nature of the catchment. The watercourse is also known to dry out during extended periods of little or no rainfall.
- 9.27 A second watercourse rises immediately to the north of the northern boundary of the proposed extension.
- 9.28 The Afon Marchlyn Mawr rises to the south of the quarry from the upland area, flowing 350m to the west of the proposed extension. The proposed extension does not extend into the Afon Marchlyn Mawr catchment area.
- 9.29 The surrounding watercourses drain to the Galedffwrdd at Mynydd Llandegai. Galedffwrdd rises on Gwaen Gynfi heathland and flows northeast to the Afon Ogwen at Tanysgafell. The catchment area for the Gwaen Gynfi heathland is ~3.71km².
- 9.30 Marchlyn Bach Reservoir and Marchlyn Mawr Reservoir (both natural dammed lakes) are situated approximately 1km and 1.5km to the south of the proposed extension, respectively. These reservoirs form the source of the Afon Marchlyn Bach and Afon Marchlyn Mawr watercourses.

Catchment Characterisation

- 9.31 Physical and hydrological catchment descriptors for the catchment draining the proposed extension have been derived from the Flood Estimation Handbook (FEH) Web Service [Ref. 7] and are provided in Table 1.
- 9.32 The standard average annual rainfall (SAAR) value is 2228mm/annum, which is consistent with the Bethesda region. The urban extent registered in the year 2000 (URBEXT2000) is stated as 0, reflecting the very rural nature of the catchment.

**Table 9-1
Flood Estimation Handbook Catchment Descriptors**

<i>Descriptor</i>	<i>Abbreviation</i>	<i>Value</i>
Mean altitude	ALTBAR	451m
Mean direction of all drainage path slopes	ASPBAR	320 degrees
Base Flow Index associated with each HOST soil class	BFIHOST	28%
Standard Percentage Runoff associated with each HOST soil class	SPRHOST	56%
Proportion of time when soil moisture deficit was equal to, or below, 6mm during 1961-1990	PROPWET	59%
Standard Average Annual Rainfall (1961 – 1990)	SAAR	2228mm/annum

<i>Descriptor</i>	<i>Abbreviation</i>	<i>Value</i>
Extent of urban and suburban land within catchment	URBEXT ₂₀₀₀	0

9.33 The Standard Percentage Runoff associated with the catchment soils (SPRHOST) is 56%, which is a high value and indicates that the proportion of runoff associated with the catchment soils is high. The Base Flow Index (BFIHOST) associated with the catchment soils of 28% indicates that there is a relatively low groundwater component in the discharge of watercourses in the catchment. Overall, the FEH catchment descriptors are consistent with the site setting and known physical and hydrogeological setting.

Interception and Recharge Leat

Catchments.

9.34 A heathland and peat bog known as Gwaen Gynfi lies down slope of the permitted extraction area and proposed extension and without mitigation, Gwaen Gynfi could be adversely affected by a reduction in surface water flow.

9.35 For the C96A/0020/16/MW planning permission granted in 2000; and subsequent planning permissions C08A/0039/16/MW and C12/0874/16/MW, it was recognised that extraction of the permitted extraction area would result in a loss of catchment draining to Gwaen Gynfi heathland. The loss of catchment (including upland area draining to extraction area) equates to an approximate area of ~29.96ha or approximately ~8% of the flow to Gwaen Gynfi heathland. The permitted extraction area represents approximately ~18.82ha of this lost catchment (Figure 4).

9.36 Therefore, mitigation measures for this were agreed as part of the planning permissions. The mitigation proposed and subsequently implemented in 2014 comprised running an interception leat around the whole upslope area of the current quarry void and the permitted extraction area roughly following the 470 – 460m AOD contour (Figure 4).

9.37 This leat conveys surface runoff water from up-catchment of this elevation, around the permitted extraction area to a downstream recharge and overspill section of the leat to feed back into the Gwaen Gynfi heathland catchment. The recharge and overspill section of the leat runs parallel to contour and has been designed to discharge water downslope along its entire length in order to replicate natural conditions more accurately. Photographs of the leat are provided in Figure 5.

9.38 Extension of the leat around the head of the main quarry void provides mitigation for the incident rainfall falling on the permitted extraction area. By constructing the leat around the top of the main quarry void (an area that historically drained directly into the quarry void) it provides an additional catchment area of approximately ~18.02ha draining to Gwaen Gynfi heathland compensating for the loss of the permitted extraction area (~18.82ha).

9.39 Therefore, the impact of the quarrying of this area has already been accounted for in the current planning permission and as such it is only the additional impact of the proposed extension we are concerned with in this assessment.

- 9.40 The proposed extension has an extraction area of ~ 1.6ha, increasing the overall extraction area to 20.42ha. This equates to ~2.4ha of lost catchment or ~0.6% of the catchment draining to Gwaen Gynfi heathland. Therefore, whilst the proposed extension has a small impact on flows to the heathland, this impact is considered negligible with the leat mitigation in place.

Storm Events

- 9.41 Leat design work was carried out by Halcrow for the 1996 planning applications. Subsequent detailed design work was undertaken by Envireau Water in 2013 including the addition of storm attenuation basins along the route of the leat.
- 9.42 During the design phase, it was considered unrealistic to design for extreme storm events in such a high rainfall environment. Sheet surface flow has been observed on the hillside at the permitted extension area during intense storm events. It is most unlikely that these extreme flow conditions could be controlled / channelled even with major civil engineering work.
- 9.43 Calculations for the expected storm flows for the leat were undertaken considering storm events up to the 1 in 100 year 24 hour storm + 20% for climate change. Flows for the 1 in 1 year and 1 in 100 year +20% climate change storm were calculated to be upwards of 0.3 cumecs and 1.5cumecs, respectively. The leat has the capacity to convey the 1 in 1 year storm event and above; however, it is likely that during more extreme events such as the 1 in 100 year, that storm water will overwhelm the leat and excess runoff water will enter the quarry voids.
- 9.44 Flow velocities can be high in the leat and following a storm event in 2015, which produced scouring, remedial works were undertaken in consultation with Natural Resources Wales (NRW). The leat was reinforced with block/key stones and slate material from the quarry, which has proved effective at controlling erosion. The leat is regularly checked and maintained by quarry personnel following storm events.

Geology

- 9.45 The geological setting of the area has been characterised using information from the British Geological Survey (BGS) 1:50,000 scale sheet 106 (Bangor) as illustrated on Figure 6.

Bedrock Geology

- 9.46 The proposed extension area and wider quarry are underlain by Cambrian age strata comprising Llanberis Slate, Fachwen Formation and Padarn Tuff Formation.
- 9.47 Two faults separate these strata at surface. Up-catchment on the slopes of Carnedd y Ffiliast the strata at surface comprises Carnedd y Ffiliast Grit, Marchlyn Formation and Bronllwyd Grit Formation.

Superficial Deposits

- 9.48 Scree and thin soil cover dominates the upper slopes but the lower slopes, including the permitted extension and realignment areas are covered with superficial deposits. The superficial

deposits comprise a mixed sequence of clay or silt bound sands, outwash gravels, boulder clay (till) and peat deposits. With the exception of the proposed extension area and permitted extension and realignment area, superficial deposits have been stripped and the bedrock strata is exposed within the worked quarry areas.

- 9.49 In late 1995, several boreholes were drilled in the extension area and detailed logs, locations and descriptions were presented in the 1996 hydrological investigation (the 1996 investigation) undertaken by Steve Bennett Groundwater Consultant [Ref. 8] to support the extension planning application.
- 9.50 The borehole locations along with the currently permitted extraction boundary (planning ref. C12/0874/16/MW) are shown on Figure 7. The proposed extension is to the northwest of where the boreholes were located. No boreholes were located within the proposed extension; however, as a result of their proximity to the proposed extension they are considered representative. Table 2 presents a simplified summary of materials encountered.
- 9.51 These investigations demonstrated the depth to bedrock through several meters of overlying superficial deposits. The superficial deposits showed varying spatial consistency, comprising mixed glacial till, boulder clay and sandy or silty clay, with some sand, gravel and cobble horizons either set in a clay matrix or washed and loose. The peat deposits are largely isolated from the bedrock by underlying clays. The investigation boreholes showed the peat cover to be thin.
- 9.52 The overall thickness of the superficial deposits increases markedly towards the south-west of the permitted extraction area to >20m. This southerly thickening is assumed to relate to an outwash channel from the corrie feature of Cwm Marchlyn. Taking into account the orientation of the proposed extension compared to the borehole locations, it is expected that the same trend in drift thickness will be observed across the proposed extension.

Table 9-2
Borehole Summary

Borehole Number	Purpose	Peat Thickness (m)	Superficial Depth (m)	Deposit	Slate Depth (m)
D1	Drift investigation	0.4	1 – 8.0		8.0 – 10.0+
D2	Drift investigation	0.3	0 – 9.5		9.5 – 12.0+
D3	Drift investigation	0.25	0 – 13.5		13.5 – 16.0+
D4	Drift investigation	0.3	0 – 15.5		15.5 – 19.0+
D5	Drift investigation	0.2	0 – 17.2		17.2 – 19.0+
D6	Drift investigation	0.55	0 – 16.0		16.0 – 19.0+
D7	Drift investigation	0.5	0 – 7.1		7.1 – 10.0+
D9	Drift investigation	0.55	0 – 10.2		10.2 – 12.0+
SP1	Slate investigation	0.4	0 – 7.6		7.6 – 30.0+
SP2	Slate investigation	0.4	0 – 11.5		11.5 – 33.5+
SP3	Slate investigation	0.25	0 – 17.0		17.5 – 40.0+
SP4	Slate investigation	0.3	0 – 13.9		13.9 – 36.0+
SP5	Slate investigation	0.7	0 – 14.1		14.1 – 35.0+
SP6	Slate investigation	0.7	0 – 10.5		10.5 – 33.0+
EN1	Geotechnical	0.55	0 – 6.8		6.8 – 8.5+
EN2	Geotechnical	0.55	0 – 9.5		9.5 – 12.0+
EN3	Geotechnical	0.27	0 – 13.0		13.0 – 14.6+
EN4	Geotechnical	0.5	0 – 16.0		16.0 – 18.0+
EN5	Geotechnical	0	0 – 17.5		17.5 – 20.0+
EN6	Geotechnical	0	0 – 23.5		23.5 – 27.7+

Hydrogeology

9.53 The hydrogeology of the proposed extension area and wider quarry is based on a review of BGS geological maps, the on-line NRW database, BGS borehole data, exploration borehole data and the current mineral workings.

Hydrogeological Setting

9.54 The mud indurated nature of Slate makes it effectively impermeable; however, faulting, jointing, fracturing and cleavage planes in Slate provide a secondary permeability. The slates of the Llanberis Slate Formation at the quarry have been designated by NRW as a secondary B aquifer - predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering.

9.55 The Llanberis Slate Formation can contain sandstone units. These sandstone units are not present at the quarry; however, they are located to the north west of the quarry as shown on Figure 6.

9.56 The sandstone units of the Llanberis Slate Formation; the Padarn Tuff Formation and the Bronllwyd Grit Formation in the vicinity of the quarry are designated as Secondary A aquifers - permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These units do not occur on the quarry or proposed extension but are present to the north west of the quarry.

9.57 The superficial deposits in the vicinity of the quarry are designated as unproductive strata.

9.58 The 1996 investigation showed the Slate to contain some water, as evidenced by seepages in the present quarry. Individual discontinuities in the Slate give rise to water inflows at various levels, depending on the discrete occurrence or otherwise of fissuring or open cleavage. However, on a small or local scale this secondary permeability is of limited significance.

9.59 Infiltration to ground would be limited to exposed bedrock via fractures, through scree or the areas of more permeable superficial deposits.

9.60 Evidence at the quarry shows that groundwater movement / storage is very low. It is reported by Welsh Slate that the quarry does not undertake any groundwater dewatering of the current quarry void. Pumping from the quarry sump area does occur to remove surface runoff and rainfall.

Hydrogeological Investigations

9.61 The 1996 investigation provided site specific hydrogeological information for the permitted extraction area.

9.62 Standpipes were installed in several site investigation boreholes, with bentonite seals placed above and below a slotted section to isolate the monitoring zone from surface water ingress or from other horizons. For example, the slate boreholes were sealed at the base of the superficial

deposits. The monitoring zones were set to record groundwater head in the slate and average head conditions in the superficial deposits beneath the thin peat cover.

- 9.63 A number of falling head tests were undertaken on the boreholes and laboratory determination of hydraulic conductivity was undertaken on core specimens. During drilling of the boreholes, the drillers recorded any water strikes apparent to them. Rest water level measurements were then taken by site (then Alfred McAlpine Ltd) staff, following surveying in of each borehole to Ordnance Datum. Data are contained within Table 9-3.

Table 9-3
Borehole Water Level Summary

Borehole Number	Water Strike (m depth)	RWL mbgl	15/01/96 mOD	RWL mbgl	30/01/96 mOD
D1	dry	4.61	391.13	7.67	388.07
D2	3.6 & 8.1	2.14	383.11	3.45	381.80
D3	dry	7.35	402.77	9.15	400.97
D4	9 - 12	8.3	419.69	10.9	417.09
D5	11.7	11.83	423.15	14.80	420.18
D6	9	3.7	421.15	6.98	417.87
D7	dry	7.36	425.81	dry	
D9	dry	9.8	430.36	9.85	430.31
SP1	dry	20.8	365.20	22.50	363.50
SP2	2	30.67	366.93	30.82	366.78
SP3	35	28.68	365.99	29.73	364.94
SP4	19	11.14	408.58	13.64	406.08
SP5	13	3.3	414.48	5.32	412.46
SP6	8.7	13.15	431.22	17.25	427.12
EN1	-	2.15	392.10	4.25	390.00
EN2	-	2.97	398.00	5.09	395.88
EN3	13 – 14.6	5.5	400.00	7.38	398.12
EN4	16 - 18	2.43	402.64	3.62	401.45
EN5	17.5 - 20	1.08	403.71	1.30	403.49
EN6	23.5 – 27.7	3.11	404.74	3.67	404.18

- 9.64 Where water strikes were observed these were variously described as “medium, fast or large”, the latter in slate boreholes SP4 and SP5. “Fast” inflows were noted in slate borehole SP3 and superficial deposit boreholes D5 and D6. Three slate boreholes showed groundwater head at a lower level than in the superficial deposits whilst three other slate boreholes showed similar groundwater head conditions to nearby superficial deposit boreholes.

- 9.65 It was concluded in 1996 that the watercourse to the southwest of the site rises at approximately 410m AOD where the piezometric head intersects the surface. It then flows westerly at a higher elevation than nearby piezometric head and is assumed to be perched along its length. Observations in 2014 during the construction of the interceptor and recharge leat support this conclusion.
- 9.66 Approximations of hydraulic conductivity of the strata were obtained from falling head and laboratory tests during the 1996 investigations. These are summarised in Table 9-4.

Table 9-4
Borehole Hydraulic Conductivity Summary

Borehole Number	Hydraulic Conductivity (ms^{-1})	Method
D1	2.1×10^{-8}	Falling head
D2	6.9×10^{-7}	Falling head
D4	3.1×10^{-6}	Falling head
SP1	1.9×10^{-9}	Falling head
SP2	2.6×10^{-7}	Falling head
SP3	4.2×10^{-6}	Falling head
EN1	5.6×10^{-7}	Falling head
EN4	8.3×10^{-10} 3.2×10^{-9}	Laboratory Laboratory
EN5	7.2×10^{-10}	Laboratory
EN6	9.4×10^{-10} 6.0×10^{-9}	Laboratory Laboratory

- 9.67 These results showed that the clays of the superficial deposits are of very low permeability, 10^{-9} – 10^{-10} ms^{-1} , whereas the mixed silt, sand and gravel superficial deposits have a higher hydraulic conductivity in the approximate range of 10^{-6} – 10^{-7} ms^{-1} . The underlying slates show a similar hydraulic conductivity range to the clays of the superficial deposits and the data suggest that fracture induced (secondary) hydraulic conductivity is having only a very limited effect.

Peat & Superficial Deposits

- 9.68 Peat is characteristically wet and forms a high storage aquifer medium with a relatively low hydraulic conductivity. The 1996 boreholes showed water to be contained within the superficial deposits, where sand and gravel deposits were intersected, with average water levels generally within a few metres of the surface, but below the thin peat cover.
- 9.69 It is assumed that the peat is primarily recharged by incident rainfall, with no groundwater component from the Slate or superficial deposits, due to the presence of clays beneath the peats and the more permeable superficial deposits being laterally discontinuous.

9.70 The distribution of water in the superficial deposits of the permitted extension area was shown to be irregular in the 1996 investigation, with both vertical and lateral movement inhibited by the presence of low permeability clays within and towards the base of the sequence. The coarser materials such as sands and clay bound gravels contained water under a piezometric head and permitted the transfer of groundwater through them.

Emergent Water and Groundwater Flow

9.71 Emergent water feeds the small watercourse rising adjacent to the permitted extraction area. It is considered that this emergence is due to rainfall that infiltrates the peats and more permeable superficial deposits, but vertical drainage is impeded by both clay deposits and the underlying bedrock geology. The water, therefore, emerges where the superficial deposits thin or where clays are found close to the surface.

9.72 Several smaller seepages arise downslope and upslope of the permitted extraction area. The downslope seepages are likely to also relate to impeded vertical drainage whilst the upslope seepages may be the result of a similar mechanism or possibly reflect the boundary between the Llanberis Slate Formation and the adjacent Bronllwyd Grit Formation.

9.73 Hydraulic analysis during the 1996 investigation showed that throughflow through the bulk of the superficial deposits is very low; similar to that of the underlying geology. The investigation also showed a gradual downslope groundwater gradient, mirroring topography.

9.74 In 2014, during construction of the upper section of interceptor and recharge leat for the permitted extraction area, a small pocket of groundwater throughflow / seepage a couple of metres wide within the superficial deposits was observed, highlighting a shallow and narrow groundwater pathway through the more permeable superficial deposits. However, flows were generally very low and were captured by the leat.

9.75 It is considered that emergent waters resulting from high rainfall provides significant input to the upland watercourses.

9.76 The removal of the superficial deposits within the permitted extraction area and proposed extension has the potential to impact on the shallow groundwater system associated with the shallow deposits; however, the groundwater throughflow for these deposits is considered to be minimal and isolated.

9.77 Many of the 1996 investigation boreholes have been lost due to the stripping of the superficial deposits and extraction of slate progressively moving southwest towards the southwestern limit of the permitted extraction boundary. As the works have progressed southwesterly, no significant groundwater has been encountered during this stripping and extraction, no groundwater dewatering is taking place and no significant inflows into the working area from the superficial deposits are occurring

Environmental Setting

- 9.78 Searches of the NRW [Ref. 9], Natural England (NE) and local authority databases have been undertaken to establish and assess the environmental setting of the proposed extension and surrounding area.
- 9.79 A search radius of 2km from the centre of the proposed extension has been applied (NGR SH 609 639) and is considered appropriate due to the nature and scale of the proposed development and its position in relation to potentially sensitive receptors. The environmental setting surrounding the proposed extension is presented on Figure 8.

Designated Sites and Protected Areas

- 9.80 A search of land-based statutory designated sites within Natural England’s MAGIC Map application, has been undertaken within a 2km radius of the proposed extension.
- 9.81 The Snowdonia Special Area of Conservation (SAC) covers an area of approximately 19,738ha and primarily consists of Bog, Marsh, Dry Grassland and Scree ecosystems. The Snowdonia SAC also consists of a SSSI component covering the majority of the designated area.
- 9.82 Of particular importance to the proposed extension is the Marchlyn and Gwaen Gynfi area of heathland and peat bog. This is located directly downgradient from the proposed extension as shown on Figure 3 and 8.
- 9.83 There are no other designated sites or protected areas within 2km of the proposed extension area.

Licensed Abstractions and Deregulated Licences

- 9.84 There are three surface water abstraction licences within a 2km radius of the proposed extension as identified on the Abstraction Licence Search carried out by NRW. The location of these abstraction licences is shown on Figure 8; with details provided in Table 9-5.
- 9.85 According to the NRW database, there are no deregulated licences or groundwater abstraction licences within a 2km radius of the proposed extension.

Table 9-5
Licensed Abstractions

Ref. No. on Figure 8	Licence Number	Licence Holder	Source	Purpose	Annual Licensed Quantity (m ³ /Year)	National Grid Reference
1	23/65/16/0053	First Hydro	Marchlyn Mawr Reservoir	Production of Energy (Electricity)	3,409,500,000	SH 6154 6207

Ref. No. on Figure 8	Licence Number	Licence Holder	Source	Purpose	Annual Licensed Quantity (m ³ /Year)	National Grid Reference
2	23/65/16/0064	Dwr Cymru Cyfyngedig	Marchlyn Bach Reservoir	Public Water Supply	1,460,000	SH 60 62
3	23/65/18/0004	Welsh Slate Ltd	Llyn Owen y Ddol (Pond)	Industrial, Commercial and Public Services (Mineral Products)	273,750,000	SH 6115 6471

Private Water Supplies (PWS)

9.86 A search of Gwynedd Council’s register of PWS has been undertaken. There are four registered PWS within a 2km radius of the proposed extension. Details of the PWS are provided in Table 9-6.

**Table 9-6
Registered Private Water Supplies**

Ref. No. on Figure 8	Supply	Source	National Grid Reference
4	Tal y Waen, Deiniolen	Unknown	SH 59454 63281
5	Clwt y Bel, Deiniolen	Unknown	SH 59220 63012
7	Llys Owain, Mynydd Llandegai	Unknown	SH 59288 65017

9.87 The information provided in Table 6 is not considered to be exhaustive. There is the potential that there are additional private water supplies within the vicinity of the quarry that are not registered. Of note, is that the Ordnance Survey map as shown on Figure 1 and 3, shows several wells to the southwest and northwest of the quarry that have not been identified as being registered. This assessment also gives consideration to those private water supplies that may not be registered.

Discharge Permits

9.88 Based on a search of the discharge permit database undertaken by NRW, there are no discharge permits within the 2km search radius of the proposed extension area.

9.89 It is known that Penrhyn Quarry holds a discharge consent (CG0145301) authorising the discharge of site drainage water down the George Adit draining to the Afon Ogwen. The location of this discharge consent is shown on Figure 8. The consented discharge is rainfall dependent and has a suspended solids limit associated with the discharge.

Landfills

9.90 Information presented on the NRW on-line database accessed on 4th June 2019 shows that there are no historic or active landfill sites within a 2km radius of the proposed extension area.

Pollution Incidents

9.91 Information presented on the NRW on-line database shows that there are two recorded significant pollution incidents within a 2km radius of the proposed extension.

9.92 The NRW database indicates that these incidents were recorded in July 2004 and had a significant impact to water. The watercourses affected by these pollution incidents are located within a different hydrological catchment to the proposed extension and quarry and its neighbouring watercourses and therefore did not impact upon the quarry or its neighbouring watercourses.

Source Protection Zones (SPZ)

9.93 NRW has defined SPZs as a general level of protection for all drinking water sources, identifying those areas close to the sources where the risk associated with groundwater contamination is greatest.

9.94 In general, SPZs are defined around public water supplies. There is also a default source protection zone of 50m radius given to all other sources of water supply.

9.95 Information supplied by the NRW indicates that there are no defined SPZs within a 2km radius of the proposed extension.

Water Framework Directive Classification Status

9.96 The WFD specifies the quality elements that are used to assess the ecological and chemical status of a water body. Quality elements are biological (e.g., fish, invertebrates, macrophytes) or chemical (e.g., heavy metals, pesticides, nutrients) [Ref. 9].

9.97 The status of a surface water body is judged using separate 'Ecological classification' and 'Chemical classification' systems. The overall status of a surface water body is determined by whichever of these is the poorer. To achieve 'good status' overall, a water body must achieve both good ecological and good chemical status [Ref. 9].

9.98 The proposed extension is situated within the North West Wales (Llyn and Eryri) WFD Management Catchment and the Western Wales River Basin District River Basin Management Plan [Ref. 10]. The major water bodies in this river basin surrounding the quarry are the Afon Ogwen, Afon Caseg, and Galedffrwd, (Figure 3). Details of ecological, chemical and overall status are provided in Table 9-7.

Table 9-7
WFD Ecological, Chemical and Overall Status

Water body	2015 Classification	2021/2027 Prediction	Objective
Ecological Status			
Afon Ogwen - Lower	Good	Good	Good
Afon Ogwen - Upper	Good	Good	Good
Afon Caseg	Good	Good	Good
Galedffrwd	Good	Good	Good
Chemical Status			
Afon Ogwen - Lower	Fail	Good	Good
Afon Ogwen - Upper	Does not require assessment	Good	Good
Afon Caseg	Does not require assessment	Good	Good
Galedffrwd	Does not require assessment	Good	Good
Overall Status			
Afon Ogwen - Lower	Moderate	Good	Good
Afon Ogwen - Upper	Good	Good	Good
Afon Caseg	Good	Good	Good
Galedffrwd	Good	Good	Good

9.99 Table 9-7 highlights that the waterbodies surrounding Penrhyn Quarry and the proposed extension have a good ecological and overall status. Based on these classifications, NRW would seek to ensure that no activity that could impact on the current or predicted ecological or chemical status would be allowed.

PROPOSED DEVELOPMENT

Overview

- 9.100 The principles of the quarry development scheme at Penrhyn Quarry were established at the time of granting planning permission for an extension to the working area in 2012 (permission ref. C12/0874/16/MW and referred to as the '*realignment application*').
- 9.101 The approved scheme can be divided into the following operations:
- mineral extraction (within the southern quarry);
 - mineral waste tips (within the southern quarry and periphery of northern quarry);
 - mineral processing for secondary aggregates (within the northern quarry area);
 - production of roofing slates and ancillary building products (within the northern quarry area);
 - mineral stockpiling (within the northern quarry area);
 - slate products stockpiling (within the northern quarry area);
 - removal of material from historic waste tips (within the northern quarry area);
 - site offices and administration (northern quarry area);
 - weighbridges and office (northern quarry area);
 - restored mineral workings.
- 9.102 In the context of the proposed extension, it is only the mineral extraction and waste tipping operations that are relevant to the consideration of this assessment.

Mineral Extraction and Processing

- 9.103 An established mineral operation site infrastructure is already in place for the proposed extension area and includes site access, wheel wash, haul road, processing plant/buildings and internal secondary haul roads.
- 9.104 The final excavation plan (FEP) for Penrhyn Quarry is presented in **Appendix 9/1**. The proposed extension area would be worked in an identical fashion to the current workings at the quarry, for which a comprehensive quarry development scheme was recently approved in 2017 as part of a review under the Environment Act 1995 (the 'Review Of Mineral Permissions (ROMP)) review' planning permission ref. C16/1164/16/MW).

Slate Reject Tipping

- 9.105 Penrhyn Quarry has several historic slate reject tips which are located on the western periphery of the quarry and between the north and south quarries encompassing its boundary. These reject tips which are formed from the rejects from the different processes, have been established over many decades with most associated with the old quarry working areas with those around the north quarry void and process area pre-dating 1989.
- 9.106 The materials comprise slate blocks of various sizes from centimetres to metres in size which has been loosely tipped, creating deposits of material with an open structure and which drain easily.
- 9.107 As the southern quarry void is extended to the south and west and into the proposed extension, it will be progressively infilled with reject slate from the north, in line with the approved scheme.

Quarry Water Management and Drainage

Current Water Management

- 9.108 The existing water management system at Penrhyn Quarry utilises a combination of drainage channels, open channels, pumped drainage and surface water attenuation areas along with settlement lagoons. An overview of the current water management at the quarry is presented on Figure 9.
- 9.109 There are three distinct operations:
- Management of water for processing;
 - Management of drainage from the quarry operations; and.
 - Management of sewage water
- 9.110 The main water use on site is for slate processing. All the water used in processing is recycled, although there are some losses which are replenished from various sources. The main operations consuming water are the weekly cleaning of the factory areas and dust suppression when the weather conditions require it. The volumes used are not measured.
- 9.111 One of the water sources available for use is Llyn Owen Y Ddôl, a small lake to the north of the quarry at an elevation of approximately 300m AOD that is fed by streams draining the surrounding land. Abstraction licence no. 23/65/18/0004, originally issued in 1965, allows the abstraction of up to 750 m³/day from the lake for cooling and dust suppression. Water flows under gravity from the lake through a concrete adit and into a pipe that feeds two water storage tanks located at elevations of 248m and 232m AOD; a meter is used to measure the volume of water abstracted from the lake. Data for the last 3 years shows that up to 80% of the licensed daily volume was abstracted on occasions, but in 2018 the volumes were typically less than 50% of the daily limit.

- 9.112 From a drainage perspective, the quarry can be split into the main quarry void (South Quarry); the processing area; the quarry haul road (connecting the void to the processing area); the slate reject tips; and the old quarry void (North Quarry). With the exception of parts of the slate reject tips, the water within the quarry is directed to the North Quarry.
- 9.113 Water accumulating in the main quarry (South Quarry) is predominantly the accumulation of rainfall and surface runoff. This accumulation of water collects in a small sump with a floor level at 240m AOD. This acts as a drain point for incident rainfall on the void and its catchment.
- 9.114 When the water level in the sump rises to approximately 250m AOD in response to rainfall, the water is pumped out at a maximum rated output of 700m³/hour. A meter was reported to have been installed in late 2017, although it has only been used to determine optimal pumping rates for fuel efficiency and no volume data is available.
- 9.115 A 315mm diameter pipe runs 660m from the main quarry sump pump to a point at an elevation of 313m AOD, where water can be directed into a gravity pipe feeding two water storage tanks for use on site or is discharged to ground under gravity as seepage and throughflow through the main (current) slate reject tip and over a natural 'strap' of rock located within the tip and into the old quarry void. No direct discharge from the main quarry void to the old quarry void is made. This seepage and throughflow allows for the filtration of suspended solids prior to entering the old quarry void.
- 9.116 The North Quarry was last worked in 1989 and has an established water body within it. This water body is clear and is tens of metres deep at its deepest point and has a surface area of approximately 180,000m² and therefore is a significant size for the settlement of any suspended solids that may enter it. The North Quarry also acts as a drain point for incident rainfall on its own void and surrounding catchment area.
- 9.117 Runoff from the haul road connecting the main quarry void with the processing area along with land adjacent to the haul road is captured by a series of settlement lagoons. These settlement lagoons allow for primary settlement of suspended solids prior to water being discharged into the water body within the old quarry void. The settlement lagoons are checked on a regular basis and desilted as and when required.
- 9.118 From a drainage perspective, the majority of the processing area is hydrologically self-contained and enclosed. Runoff that is generated within the enclosed area pools at low points and infiltrates to ground without a direct discharge to any watercourse. For those parts of the processing area that are not hydrologically enclosed, surface water is directed to the water body within the North Quarry.
- 9.119 Therefore, all runoff from the current quarry void (South Quarry) and processing area is either captured by the North Quarry void water body or infiltrates to ground.
- 9.120 The means of discharge from the water body within the North Quarry is via an old worked adit (George Adit) at the northern end of the water body. This controls the water level within the quarry void to circa. 122m AOD and well below the "lip" of the void, ensuring that no overspill from the old quarry void occurs. The old quarry void water level is circa. 25m below the water

level of the adjacent Afon Ogwen; however, the two waterbodies are separated by a slate ridge that is sufficiently high so that surface water from the watercourse cannot spill into the void during extreme storm events.

- 9.121 The quarry discharge consent (ref. CG0145301) is for the discharge of water from the George Adit to the Afon Ogwen some 1.8km to the northwest of the adit entrance. Water is not actively pumped into the George Adit for discharge; rather it flows to the adit under gravity, falling to the Afon Ogwen where it discharges at an elevation of circa. 115mAOD.
- 9.122 Lord Pump Shaft is a 60m deep shaft linked to North Quarry waterbody by an adit. As such, the source of the water in the shaft is drainage from the North Quarry. In times of water scarcity, water is pumped from the shaft to supplement other water sources on site.
- 9.123 No connection to the foul mains sewer is available at the site. Sewage effluent is treated on site via a package treatment plant sized to accommodate the number of staff at the site and is regularly maintained and serviced. Treated water is discharged to the old quarry void water body which provides a significant dilution factor.

Interceptor and Recharge Leat

- 9.124 As discussed in above, a heathland and peat bog known as Gwaen Gynfi lies down slope of the proposed extension and permitted extraction areas at Penrhyn Quarry and without mitigation, Gwaen Gynfi could be adversely affected by a reduction in surface water flow.
- 9.125 The current permitted mitigation scheme comprises an interception leat which is positioned to intercept and convey surface water from up-slope of the permitted extraction area feeding the surface runoff along the south-western boundary of the quarry via two storm storage attenuation and sediment settlement areas. From these areas, water is directed to a recharge / overspill section of the leat on the north-western boundary of the proposed extension providing a source of seepage and throughflow and also overspill water to the downgradient Gwaen Gynfi heathland.
- 9.126 The primary purpose of the leat is to compensate for the loss of hydrological catchment and maintain a source of water supply to the downgradient heathland that would otherwise have been intercepted by the permitted extraction area and the now proposed extension.
- 9.127 No diverts or alterations of the leat are required or will take place for the proposed extension. The leat will continue to function in its current location and form. The leat has been shown to perform well since its construction and meets the design principles set out in the mitigation scheme. The leat is routinely inspected, managed and maintained and is inspected after every large storm event.

Restoration

- 9.128 As part of the ROMP review, a comprehensive restoration scheme was approved for the quarry workings, based on earlier reviews undertaken in 2012 and 2014. The restoration of the proposed

extension area would be integrated into the wider restoration scheme at Penrhyn Quarry and will employ the principles adopted as part of the restoration works.

- 9.129 The aim of the restoration programme at Penrhyn Quarry and proposed extension area is to encourage the natural process of regeneration in reinstated land affected by quarrying activity. Many areas of the quarry have regenerated naturally. These areas are considered by the applicant as a conservation model to follow and as a precedent for the restoration and management for the rest of the quarry.
- 9.130 Sections of the landholding are subject to agricultural tenancies, including wetland and heathland, untouched by quarry working and regularly inspected to maintain their conservation value.

HYDROGEOLOGICAL IMPACT ASSESSMENT

Assessment Methodology

- 9.131 A hydrogeological impact assessment (HIA) for the Proposed Development has been carried out following a Source-Pathway-Receptor (S-P-R) approach described in GL III [Ref.2] and the general principles described in the Environment Agency's H1 Environmental Risk Assessment framework – Annex J (Groundwater) [Ref.11]. It is acknowledged that the Environment Agency's H1 Environmental Risk Assessment has been withdrawn; however, the basis of the guidance remains suitable and continues to be widely used.
- 9.132 The basis of the impact assessment method is the selection of an appropriate level of detail for the assessment. Ref.11 proposes three levels of detail or Tiers, from Tier 1 to Tier 3, where Tier 1 is qualitative, and Tier 3 is highly quantitative. The selection of the appropriate tier requires an iterative approach based on an initial assessment and consideration of the outcome using a Tier 1 system. If that approach shows that the system is too complex or outcomes cannot be fully mitigated, then a more detailed or quantitative approach would be warranted.
- 9.133 The operation of the proposed extension will be directly analogous to the slate working practices at the quarry which have been in operation for many years. Therefore, a Tier 1 assessment is considered to be appropriate..
- 9.134 The assessment method, scoring and risk calculation is presented in **Appendix 9/2**.

Hazard Identification

- 9.135 The hazards associated with the operation and restoration of the Proposed Development identified within this Risk Assessment are:
- Plant and vehicle fuels or lubrication spills;
 - Slate reject tipping's;
 - Discharge of polluted water / increase in discharge volume;

- Dewatering;
- Soil Movement.

9.136 The sources involved within these hazards are from on-site quarrying activities, including:

- Hydrocarbons & additives;
- Flushing of fines / oxides during rainfall events;
- Quarry runoff / trade effluent / sewage effluent (including on site water management);
- Shallow and deep groundwater;
- Flushing of soils during rainfall events;
- Surface water.

Receptor and Pathway Identification

9.137 The data review has identified sensitive receptors that may be impacted by the proposed extension. Pathways between the identified receptors and sources have been reviewed and those receptors with a pathway to at least some are:

- Afon Ogwen (Upper) running upstream of the quarry;
- Afon Ogwen (Lower) running adjacent and downstream of the quarry;
- Gwaen Gynfi Heathland located downstream of the permitted extension and realignment area;
- Galedffrwd Watercourse located downstream of Gwaen Gynfi Heathland and the main quarry;
- Afon Caseg located to the east of the quarry;
- Groundwater that may be present in the Superficial Deposits;
- The Bronllwyd Grit Formation Secondary A aquifer;
- The Padarn Tuff Formation Secondary A aquifer;
- The Llanberis Slate Formation Secondary B aquifer.

9.138 Table A in **Appendix 9/3** presents the source-pathway-receptor linkage for the hazards/sources during operation and restoration. This identifies the potential linkages (pathways) between the sources within the proposed extension and sensitive receptors.

Risk Assessment

9.139 The risk assessment has been carried out based on the identified hazards in accordance with the methodology presented in **Appendix 9/2**. A summary is presented in Table A in **Appendix 9/4** and discussed in the subsections below.

Receptor sensitivity

9.140 Receptor sensitivity has been assigned in accordance with Table A in **Appendix 9/2**.

9.141 The Afon Ogwen is a main river with a designated ecological and chemical status and has been assessed as having a high sensitivity. The most significant receptor is Gwaen Gynfi heathland that is a component of the Snowdonia Special Area of Conservation (SAC) which has been given a very high sensitivity.

9.142 The groundwater component of the Llanberis Slate Formation at the quarry is considered minimal and as these strata are designated as a Secondary B aquifer, they have been given a low sensitivity. Water bearing strata within the Bronllwyd Grit Formation and the Padarn Tuff Formation are designated as Secondary A aquifers and are considered to have a medium sensitivity.

Magnitude of impact

9.143 The magnitude of impact has been assigned with reference to Table B in Appendix B. Given the scale and longevity of the quarrying activities it is considered likely that potential impacts are likely to have already manifested. However, consideration has been given for the potential for further impacts to manifest given the current nature of the receptor.

9.144 In general, the magnitude of impact from quarrying activities for the groundwater system including the Superficial Deposits; the Bronllwyd Grit Formation; the Padarn Tuff Formation and the Llanberis Slate Formation is considered to be medium to very low. The magnitude of impact to the Afon Ogwen and Gwaen Gynfi heathland is considered to be high.

Potential significance of effect

9.145 A potential significance of effect has been calculated from the receptor sensitivity and magnitude of impact described above. It follows that the potential significance of effect to the Afon Ogwen and Gwaen Gynfi heathland are moderate to major.

9.146 In general, there is a negligible significance of impact for the Superficial Deposits; the Bronllwyd Grit Formation; the Padarn Tuff Formation and the Llanberis Slate Formation.

Likelihood of occurrence with mitigation

9.147 The likelihood of occurrence is applied to the potential significance of effect to determine the potential risk to the identified features. The likelihood of occurrence has been assigned with

reference to Table D in **Appendix 9/2** and includes the built in mitigation which forms part of the proposed extension.

- 9.148 A summary of the likelihood of occurrence to receptors with embedded mitigation is provided in Table 9-8.

Table 9-6
Summary of the likelihood of occurrence

Hazard	Receptor	Likelihood of Occurrence
Plant and vehicle fuels and lubricants	All	Very Unlikely
Slate Reject tipping's	All	Very Unlikely
Discharge of polluted water / increase in water discharge	All	Unlikely
Dewatering	SW; Afon Ogwen (Lower), GW; Bronllwyd Grit Formation; GW; Padarn Tuff Formation; GW; Llanberis Slate Formation	Very Unlikely
	SW; Gwaen Gynfi Heathland; SW; Galedffrwd Watercourse	Unlikely
	GW; Superficial Deposits	Likely
Soil Movement	SW; Gwaen Gynfi Heathland	Unlikely
	SW; Galedffrwd Watercourse	Very Unlikely

Risk Analysis and Mitigation

- 9.149 A qualitative risk analysis has been carried out in accordance with Table E in **Appendix 9/2**.

Groundwater

- 9.150 The quarry voids at Penrhyn Quarry have been established for many years, if not decades. It is considered that due to the very low permeability of the surrounding strata and the length of time the voids have been open and worked that groundwater levels within the environs of the quarry have reached a pseudo equilibrium. Therefore, any groundwater impacts brought about by the quarry operations would have already manifested.
- 9.151 The Llanberis Slate at the quarry location is void of water bearing sandstone horizons and is essentially a non-aquifer, incapable of sustaining a reliable water supply. Hydraulic conductivity is low with flow restricted to fissures that have developed largely in association with the northeast – southwest trending cleavage. However, it is still important to review protected abstraction rights.

- 9.152 The expansion of slate extraction into the permitted extraction area and proposed extension will result in drainage of water into the void from a slightly larger area. The expansion has the potential to lower the water table in the vicinity of the quarry and therefore there is the potential to derogate users of any existing groundwater usage. However, given the nature of the slate, it is considered that any lowering of the water table will be limited to the immediate environs of the quarry and will not affect abstraction rights or groundwater usage.
- 9.153 The removal of the superficial deposits within the permitted extraction area and proposed extension has the potential to impact on the shallow groundwater system associated with the shallow deposits; however, the groundwater throughflow for these deposits is considered to be minimal and isolated. Therefore, the impact to the shallow groundwater system is also considered to be minimal.
- 9.154 Given the above, and other quarry operation mitigation measures, i.e., conforming to environmental best practice standards, bunded areas for fuel and oil stores, hardstanding areas for plant maintenance, regularly maintained and serviced treatment works along with the considered placement of recent and new tipping's and controlled runoff, the residual risk of impact to groundwater systems after mitigation is not considered to be significant..

Surface Water

- 9.155 As highlighted above and in previous sections, the quarrying operations at Penrhyn Quarry have been established for decades. With the exception of some of the historic and established slate reject tips, the runoff generated in and at the quarry is routed to the old quarry void water body which provides a significant dilution / settlement factor before discharging to the Afon Ogwen via George Adit. Therefore, due to the length of time that this operation has been established, it is considered that any impacts brought about by the quarry operations would have already manifested and no long standing issues have been raised in relation to the quarry discharge.
- 9.156 Sewage effluent is treated via a package treatment plant that is regularly maintained and serviced before discharging to old quarry void water body.
- 9.157 Three current licensed surface water abstraction licences have been identified (Table 5). One of these belongs to the quarry. The two reservoir abstractions from Marchlyn Mawr and Marchlyn Bach are located up-catchment from the quarry meaning that quarry operations do not have the potential to impact upon these protected rights.
- 9.158 Four registered private water supplies have been identified (Table 6). Given their distance away from the proposed extension the quarry operations do not have the potential to impact upon these abstractions.
- 9.159 The proposed extension of the main quarry void could mean increased risk of increased sediment volumes. However, given the means by which water is captured by the main quarry void and transferred to the old quarry void water body, it is considered that there is no risk to the water body and in turn, the Afon Ogwen from increased sediment volumes.

- 9.160 Without mitigation measures, the permitted extraction area and proposed extension would have an impact on the surface water system that feeds into the heathland that forms part of Gwaen Gynfi. Mitigation measures were agreed in the 2000 planning permission and subsequently amended as outlined in Envireau Water 2011 report [Ref. 1] and 2012 supplementary report [Ref. 12] to address the potential impact of the permitted extraction area.
- 9.161 The leat installed provides the approved mitigation measures. These mitigation measures are considered appropriate, have performed well to date meeting the permitted mitigation scheme requirements and will continue to be used for the proposed extension.
- 9.162 There is no proposal to re-direct groundwater flow, just surface runoff water. As described in previous sections rainfall is very high with intense storms and the area is dominated by surface water flow and shallow rapid interflow. Groundwater, if present, forms a tiny proportion of flow in the area.
- 9.163 A maintenance plan is in place for the leat drainage works including regular visual assessments and the current leat is well established and been subjected to various seasonal weather conditions. The visual assessment looks for signs of scour or uncontrolled overspill areas particularly during and / or following storm events and if necessary, provide remediation works to reinforce areas of scour or weakness.
- 9.164 The attenuation ponds and recharge / overspill section of the leat are areas where the velocity of water is slowed and therefore there is the potential for any sediment carried in suspension to drop out. Therefore, the maintenance plan includes visual assessment of the condition of the ponds and recharge / overspill section of leat, and any build-up of sediment removed as and when necessary, in order to maintain the functionality.
- 9.165 Overburden stripping of the proposed extension will be carried out according to best practice and giving consideration to minimising soil mobilisation. The leat drainage will act as a buffer for soil mobilisation and the leat drainage management plan will keep the leat free from silts. De-silting of the leat will be undertaken in a manner as to avoid the off-site mobilisation of the silts.
- 9.166 Given the above, the residual risk of impact to the surrounding watercourses after mitigation is not considered to be significant whilst the residual risk of impact after mitigation for the Gwaen Gynfi heathland is considered to be low and therefore not significant.

Fuels and Oils

- 9.167 The applicant operates an Integrated Management System encompassing quality (ISO 9001:2008); Environment (ISO 14001:2004) and Health and Safety (BS OHSAS 18001:2007) which is accredited and certified by the British Standards Institute (BSI). BSI inspections are conducted every 6 months to maintain certification.
- 9.168 The storage of oils, fuels, lubricants, and chemicals are all contained within impervious bunds to a capacity of at least 110% of the tank capacity in order to contain any spillage in the unlikely event of the tank walls being breached.

- 9.169 As previously stated, during the operations only vehicles and diggers will be present on site. Good management practice is used to clean up infrequent spills, although no filling of fuel or other lubricants occurs within the working area.
- 9.170 Given the above, the residual risk of impact resultant from plant and vehicle fuels and oils is not considered to be significant.

FLOOD CONSEQUENCES ASSESSMENT

- 9.171 The potential risk of flooding at and associated with the proposed extension area has been assessed in accordance with guidelines laid out in the Technical Advice Note 15: Development and Flood Risk (TAN15) 2004 [Ref. 5].
- 9.172 The principal objectives of this FCA are to demonstrate that the slate extraction activities within the proposed extension will:
- Result in no net loss of floodplain storage;
 - Not impede water flows; and
 - Not increase the risk of flooding at the quarry or elsewhere.

Flood Zones

- 9.173 An extract of the Development Advice Map (DAM) covering the proposed extension area and wider surrounding area of the quarry is shown on Figure 10.
- 9.174 The proposed extension is located entirely within DAM Zone A, which describes land as 'considered to be at little or no risk of fluvial or tidal/coastal flooding'.

Vulnerability of Development

- 9.175 The proposed slate extraction activities at the extension area are categorised under the TAN15 guidelines as 'Less vulnerable development' and are therefore considered appropriate development type within DAM Zone A.

Existing Flood Risk

Risk of flooding from the sea (tidal)

- 9.176 The proposed extension area and wider quarry area is situated a significant distance inland and not at risk of flooding from the sea. Local watercourses are not tidally influenced.

Risk of flooding from rivers and streams (fluvial)

- 9.177 The proposed extension is situated in a separate hydrological catchment to the Afon Ogwen. The Afon Ogwen is also situated within a steep sided valley, flowing north and away from the quarry. Two further watercourses in the surrounding area; the Afon Caseg and Galedffrwd flow north-westerly and are a significant distance away from the proposed extension.
- 9.178 Smaller watercourses located southwest of the proposed extension, principally the Afon Marchlyn Mawr and Galedffrwd are again situated within a separate hydrological catchment and flow north-westerly away from the proposed extension.
- 9.179 Based on the above, it is considered that the risk of fluvial flooding to the proposed extension is negligible..

Risk of flooding from surface water (pluvial)

- 9.180 Surface water flooding occurs when rainwater does not drain away or soak into the ground but lies on or flows over the ground surface. Areas that are most vulnerable to surface water flooding are low lying areas and developed impermeable sites such as concrete, tarmac or buildings, where runoff can accumulate.
- 9.181 The NRW Risk of Surface Flooding Map (Figure 11) indicates that the proposed extension is at a 'very low' (land that has less than a 1 in 1000 (0.1%) chance of flooding) to 'low' risk from surface water flooding (land that has a chance of flooding between 1 in 1000 (0.1%) and 1 in 100 (1%)).
- 9.182 Penrhyn Quarry and the proposed extension is situated within a rural, upland catchment and as such there are no sewer systems or road drainage in the vicinity that may have otherwise posed a risk of flooding if they were to surcharge during a storm event.
- 9.183 Surface water will be intercepted by the existing interceptor and recharge drainage leat. The leat has been designed to accommodate storm events. The leat acts to slow water down by channelling water across a flat gradient which then allows controlled spills along its length towards the downstream heathland.
- 9.184 Based on the above, the risk of surface water flooding to and from the proposed extension is considered to be very low, provided that surface runoff is continued to be managed appropriately.

Risk of flooding from groundwater

- 9.185 Groundwater flooding is the emergence of groundwater at the ground surface. Groundwater flooding occurs in response to a combination of already high groundwater levels (usually during mid or late winter) and intense or unusually lengthy storm events. Groundwater issues are often slow, prolonged, and very localised.
- 9.186 Penrhyn Quarry and the proposed extension are situated in an elevated position relative to the surrounding landscape. The underlying strata are poorly permeable aquifers which convey water

through joints and cleavage fractures whilst the groundwater in the overlying drift deposits is generally within a few metres of the surface in isolated lenses or pockets.

- 9.187 Given the nature of the geology and the elevation of the proposed extension, the risk of groundwater flooding is considered negligible.

Risk of flooding from reservoirs

- 9.188 Marchlyn Mawr and Marchlyn Bach reservoirs exist up gradient of Penrhyn Quarry. Natural Resources Wales’s Risk of Reservoir Failure map [Ref.13] shows that there is a residual risk of flooding to the western portion of the proposed extension from Marchlyn Mawr Reservoir in the event of a structural failure or breach. However, reservoir flooding is extremely unlikely to happen. There has been no loss of life in the UK from reservoir flooding since 1925. All large reservoirs must be inspected and supervised by reservoir panel engineers and therefore the risk of failure or breach is very low.

Summary of Potential Flood Risk

- 9.189 A summary of the potential flood risks to the proposed extension area assessed in the previous sections is provided in Table 9-9.

**Table 9-9
Flood Risk**

Flood Source	Potential Risk				
	No Risk	Very Low	Low	Medium	High
Tidal	X				
Fluvial	X				
Pluvial		X			
Groundwater		X			
Reservoirs		X			

- 9.190 This FCA demonstrates that the proposed extension will not reduce existing floodplain storage; will not impede surface water or flood flows beyond the current scenario; and will not increase the risk of flooding at the proposed extension or elsewhere.

CONCLUSIONS

- 9.191 This assessment has defined the current conditions at and in the vicinity of Penrhyn Quarry relating to aspects of water and its management and the proposed extension.

- 9.192 The quarry including the proposed extension is underlain by Cambrian age strata predominantly comprising Llanberis Slate. The faulting, jointing; fracturing and cleavage planes in Slate affords it a secondary permeability. On the quarry scale, this secondary permeability is of limited significance. The Llanberis Slate Formation at the quarry is designated by the Environment Agency / Natural Resource Wales as a Secondary B aquifer.
- 9.193 In the vicinity of the quarry, scree and thin soil cover dominates the upper slopes but the lower slopes, including the proposed extension are covered with superficial deposits. The superficial deposits comprise a mixed sequence of clay or silt bound sands, outwash gravels, boulder clay (till) and peat deposits.
- 9.194 The distribution of water in the superficial deposits has been shown to be irregular, with both vertical and lateral movement inhibited by the presence of low permeability clays. Water flow through the bulk of the superficial deposits is very low; similar to that of the underlying geology. The coarser materials such as sands and clay bound gravels contain water that provide groundwater throughflow within the superficial deposits providing shallow and narrow groundwater pathways potentially of limited spatial extent.
- 9.195 The existing water management system at Penrhyn Quarry utilises a combination of drainage channels, open channels, pumped drainage, and surface water attenuation areas along with settlement lagoons. From a drainage perspective, the quarry can be split into the main quarry void; the processing area; the quarry haul road; the spoil tips; and the old quarry void. With the exception of parts of the spoil tips, the water within the quarry is directed to the old quarry void water body before being discharged to the Afon Ogwen. The Old quarry void water body provides a significant amount of dilution, storage, and settlement.
- 9.196 In November 2014, a new interceptor and recharge leat was completed for the westward expansion of the quarry. The leat is positioned to intercept and convey surface drainage water from up-slope of the permitted extraction area to the downgradient heathland which forms part of Gwaen Gynfi. The primary purpose of the leat is to compensate for the loss of hydrological catchment and maintain a source of water to the downgradient heathland. The proposed extension will not change or divert the existing leat allowing the compensation to continue.
- 9.197 There is no mains foul sewer associated with the Penrhyn Quarry. Foul sewage is managed by way of a package treatment plant that has been sized to accommodate the number of personnel at the quarry. The package treatment plant condition and functionality are checked on a regular basis and maintained and serviced as and when required.
- 9.198 The quarry is considered not to be at 'high' risk from either fluvial or pluvial flooding and is not located in designated flood risk zones. Water and surface runoff within the quarry is managed in a manner that provides a significant amount of storm runoff attenuation. Flood risk will not be increased as a result of the proposed extension. Therefore, the quarry water management will not increase the flood risk elsewhere and provides a betterment to flood risk downstream.
- 9.199 This assessment has identified and evaluated any impacts due to the current quarry footprint, including those of the proposed extension. With the exception of Gwaen Gynfi heathland where the residual risk of impact is considered to be low, the general residual risk of impact to surface

and groundwater features is considered to be none to very low, provided mitigation measures are in place and monitored; assessed and adjusted, if required. Although a residual risk is present, this is not considered to be significant.

References

- Ref.1 Planning Policy Wales. Technical Advice Note (TAN) 15: Development and flood risk dated July 2004
- Ref.2 Groundwater Protection: Principles and Practice (GP3), Version 1.1, Environment Agency, August 2013.
- Ref.3 Green Leaves III - Guidelines for Environmental Risk Assessment and Management: Green Leaves III. Revised Departmental Guidance Prepared by Defra and the Collaborative Centre of Excellence in Understanding and Managing Natural and Environmental Risks, Cranfield University November, 2011.
- Ref.4 Envireau Water (May 2015) Review of Old Mineral Permissions at Penrhyn Quarry, Bethesda, Gwynedd: Hydrogeology, Hydrology, Water Quality, Drainage and Flood Risk.
- Ref.5 Soilscales [Cranfield University] (2017). Cranfield Soil and Agrifood Institute. Retrieved from <http://www.landis.org.uk/soilscales>
- Ref.6 Flood Estimation Handbook obtained from <https://fehweb.ceh.ac.uk/>
- Ref.7 Steve Bennett Groundwater Consultant, (1996), Hydrological & Hydrogeological Investigations. Proposed Extension of Penrhyn Quarry.
- Ref.8 Natural Resource Wales. Geo-portal <http://lle.gov.wales/home> Accessed in June 2019.
- Ref.9 Natural Resource Wales (2009) Western Wales River Basin District River Basin Management Plan; & (2015) Western Wales River Basin Management Plan 2015-2021 Summary.
- Ref.10 H1 Environmental Risk Assessment framework – Annex J (Groundwater), Environment Agency, 2010.
- Ref.11 Envireau Water (Nov. 2011). Hydrology, Hydrogeology, Water Quality & Flood Risk. Proposed realignment of quarry workings at Penrhyn Quarry, Bethesda in order to optimise recovery of high quality slate and subsequent restoration.
- Ref.12 Envireau Water (Sept. 2012). Supplementary information relating to mitigation leat design. Proposed realignment of quarry workings at Penrhyn Quarry, Bethesda in order to optimise recovery of high quality slate and subsequent restoration.
- Ref.13 Natural Resources Wales's Risk of Reservoir Failure Map