GWYNDY QUARRY HYDROGEOLOGICAL ASSESSMENT

PREPARED FOR HOGAN GROUP

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QUALITY CONTROL

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Gwyndy Quarry hydrogeological assessment

EXECUTIVE SUMMARY

Background

Hogan Group commissioned Hydrotechnica Ltd to investigate the hydrogeology of Gwyndy Quarry and assess the potential impacts of deepening the quarry on surrounding water resources. For the purpose of this assessment, the quarry will be deepened by two benches (30 m) and extend laterally to the extraction limit.

Following a site visit and initial data review by Hydrotechnica, Hogan Group installed a flow meter on the quarry discharge line and commissioned a drilling contractor to install groundwater monitoring boreholes. Hydrotechnica subsequently advised on groundwater monitoring and visited Gwyndy to collect water quality samples and undertake hydraulic tests in the monitoring boreholes.

In addition to information collected on site, Hydrotechnica obtained local rainfall records, reviewed regional borehole logs and geological mapping available through the British Geological Survey and contacted Anglesey Council for records of private groundwater supplies.

Methodology

The initial aim was to achieve confidence in the quarry water balance with the objectives of: 1) calculating hydraulic conductivity, a measure of ground permeability, and 2) quantifying surface water contributions to quarry discharge. Calculations are presented in two stages, initially to develop a reliable value of hydraulic conductivity and secondly to determine future impacts.

Hydraulic conductivity, the key parameter to be applied in the prediction of future impacts, was calculated in two different ways: using a quarry water balance to estimate groundwater inflows to the quarry and direct measurements in boreholes. Knowledge of both the quarry discharge and surrounding groundwater levels helped constrain the value of hydraulic conductivity adopted for future predictions.

With confidence in hydraulic conductivity (and therefore groundwater inflows), the contribution from surface water originating from outside of the quarry void was estimated for wet periods.

The findings from the water balance, site visits and other available information is summarised in a hydrogeological conceptual model. The conceptual model describes our understanding the hydrogeology of the quarry and surrounding area and lays the platform for the assessment of potential impacts.

Impact assessment

The main potential impacts are described as follows:

- Future groundwater inflows;
- water table drawdown (in the context of nearby water users);
- change to water quality; and,
- the period of quarry closure, e.g. the time required for lake formation.

Groundwater inflows. Groundwater inflow to the current quarry void is estimated at approximately 100 m^3/day. Future inflows are predicted to rise to approximately 200 m^3/day, which for context represents less than 0.2% of rainfall within the Afon Crigyll catchment that contains Gwyndy Quarry. In the absence of evaporation, all groundwater inflows would be discharged to a local field drain. Therefore, the value of 0.2% may be considered a worst case impact on water resources, one that may only occur during the summer when evaporation from the quarry floor removes inflowing groundwater before it can be discharged. Throughout the majority of the year water flowing into the quarry is discharged into a drain that feeds eventually into the Afon Crigyll, therefore, reducing the impact on catchment scale water resources close to zero.

Water table drawdown in response to quarry dewatering has the potential to reduce water availability to other groundwater users within the 'area of influence'.

Hydrotechnica undertook an assessment of future water table drawdown (the area of influence). An analytical model indicates that, in a worst-case scenario, there could be 1 m drawdown at a distance of 1,000 m from the quarry (in the SW-NE direction of geological strike). Field data indicates considerably less drawdown in the NW-SE direction.

Details of private water supplies within 2 km of Gwyndy Quarry were provided by Anglesey Council (three boreholes and seven wells). Three of the seven wells are identified within the area of potential influence. A combination of the records received and inquiries at the relevant properties show that the three boreholes and three wells considered potentially at risk are no longer in use.

Water quality. The quality of water sampled from the three groundwater observation boreholes, which all extend below the future quarry floor is generally good. All water is 'fresh', i.e. salinity < 1,000 mg/L. One borehole, (BH1), which penetrates a sedimentary rock west of the quarry contains water high in dissolved iron (1.2 mg/L measured in one sample). It is unlikely that the quarry will extend into these sediments due to the lack of mineral value, meaning that the water with elevated iron concentrations is unlikely to flow into the quarry. However, should the sediments contribute water to the future quarry void, water balance analysis indicates typical dilution from rainfall between 3:1 and 10: during dry and wet weeks respectively. Even if the sediments contributed all of the groundwater entering the quarry void, dilution of this scale would lower the concentration close to or below the drinking water standard of 0.2 mg/L. Further sampling of BH1 is recommended.

Closure. A closure water balance model was developed to predict the recovery of the water levels within the quarry void. The model, which was based on average climatic conditions and required assumptions regarding future climate conditions, the groundwater flow system and surface water catchment, predicts at least 36 years for the formation of a quarry lake to pre-existing groundwater levels. A longer time frame is considered likely.

Water level recovery is not linear, the steeper the hydraulic gradient towards the quarry, the faster a lake will form. Water level recovery will, therefore, be greatest in early years. For example, depending on hydraulic and climatic variables, between 15 and 30 m of water level recovery is predicted within the first 10 years.

1 INTRODUCTION

1.1 Background

The granite resource at Gwyndy Quarry extends below the current floor level which is approximately 20 m Above Ordnance Datum (AOD), (c. 40 m Below Ground Level (BGL), at its deepest point. As part of preparations for a planning application, Hogan Group commissioned Hydrotechnica Ltd to investigate the hydrogeology of the site and identify the potential impacts of deepening the quarry on surrounding water resources.

1.2 Scope

Commissioned initially in September2021, Hydrotechnica undertook a review of quarry hydrology. Further to that review, Hogan Group followed recommendations to install groundwater monitoring boreholes and install a flow meter to the quarry discharge.

The hydrogeological assessment presented in this report has been prepared after approximately six-months of monitoring. The objective of the study presented herein is to assess whether deepening the quarry by a further two benches, i.e. a total of 30 m, is feasible with regards to impacts on the local groundwater resources.

1.3 Report structure

The report is structured as follows:

- Section 2 describes the site setting including an overview of the quarrying operation, an introduction to local hydrology, geology and hydrogeology.
- Section 3 presents a water balance for Gwyndy Quarry in its current extent using discharge measurements from site and publicly available climate data. The findings are used to constrain an analytical model of groundwater flow, estimate hydraulic properties and estimate the quarry surface water catchment.
- Section 4 presents the findings from the site investigation including geological observations, hydraulic tests and water quality results from the three purpose drilled boreholes. The information is summarised in a hydrogeological conceptual model.

- Section 5 assesses the groundwater impacts of an enlarged quarry. Groundwater inflows and water table drawdown are discussed in the context of the conceptual model and nearby groundwater users.
- Section 6 includes the results of a post operational, (closure), water balance. The section estimates the speed at which a quarry lake will form.
- Section 7 presents the summary and conclusions.

2 SITE SETTING

2.1 Location

Gwyndy Quarry is located approximately 10 km from the coast in central Anglesey (central grid reference is 239790E, 379480N). The surrounding land is relatively flat, 55 – 60 m AOD, sloping gently to the southwest towards Rhosneigr.

2.2 Quarry

Gwyndy Quarry, located in Llandrygan, Llannerch-y-medd in central Anglesey, has been operational since 1960. Granite is quarried for a variety of aggregate uses. Annual production is approximately 250,000 tonnes from three active benches. The quarry extends to 20 m AOD, approximately 40 m below the original ground surface. Quarrying is anticipated to progress in the future at similar rates.

Rainfall and seepage entering the quarry are directed along the eastern side of the quarry to the quarry sump via an internal bunded-ditch. From there water is pumped vertically to the quarry lagoon. Water is discharged from the lagoon to a field drain periodically according to the amount of rainfall.

Water is used within the quarry operation for dust suppression, up to 40,000 litres per day during dry spells, and for washing the stone to be used for surface dressing, off which approximately 2,000 tonnes per year is processed.

2.3 Hydrology

2.3.1 Rainfall

Daily rainfall data are available from three locations (Table 2-1): gauges at two reservoirs (Llyn Alaw and Llyn Cefni), and a third at RAF Valley. The record at RAF Valley dates back to 1931, however, Gwyndy is located approximately mid-way between Llyn Alaw and Llyn Cefni, the rainfall records from which are considered more representative of Gwyndy.

Table 2-1. Rain-gauge location details

Gauge Name	Eastings	Northings	Data range	Distance from Gwyndy	Approximate elevation
Llyn Alaw	237583	385286	2005 -	6.3 km NW	49 m AOD
Llyn Cefni	244490	377120	2005 -	5.3 km E	33 m AOD
RAF Valley	230800	375800	1931 -	9.5 km SW	10 m AOD

2.3.2 Evaporation and effective rainfall

Water is lost from the land-surface by direct evaporation and indirectly via the transpiration of plants and trees, the combination of which is referred to as evapo-transpiration. Evaporation and transpiration are difficult to calculate and even more difficult to measure. Evaporation is influenced by climatic factors, principally temperature (of the ground and air), and wind and evaporation and transpiration by the type of vegetation.

Daily historical calculations of potential evapo-transpiration (PET) are available for the area around Gwyndy from the period 1961-2017 (CHESS[1]). Annual PET data are summarised along with the long-term rainfall record from RAF valley in Table 2-2. Evaporation from open water differs from PET, historically factors have been applied to convert calculated PET to open water evaporation. The factors tend to vary between 1.25 and 1.5, i.e. open water evaporation is up to 1.5 times more than calculated PET[2]. Although a range of factors impact on the reliability of evaporation data, it is a very important component of water balances, exceeding rainfall in summer months, and as such has been applied in this study.

Data from the long-term record at RAF Valley and CHESS are summarised in Table 2-2, and illustrated in Figure 2-1. In summer months potential evaporation exceeds rainfall and the 'effective' rainfall, (rainfall less actual evaporation), is zero. Annual evaporation varies less than annual rainfall and in very dry years annual evaporation is similar to rainfall. In average years rainfall exceeds evaporation by approximately 0.34 m, this is important as it demonstrates that Gwyndy is a 'water-positive' site.

[1] Robinson, E.L.; Blyth, E.M.; Clark, D.B.; Comyn-Platt, E.; Rudd, A.C. (2020). Climate hydrology and ecology research support system potential evapotranspiration dataset for Great Britain (1961-2017) [CHESS-PE]. NERC Environmental Information Data Centre.

[2] Finch, J.W. and Hall, R.L. 2001. Estimation of Open Water Evaporation A Review of Methods R&D Technical Report W6-043/TR. ISBN: 1 85705 604 3

Table 2-2. Summary of long-term rainfall and PET

	Rainfall at RAF Valley (mm)	PET (mm)
Long-term minimum	592.2	459.9
Long-term mean	853.9	513.5
Long-term maximum	1208.8	590.9

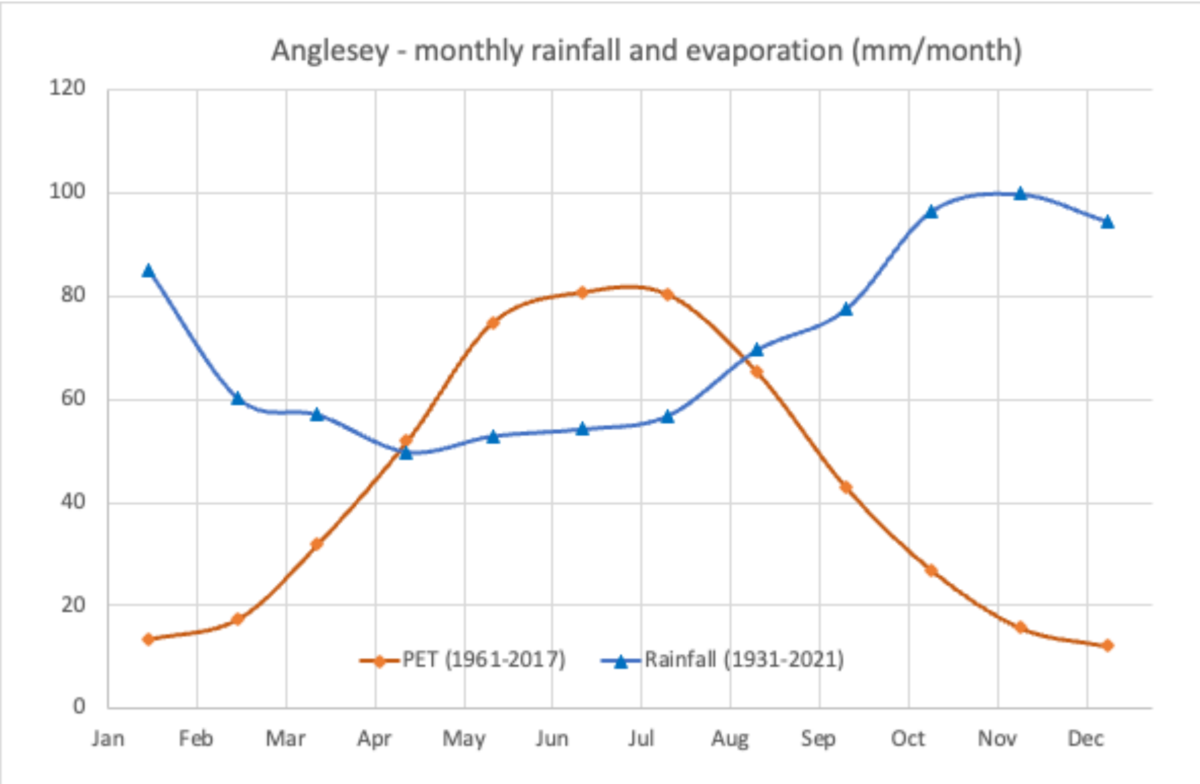


Figure 2-1. Long-term monthly rainfall potential evapotranspiration

In general, terms effective rainfall partitions between overland flow and groundwater recharge, the relative proportions of each are influenced by the slope gradient, soil type and the antecedent conditions.

2.3.3 Drainage and site discharge

Gwyndy Quarry is situated within the catchment of the Afon Caradog, which flows into Afon Crigyll, which in turn discharges to the sea at Rhosneigr (Figure 2-2).

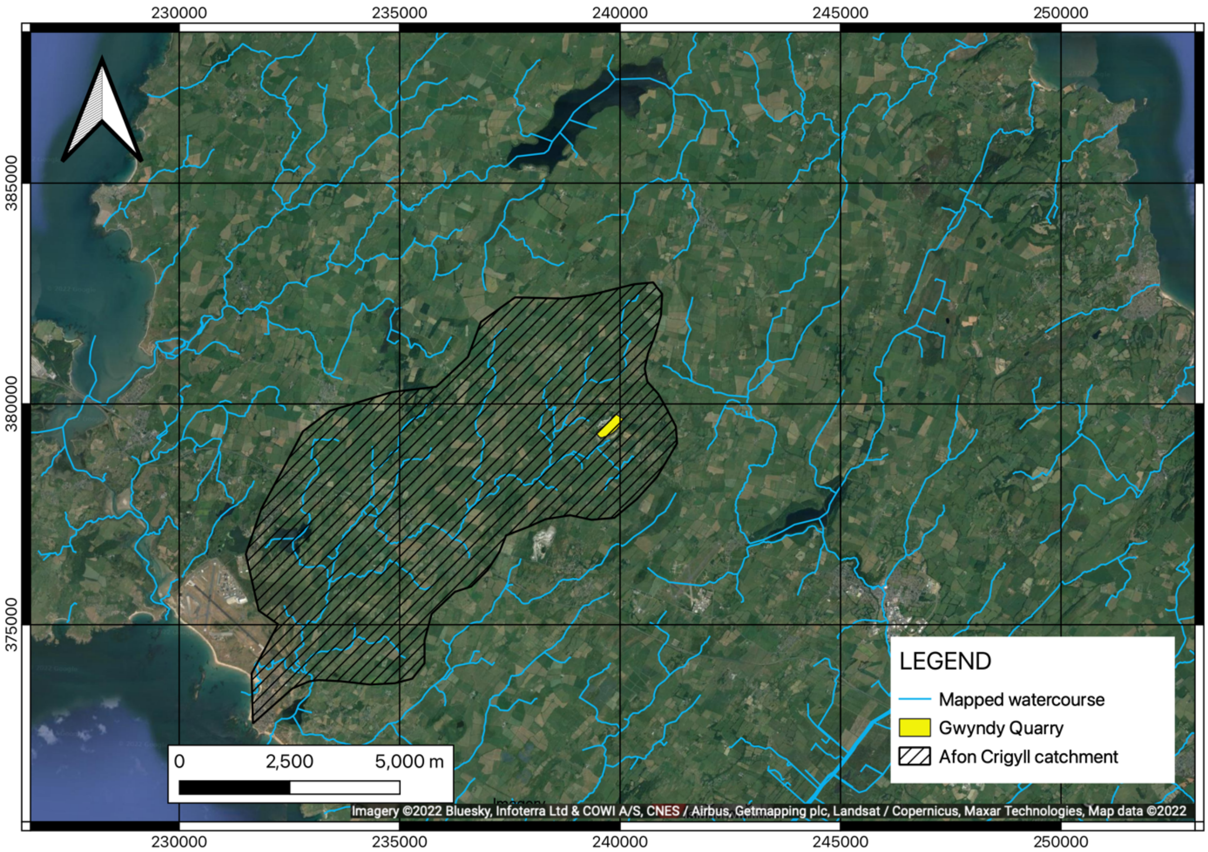


Figure 2-2. Gwyndy quarry in the Afon Crigyll catchment

An unnamed drainage channel flows along the eastern boundary of Gwyndy Quarry. The channel is less than 1 m in width and appears man-made for the purpose of accepting quarry discharge and/or field drainage. The channel originates close to the north-eastern boundary of the quarry and the quarry discharge lagoon. The channel was observed 'dry' on the 21 July 2022, following two weeks of very little rain. The observation suggests flow in the channel is not sustained by groundwater (during the summer months, at least).

Water is discharged, consented reference CG0387601, after first collecting in the quarry sump and then passing through the discharge lagoon (Figure 2-3). Discharges have been measured since March 2022 on a cumulative flow meter. Figure 2-4 is a graph showing cumulative quarry discharge and the average of rainfall at Llyn Alaw and Llyn Cefni rain gauges.

Figure 2-3. Gwyndy quarry discharge lagoon

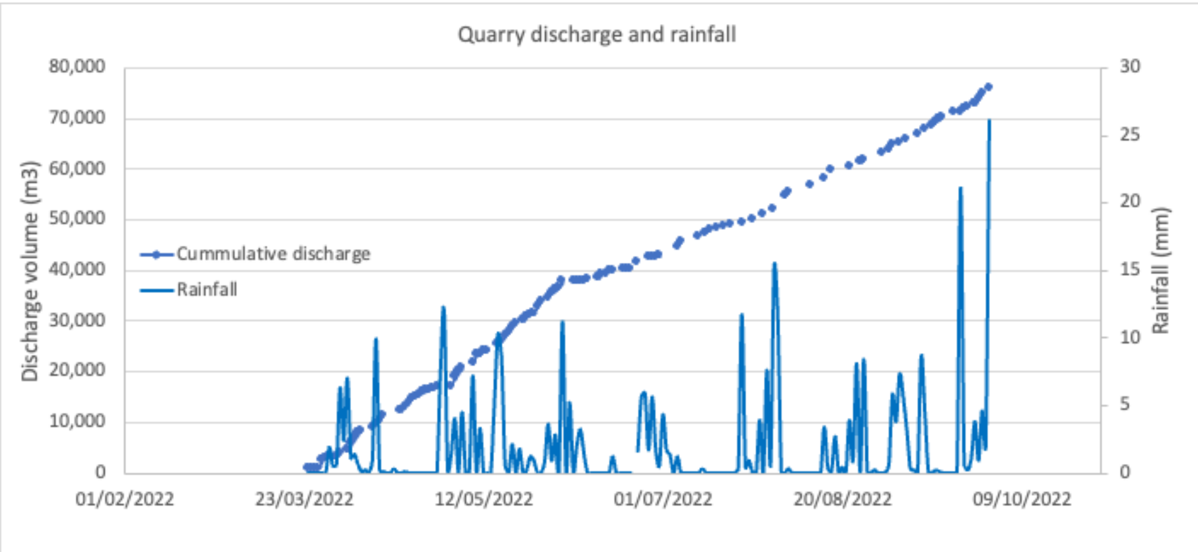


Figure 2-4. Quarry discharge and rainfall (March-September 2022)

Water can be observed seeping through the eastern quarry wall in response to rainfall and following discharge from the quarry. The source of the seepage is almost certainly the surface drainage channel meaning that a certain amount of water discharged is circulating back to the quarry (refer to the water balance in Section 3 for more information).

2.4 Geology

Thin till, (a clay-rich glacial deposit), covers much of Anglesey. Although till has not been mapped by the British Geological Survey at Gwyndy, borehole drilling proved the presence of till-like deposits (clay, silts and gravels).

The stone extracted by the Hogan Group at Gwyndy quarry is granite of the Coedana Complex, (541 – 635 million years old). The granite has locally metamorphosed to hornfels, also part of the Coedana Complex. The granite outcrop is approximately 2 km wide and trends SW-NE, spanning most of the Isle of Anglesey. Gywndy quarry is located approximately 500 m from the western contact between the granite and gneiss also of the Coedana Complex and 1.5 km from the metamorphic rocks of the Central Anglesey Shear Zone to the east.

2.5 Hydrogeology

Both the superficial glacial till and the underlying granite are capable of producing minor quantities of water.

Glacial till was proved by drilling at Gwyndy (Section 4.2), it is variable in nature, from silty gravel to clay. The water table typically sits within the glacial till within a few metres of ground level. Glacial till is typically considered a low productivity 'non-aquifer', although locally water may be encountered in sufficient quantities for domestic supplies where the till contains high proportions of sand and gravel and relatively little clay. Lateral variations in the till from clay dominated to sandier deposits mean that localised aquifer are generally discontinuous.

Local wells are recorded by Anglesey Council (**Appendix A**), presumably these targeted water near the base of the glacial till.

Evidence from drilling at Gwyndy (Section 4.2) suggests that water in the superficial deposits is likely to be in continuity with the underlying weathered granite.

The weathered zone of the granite can vary from approximately 2 – 10 m or more where intensely fractured. Below the weathered zone the granite contains minor quantifies of water in fractures, as evidenced by the virtual absence of water strikes in fresh granite during drilling and limited seepages around the quarry (with the notable exception of the east wall (Section 4.1)). There is, however, evidence from the quarry walls, that the fresh granite is not homogenous: granite hardness and fracturing change from east to west across strike. For example, a seepage is visible in a weaker section of granite in the south wall, close to the contact with hard 'blue' granite, (Section 4.1).

The British Geological Survey classify the granite of the Coedana Complex as a 'low productivity aquifer', through which flow is virtually all through fractures and other discontinuities. The aquifer is summarised as "*highly indurated rocks with limited groundwater in near surface weathered zone and secondary fractures*[3]".

[3] https://mangomap.com/land-information/maps/54498/groundwater-productivity-uk#

3 WATER BALANCE ANALSIS

This section of the report uses water balance methods to analyse the water discharge data, and then apply the results. The water balance is used to:

- Calculate the amount of groundwater flowing into Gwyndy Quarry using 'dry weather' discharges and estimate a bulk permeability (hydraulic conductivity); and,
- calculate the amount of effective rainfall and estimate a surface water catchment for the quarry.

The bulk hydraulic conductivity and surface water catchment area are then used in Section 5 (dewatering assessment), and Section 6 (closure assessment).

3.1 Dry period water balance and groundwater inflows

3.1.1 Water balance analysis

A simple quarry water balance is structured as follows:

Quarry discharge = Groundwater Inflow + Rainfall – Evaporation - Usage

Assuming minimal or fixed water usage, the equation can be simplified and rearranged:

Equation 1. Water balance equation

Groundwater Inflow = Discharge – Rainfall + Evaporation.

From Equation 1 it follows that when there is no discharge or rainfall, groundwater inflow equals the actual evaporation.

Periods of dry weather between rainfall events are identified in order to reduce the influence of rainfall and better evaluate groundwater contributions. Table 3-1 summarises three dry periods utilised for further analysis, the quarry discharge for the three periods is shown in Figure 3-1.

We can observe from Figure 3-1 that water continues to be discharged from the quarry for several days following rainfall. Eventually, towards the end of prolonged dry periods, very little water is discharged. The decrease in flow indicates the transition from days where discharge is dominated by rainfall to those dominated by groundwater, (or days of no discharge at all).

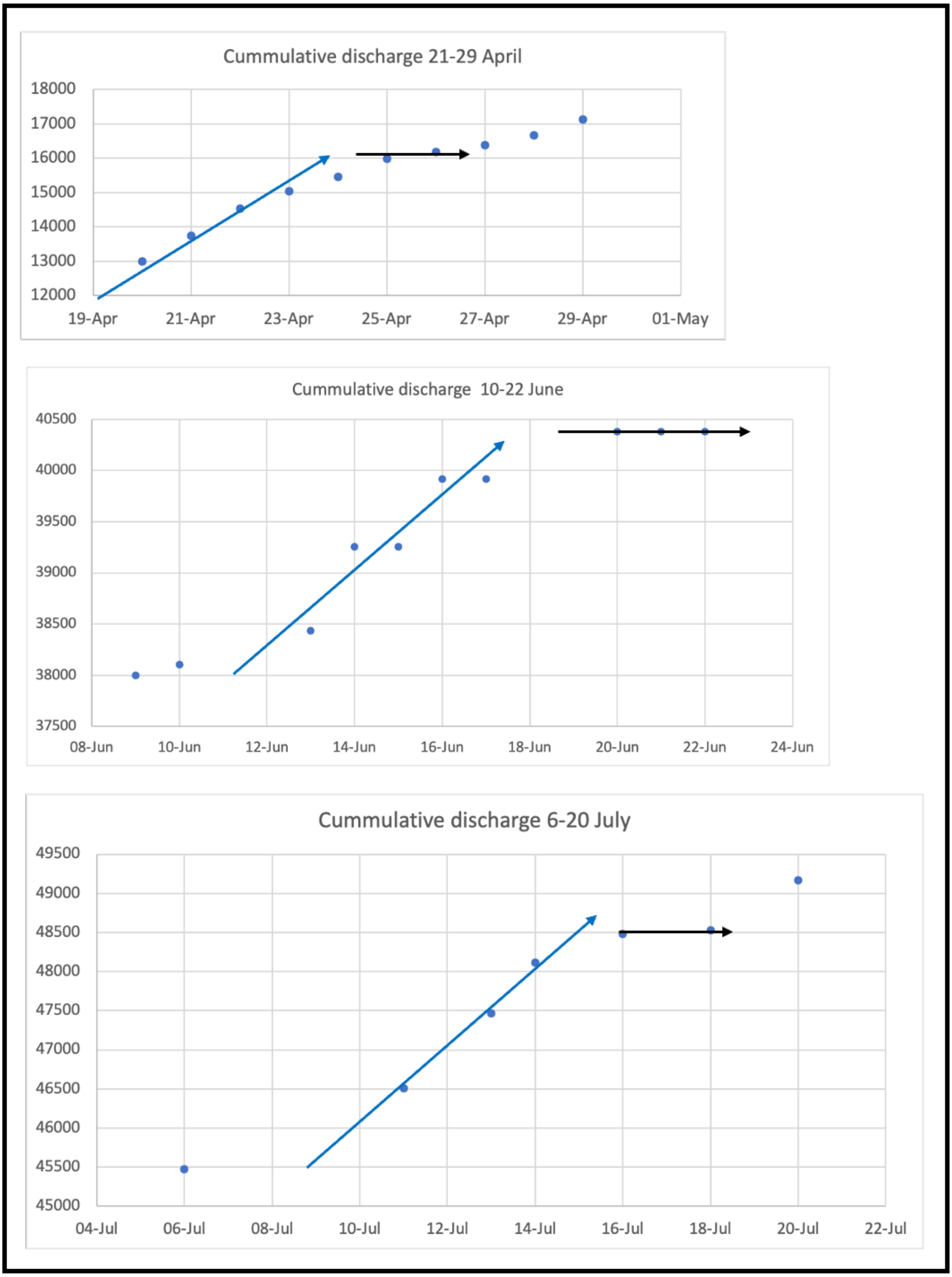


Figure 3-1. Quarry discharge during three dry periods in the summer of 2022

Table 3-1. Dry period water balance summaries – daily groundwater flows highlighted blue

Date range	Whole period or per day	Quarry discharge (m^3)	Rainfall (m^3)	Evaporation, range (m^3)	GW inflow, range (m^3)
First dry period 20 - 29 April					
20-29 April	Whole period	3375	0	1051-21	4426-3396
	Per day	375	0	131-2	553-424
25-27 April	Whole period	402	0	262-5	664-407
	Per day	201		131-2	**332-203**
Second dry period 10 - 23 June					
10-23 June	Whole period	3519	91	2659-55	6087-3482
	Per day	251	7	204-4	468-267
20-22 June	Whole period	0	0	409-8	409-8
	Per day	0	0	204-4	**204-4**
Third dry period 7 - 20 July					
7-20 July	Whole period	3687	23	2756-57	6420-3721
	Per day	263	2	196-4	458-265
16-18 July	Whole period	46	0	393-8	439-54
	Per day	23	0	196-4	**219-27**

The following assumptions apply to the water balance and Table 3-1:

- All water flows are in m^3 water, for evaporation and rainfall the daily values are multiplied by the quarry area.
    - Quarry area assumed to receive rainfall = 76,100 m^2, this equates approximately the area below 35 m AOD.
    - Daily rainfall is an average of rainfall at Llyn Alaw and Llyn Cefni.
    - Daily evaporation is estimated from the CHESS long-term monthly average.
- The calculated groundwater inflow is very sensitive to evaporation. When there is no discharge, the water balance equation assumes that groundwater inflow = evaporation.
- The large range in evaporation and groundwater inflow relates to the surface area applied to calculate evaporation, the larger evaporation (and larger groundwater inflow) results from the full quarry area (76,100 m^2), in reality evaporation will not occur from the full area unless the quarry floor is completely flooded. A lower limit for evaporation was estimated using the areas of open water (equivalent to the internal drainage ditch and quarry sump).

The maximum and minimum value in the range of groundwater inflows are unlikely, the real daily inflow rate is likely to be somewhere in the range, e.g. **50 - 150 m^3/day**. There is further uncertainty related to water used for dust suppression, understood to be a maximum of 50 m^3/day, and recirculation of seepage occurring from the drainage ditch through the east wall.

3.1.2 Estimating hydraulic conductivity from quarry inflows

The groundwater inflows estimated in Section 3.1.1 and the water level data (Section 4) can be used as inputs to a simple equation of groundwater flow to estimate a value of bulk hydraulic conductivity – the main parameter governing groundwater seepage rates.

The Dupuit-Forchheimer equation for flow to a well is used (Equation 2). This type of lumped parameter analysis is subject to a number of simplifications and assumptions. However, where the groundwater flow component and the water table drawdown is known, the formula is well constrained and when the objective is to 'back-calculate' hydraulic conductivity for a long standing / stable quarrying operation, the formula is appropriate.

Equation 2. The basic Dupuit-Forchheimer equation

$$\mathrm{Q} = \frac{\pi \mathrm{K}(h0^2 - Hq^2)}{ln\left(\frac{r_0}{r_q}\right)}$$

Where:

Q = Groundwater inflow (m^3/day - Assumed 50 – 150 m^3/day based on the water balance, and constrained additionally by observed drawdown Figure 3-2.

K = Hydraulic conductivity (m/day) - Estimated by matching inflows and drawdown.

$h0$= height of static water level above base of aquifer - Assumed 35 m, i.e. height of water table above the base of quarry.

hq = height of depressed water level - Assumed 0 m, i.e. the base of the quarry.

r_0 = The radial distance to zero drawdown, also known as the radius of influence (m), which is either calculated or estimated based on available information - Assumed 200 m from the groundwater level profiles shown in Figure 3-2.

r_q = The radius of quarry workings or equivalent radius if not circular (m) - For the current quarry void this is c. 87.8 m.

The equation is well constrained – hydraulic conductivity is the only unknown variable, other variables are either known or well understood. The analytical objective, therefore, is to solve the equation by varying hydraulic conductivity, (while respecting the observed drawdown and the potential range in groundwater flows).

The target groundwater inflow is 50 – 150 m^3/day and the drawdown profile should match approximately with the water levels observed around the quarry.

Two groundwater level profiles, the SW and NW sections, are created by using a combination of the observed groundwater levels and assuming the water table coincides with the 'toe' of each quarry bench. Figure 3-2 compares these groundwater profiles with a series of synthetic (modelled) profiles created using the Theis equation (Theis, 1935)[4] for groundwater flow.

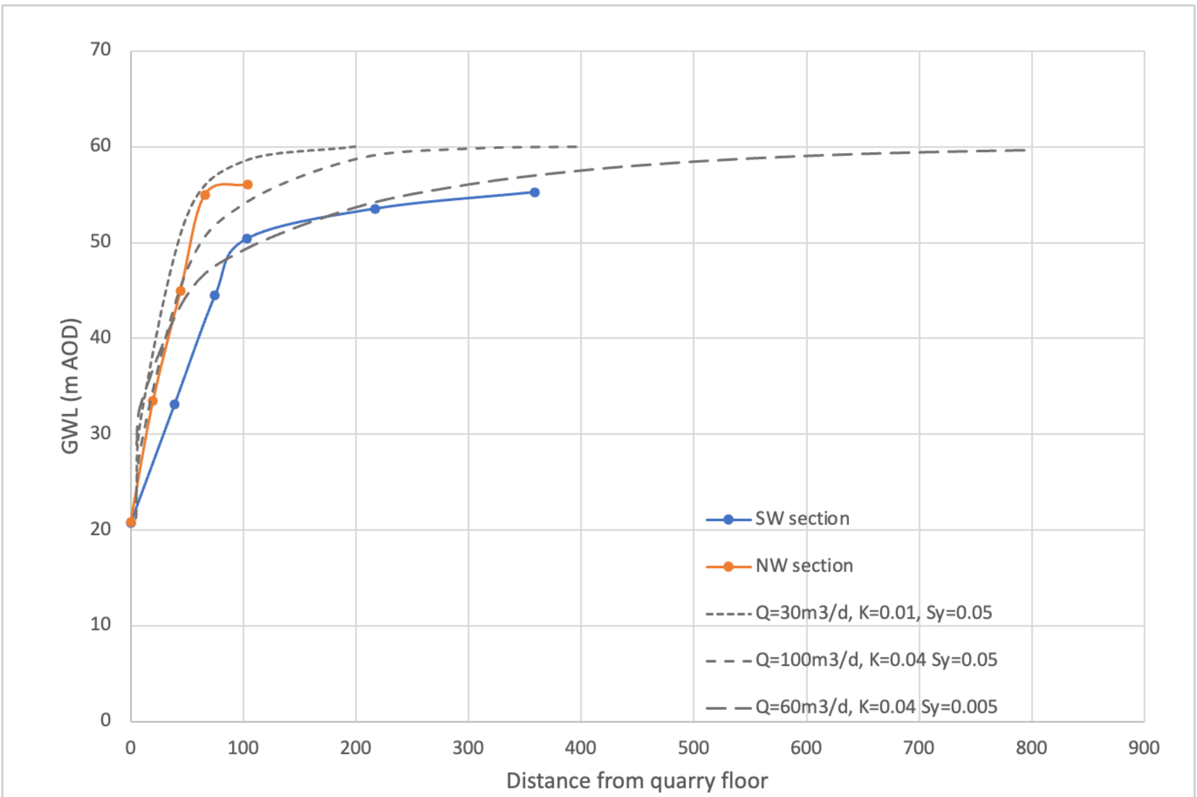


Figure 3-2. Comparison of modelled and actual groundwater levels

[4] Theis, C. V. 1935. The relation between the lowering of the piezometric surface and rate and duration of discharge of a well using groundwater storage. *Transactions of the America Geophysical Union 16, 519-524*

The best fit between the modelled and actual groundwater levels is achieved when the rate of quarry inflow is at the lower end of the likely range, and the hydraulic conductivity is between 0.01 and 0.04 m/day. A specific yield (drainable porosity) of 5% is required to 'fit' the higher flow of 100 m^3/day. Five percent is very high for fractured granite, a more realistic value is 0.5%, suggesting groundwater inflows may be less than 100 m^3/day.

The results of the modelling exercise suggest the following hydraulic properties:

- Hydraulic conductivity (k) 0.01-0.04 m/day
- Specific yield (Sy), variable but likely close to 0.5%

3.2 Surface water contribution

With a clearer knowledge of groundwater inflows, the water balance equation can be used to estimate the amount of surface water run-off entering from outside of the quarry void, which in turn can be used to estimate the size of the surface water catchment.

Groundwater levels vary little over the course of a rainfall event and the contribution from groundwater will remain relatively constant during wet periods, (or at least, any increase in groundwater inflow is not insignificant).

The amount of water discharged from the quarry increases significantly in response to prolonged rainfall. As noted above, the increased discharge is not related to an increase in groundwater inflow, but from a combination of increased surface run-off from saturated ground and less evaporation due to increased cloud cover.

Based on the findings of Section 3.1 it is reasonable to assume groundwater inflow between 50 - 100 m^3/day, meaning it is possible to estimate the contribution from surface water run-off during periods of heavy / prolonged rainfall.

Equation 3. Water balance equation for the estimate of surface run-off entering the quarry

Surface run-off = Discharge – Direct rainfall + evaporation from quarry floor – GW inflow

Table 3-2 summarises the water balance described in Equation 3 for the 9-day long wet period at the end of September (60.4 mm rainfall). As in Equation 1 and the calculation of groundwater inflows during dry periods presented earlier in the report, the estimate of surface water run-off is very sensitive to evaporation. The maximum value of evaporation (885 m^3) assumes evaporation from the full quarry floor and the minimum assumes just the internal ditch and sump. The water balance indicates a maximum of 13% of the quarry discharge, (620 m^3), could be from rain falling outside of the quarry.

The area of the contributing catchment is estimated by dividing the volume of surface run-off by the amount of rainfall, ($m^3/m = m^2$), and then dividing by the run-off coefficient, which is estimated at 0.15 (i.e. 15%, for moderately sloping sandy soil[5]).

Table 3-2. Water balance for the period 22 - 30 September and estimate of contributing surface water catchment.

Period	Discharge (m^3)	Direct rainfall (m^3)	Evaporation (m^3)	Groundwater inflow (m^3)	Surface run-off (m^3)	Contributing catchment (m^2)
22 - 30 September	4,781	4,596	18.4 - 885	450	0 to 620	0 to 68,400
	4,781	4,596	18.4 - 885	900	0 -170	0 to 18,750

The maximum catchment area, estimated at 73,390 m^2 for the higher groundwater inflow scenario, equates to a distance of approximately 40 m around the full perimeter of the quarry.

[5] https://www.fao.org/3/T0099E/T0099e04.htm

4 SITE INVESTIGATIONS AND CONCEPTUAL MODEL

4.1 Observations from the quarry

Gwyndy quarry was visited by Hydrotechnica hydrogeologist, Alex Gallagher, on two occasions, the 16th September 2021 and 21st July 2022.

- The visit on the 16th September 2021 was for general orientation, to assess the need for site investigations and plan data collection.
- Water level data loggers were installed, boreholes sampled for water quality analyses and permeability tests undertaken on the 21st July 2022.
- On both site visits, the quarry walls were inspected for differences in weathering, fracturing and water seepages, and the quarry discharge was observed.

Photographs of the quarry wall are included in **Appendix B**. The main observations are summarised below:

- East wall – widespread seepage is observed following rainfall and discharge from the quarry. The discharge channel runs within 50 m of the quarry wall for nearly 200m.
- South wall – looking along strike, changes fracturing can be observed. Very hard and largely unfractured 'blue' granite sits alongside granite stained by seepage and precipitation on fracture surfaces.
- West wall - hard granite, very few / no seepages.

4.2 Drilling results

4.2.1 Borehole geology

Three groundwater monitoring boreholes are installed at Gwyndy Quarry 9 – 22 November 2021, see Figure 4-1 for the borehole locations. The boreholes are located to measure drawdown: BH1 is located perpendicular to geological strike adjacent to the west wall of the quarry, and BHs 2 and 3 are aligned parallel to strike, extending to the southwest of the existing void.

Borehole geology is summarised in Table 4-1. Overburden of clay, silt and gravel was recorded in all boreholes, suggesting that glacial till extends across the quarry area, which is in contrast to the published geological map[6]. Fresh granite was recorded 6-7 m BGL in all boreholes.

Granite bedrock was recorded to the base of BHs 2 and 3, whereas a change in rock type was recorded at depth in BH1, which is located on the western margin of the quarry.

Table 4-1. Borehole geology

BH1	BH2	BH3
0-6 silt and gravel	0-7 clay	0-4 silt and gravel
6-74 fresh granite	7-84 fresh granite	4-6 fractured granite
74-84 soft dark material (meta-sediments?hornfels?)		6-84 fresh granite

4.2.2 Borehole construction

Observations from drilling and borehole construction details are summarised in Table 4-2. All boreholes were advanced to the same depth, 84 m below ground level (BGL). Water was struck 5-7 m BGL in all boreholes, at or just above the top of fresh granite. A deep water strike was observed in just one of the three boreholes, BH1. While the water strike in BH1 was recorded by the drilling contractor at 70 m and the change in lithology at 74 m BGL, it is likely that the water strike coincided with the change in geology.

All boreholes were screened in the fresh rock so that future monitoring, sampling and permeability tests would be representative of the material quarried and conditions at depth.

Table 4-2. Borehole construction details and observations during drilling

Borehole ID	BH1	BH2	BH3
Easting	239804	239520	239391
Northing	379714	379443	379384
Top of casing, datum (m AOD)[1]	61.43	57.10	58.79
Approximate distance from the quarry void (m).	104	217	359

[6] https://geologyviewer.bgs.ac.uk/?_ga=2.15868085.2005933592.1668435186-522320958.1668435186

Depth (m BGL)	84	84	84
Screen interval (m BGL)	30 - 78	12 - 72	12 - 72
Water strikes (m BGL)	5, 70	7, 15	6
Average GWL depth March. – September '22 (and in m BD)	5.36 (56.07)	3.58 (53.52)	3.56 (55.23)
Airlift flow (l/minute)	5 – 10	1 - 3	unknown
[1] The boreholes were surveyed by a professional surveyor, borehole datums are accurate to less than one centimetre in the vertical and horizontal.			

4.3 Groundwater level monitoring

Figure 4-2 shows groundwater levels measured at the three boreholes and daily rainfall, (the average of rainfall measured at Llyn Alaw and Llyn Cefni). Manual monitoring of groundwater levels commenced in March 2022 and Solinst data loggers were installed in July 2022, manual monitoring continues.

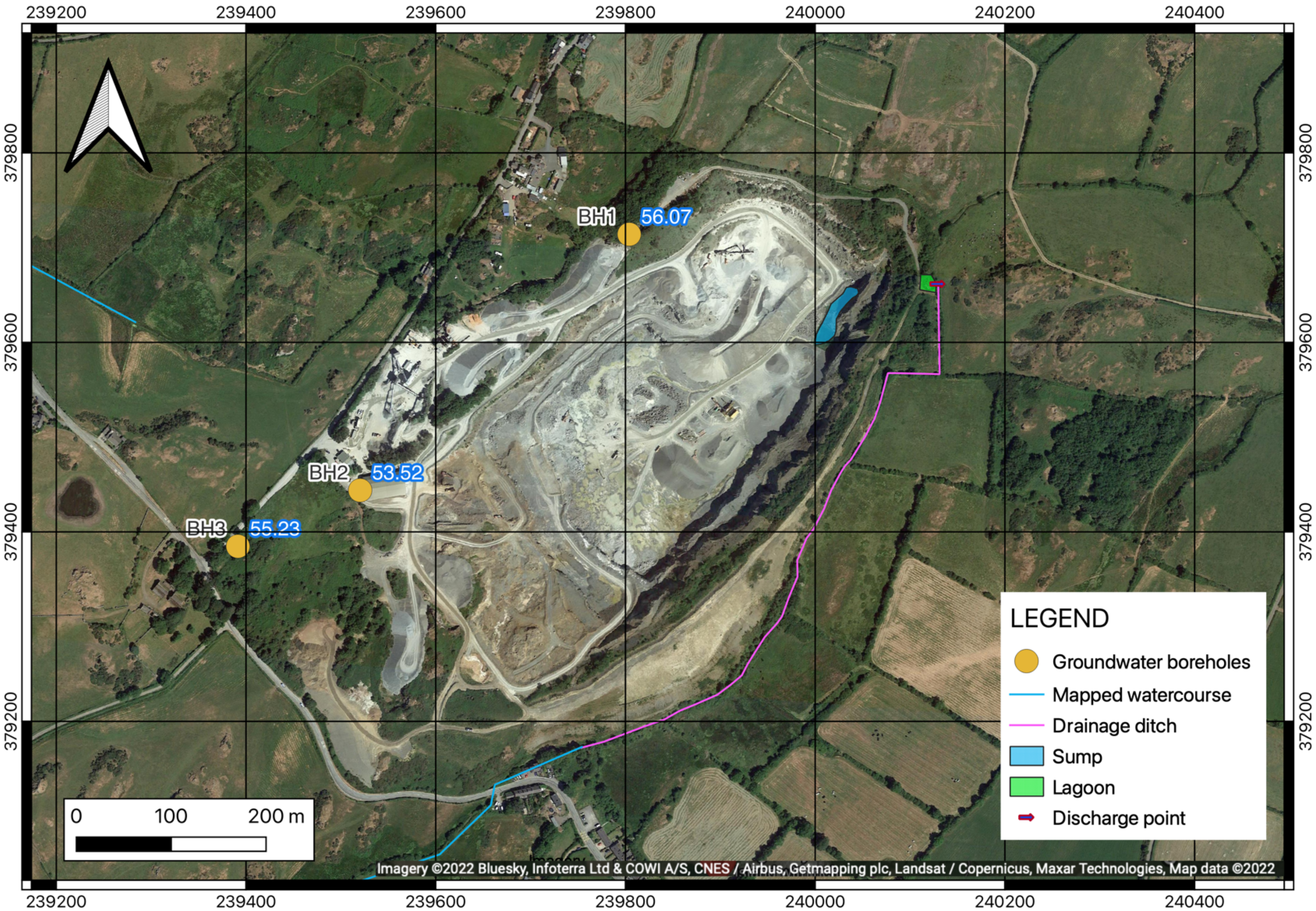


Figure 4-1. Groundwater monitoring boreholes (with groundwater levels highlighted blue), and water features.

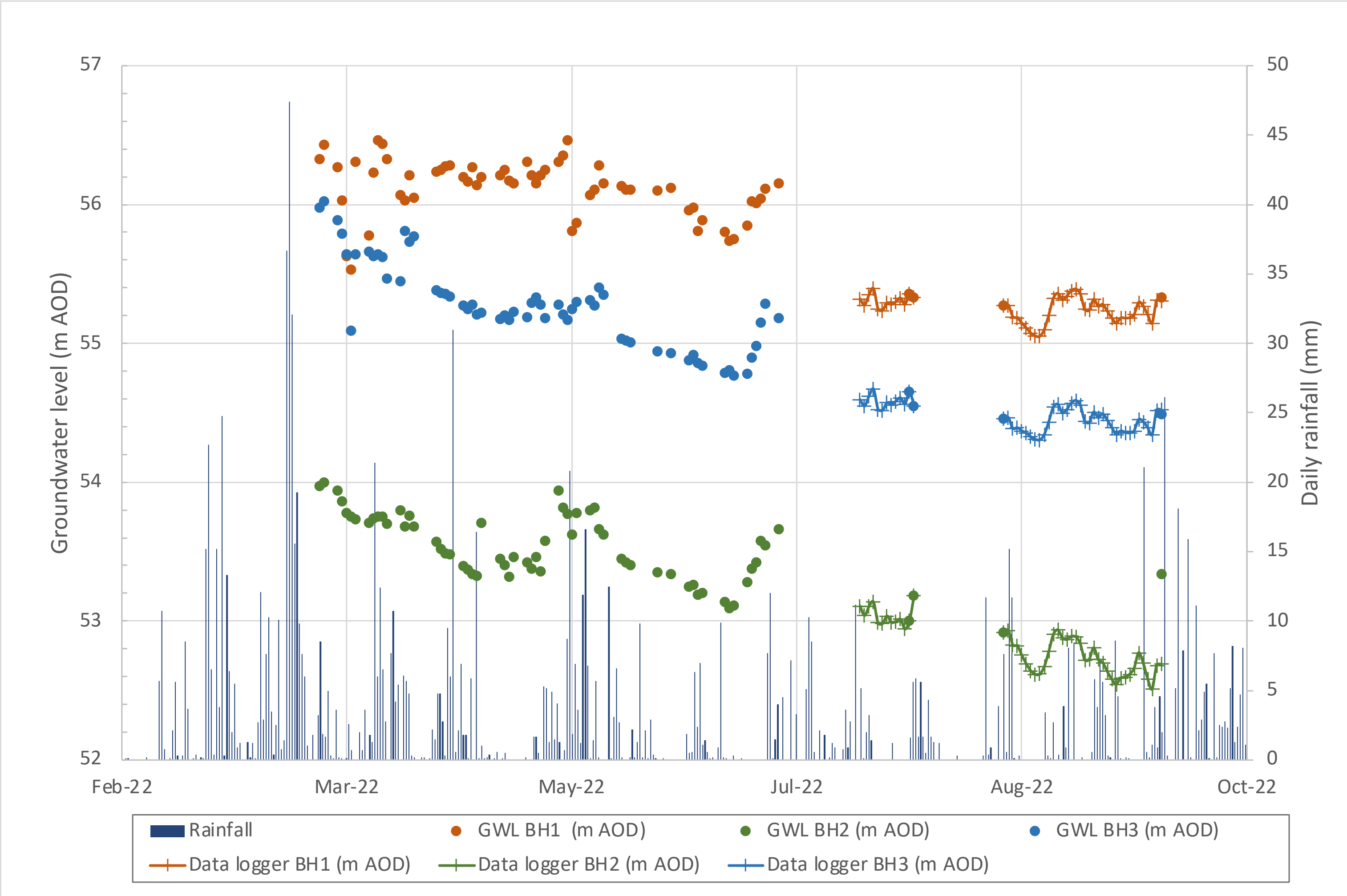


Figure 4-2. Monitored groundwater levels and daily rainfall

The lowest groundwater level measured is at BH2. Both boreholes BH2 and BH3 have lower groundwater levels than BH1, which counter-intuitively, is the borehole located closest to the quarry void. If the hydraulic properties are equal in all directions, one would expect to observe lower groundwater levels at BH1.

The fact that groundwater is relatively high to the west of the quarry (perpendicular to geological strike) compared to the southwest, where the boreholes are located along strike, suggests: 1) local differences in hydraulic properties potentially related to the orientation of geological strata; and 2) drawdown will propagate preferentially in the southwest -northeast direction.

4.4 Permeability tests

The results of single borehole hydraulic tests, known as slug tests, are reported in Table 4-3, the test analyses are included in **Appendix C.** The average hydraulic conductivity is 0.007 m/day. The highest value is interpreted at BH1, where the highest airlift yield was also recorded, it is the only borehole with a 'deep' water strike, which coincided approximately with a change in fresh rock.

Table 4-3. Hydraulic tests – results summary

Borehole ID	Initial displacement (m)	Time to 80% recovery (seconds)	Interpreted hydraulic conductivity (m/day)
BH1	0.78	608	0.011
BH2	0.80	790	0.008
BH3	1.39	2,549	0.003

4.5 Water quality

The three boreholes, the quarry sump and the lagoon discharge pipe were sampled on the 21st July 2021 following two-weeks of very little rainfall. The samples were analysed by ALS Laboratories for major and minor ions (a water typing analytical suite). The results are provided in Table 4-4 and the certified laboratory sheets contained in **Appendix D**.

All water samples are fresh (TDS < 1000 mg/L). The sump and discharge waters, which are virtually identical, contain smaller concentrations of dissolved salts than the groundwater. Chloride is a conservative tracer, meaning it is little affected by hydrochemical processes, the lower chloride measured in the sump and lagoon indicate mixing with rainfall (which is typically <2 mg/L chloride). Chloride is present in the groundwater samples at two-three times higher concentrations than the sump and discharge water, which can be interpreted roughly to mean that the water discharged on that day in July, (after a long dry period), comprised approximately one third groundwater.

There are differences in the groundwater samples. Compared to BH2 and BH3, water in BH1 is higher in bicarbonate and lower in chloride (Table 4-4 and Figure 4-3), it also contains very high concentrations of iron (1.2mg/L), the UK drinking water standard is 0.2 mg/L. Figure 4-4 interprets the major ion chemistry for water 'type'. Water from BH1 falls into the 'recharge' type and the others into more of a 'mixing' type.

The differences in borehole water chemistry complement other observations from BH1 that suggest a local change in geology and groundwater flow west of the quarry: the steep hydraulic gradient, which is likely to be related to the SW-NE structural fabric indicates a lack of hydraulic connectivity from west to east; the change in geology at the base of the borehole and the deep water strike indicates a structural control on groundwater flow; furthermore, the relatively high airlift yield and borehole permeability suggest the deeper geology is likely to be contribute water to the samples collected and analysed.

4.6 Summary of the conceptual model

Reviewing the findings from Sections 2-4 the conceptual model is summarised below.

The quarry is located in granite, which is overlain by thin superficial deposits. The granite is generally very hard, although there is evidence of zones of weaker granite following the NE strike.

Below the weathered granite, groundwater is restricted to occasional fractures. During drilling of three boreholes, one water strike was recorded below 15 m and that was related to a change in bedrock lithology, most likely a transition from granite to meta-sediments at c.74 m in borehole BH1. There are very few seepages visible around the quarry, with the exception of the east wall through which water recirculates from the discharge channel.

After c. 60 years of quarrying, the groundwater system is likely to be close to steady state conditions, meaning little change in groundwater storage and relatively constant groundwater inflows.

Table 4-4. Water sample - analytical results

Sample Ref.		BH1	BH2	BH3	Sump	Discharge
Sample Date/Time		**21/07/2022 08:30:00**	**21/07/2022 08:55:00**	**21/07/2022 09:21:00**	**21/07/2022 10:30:00**	**21/07/2022 10:21:00**
pH	pH units	7.7	7.9	8	8.2	8
Bicarbonate Alkalinity	mg/l	245	137	141	120	123
Chloride as Cl	mg/l	55.9	105	84.6	31.8	31.9
Sulphate as SO4	mg/l	52.1	46.2	112	52.2	53.9
Solids, Tot Dissolved 180 DegC	mg/l	472	552	485	287	299
Boron, total as B (mg/l)	mg/l	<0.06	<0.06	<0.06	<0.06	<0.06
Cadmium, total as Cd (mg/l)	mg/l	<0.00007	<0.00007	<0.00007	<0.00007	<0.00007
Calcium, total as Ca (mg/l)	mg/l	96.5	70.3	81.2	52.3	53.1
Chromium, total as Cr (mg/l)	mg/l	0.0053	0.0007	0.00055	<0.00051	<0.00051
Copper, total as Cu (mg/l)	mg/l	0.0097	<0.0018	0.0041	<0.0018	<0.0018
Iron, total as Fe (mg/l)	mg/l	1.5	0.202	0.333	0.035	0.027
Lead, total as Pb (mg/l)	mg/l	0.004	0.0006	0.0007	<0.0003	<0.0003
Magnesium, total as Mg (mg/l)	mg/l	15	26	9.7	10	11
Nickel, total as Ni (mg/l)	mg/l	0.0048	0.0014	0.0014	<0.0010	<0.0010
Potassium, total as K (mg/l)	mg/l	1.9	1.6	3.5	2.2	2.2
Sodium, total as Na (mg/l)	mg/l	40	25	56	22	22
Strontium, total as Sr (mg/l)	mg/l	0.43	0.49	0.29	0.27	0.28
Zinc, total as Zn (mg/l)	mg/l	0.022	0.011	0.009	<0.006	<0.006

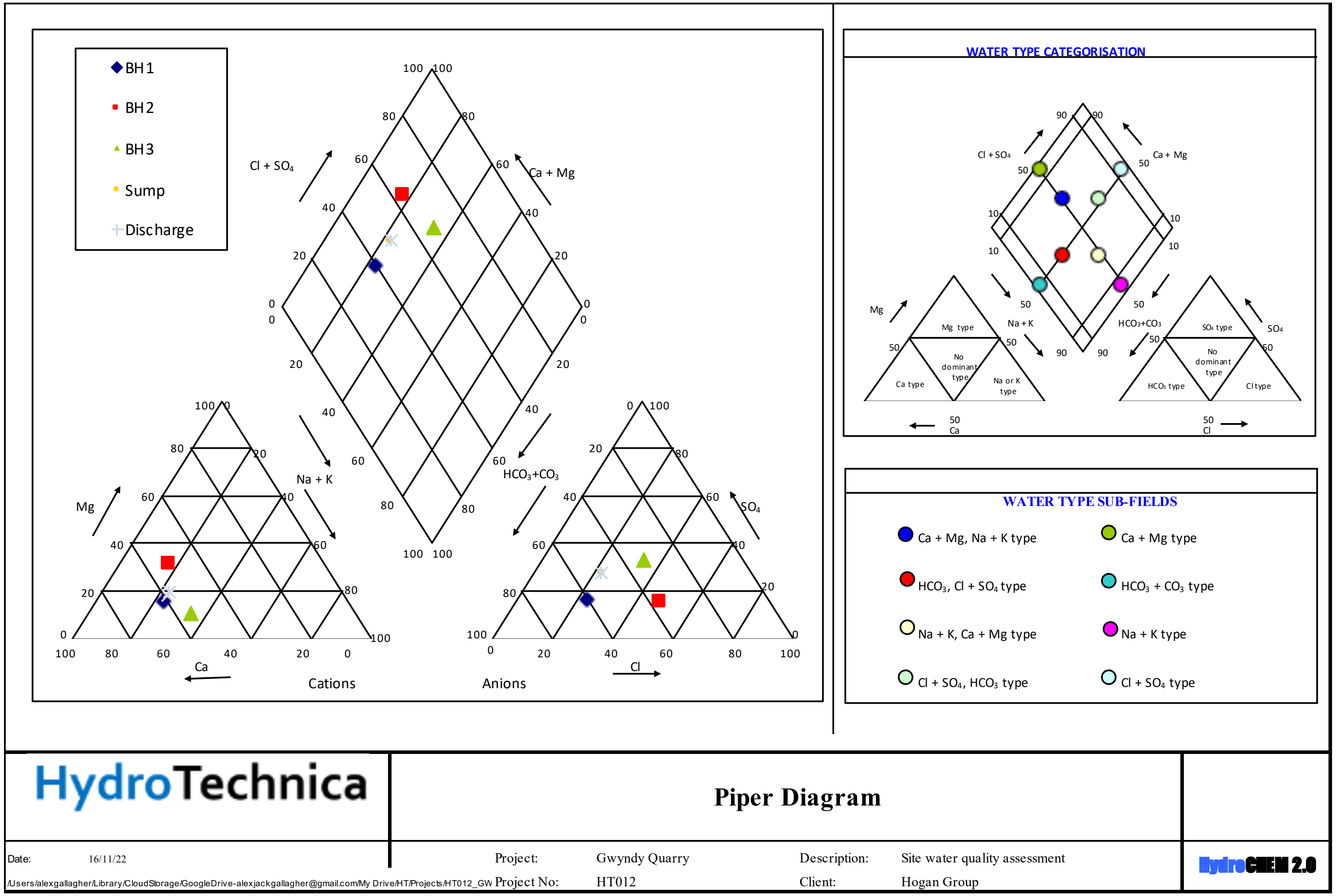


Figure 4-3. Piper diagram

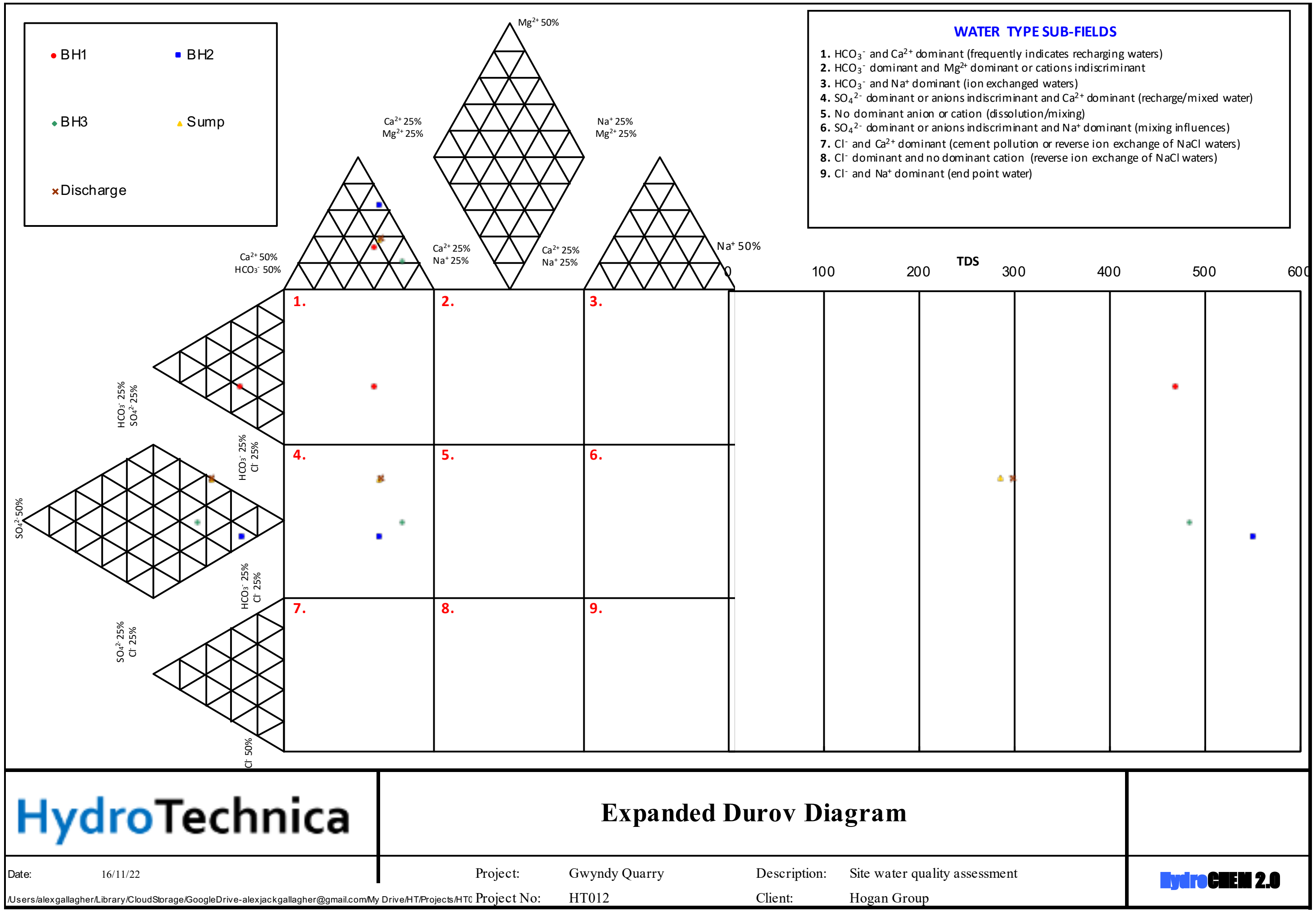


Figure 4-4. Expanded Durov diagram

Groundwater level monitoring does show changes in response to rainfall super-imposed on a steady decline. Longer-term monitoring will show whether the levels continue to fall or return to the 'steady-state' baseline.

The hydraulic gradients, (and hydrogeological conditions), are not uniform around the quarry. The gradient is steeper to the northwest of the void and shallower to the southwest. The difference is likely to relate to the changes in geology from east to west perpendicular to the geological strike. The water quality supports this observation (see later paragraph). Extrapolating these observations into the future, the effect of water table drawdown is likely to extend to the southwest along strike and be relatively limited perpendicular to strike.

The permeability (hydraulic conductivity) of the granite was estimated in two ways:

1. a combination of the quarry water balance and an analytical groundwater model that was semi-calibrated to groundwater levels; and,
2. permeability (slug) tests undertaken in the three boreholes.

The groundwater model indicated a range between 0.01 – 0.04 m/d and the permeability tests returned an average hydraulic conductivity of 0.007 m/d. The highest hydraulic conductivity measured was in borehole BH1, which is likely to be due to the groundwater flow horizon recorded at the change in lithology 70 – 74 m below ground level. The results from the small-scale borehole tests agree well with the larger scale of the quarry inflow. Lower values are expected from the borehole, because they are more representative of the intact granite and less representative of the fractures that drain to the quarry void.

Groundwater sampled from boreholes, sumps and the discharge lagoon is fresh. The three samples retrieved from the boreholes show no evidence of saline water, despite extending to 84 metres below ground level (c. 25 metres below sea level). There is, however, a significant difference between borehole BH1 and boreholes BH2 and BH3. Borehole BH1 encountered water at depth, the inflow at 70 – 74 m BGL, which coincides with a change in lithology is likely responsible for the higher permeability and higher airlift flow rate measured during slug testing and drilling, respectively. Borehole BH1 contains water high in iron (1.2 mg/L) and has a general 'recharge' signature, indicative of relatively rapid flow from ground surface to the borehole.

5 DEWATERING IMPACT ASSESSMENT

Information collected during the hydrogeological study, e.g. Sections 2-4 is used in this section to understand the impacts of extending the quarry laterally and to depth. For the purpose of the impact assessment, the quarry is assumed to deepen by 2 benches (an additional 30 m) and extend laterally to the extraction limit.

The objective of the assessment is to:

1. Predict future groundwater inflows
2. Predict the extent of future drawdown

Discuss the two predictions in the context of the local water resources and nearby water users.

5.1 Future inflows

Equation 2 for flow to a well, which was applied in Section 3 to estimate the bulk hydraulic conductivity, can be used to predict future inflows. The equation remains the same except for the input terms that relate to the quarry dimensions, which are adjusted as follows:

$h0$= Assumed 65 m, i.e. height of water table above the base of a quarry extended 30 m in depth to – 10 m AOD.

hq = Assumed 0 m, i.e. the base of the quarry.

r_0 = This is uncertain, but estimated from the Theis equation to be 1,500 m.

r_q = This is 123 m for the area of permitted extraction (which is approximately 149,300 m^2).

K = 0.04 m/d as calculated in Section 3.

Inflow to the final quarry void is predicted to be 212 m^3/day, (2.5 L/s), which is two to four times that currently flowing to the quarry. The low permeability granite means that despite simulating the 30 m increase in depth and approximate doubling of the quarry area, groundwater inflow rates are predicted to remain low.

To help understand the impact of future groundwater inflows on local water resources, the surface water catchment that contains Gwyndy, i.e. the Afon Crigyll, has a surface area of approximately 50 km^2 (Figure 2-2). *The average annual rainfall, (Table 2-2), equates to an average daily rainfall within the*

Afon Crigyll *catchment of 117,000 m^3/day . Groundwater inflows to the quarry, predicted to rise to approximately 200 m^3/day, would therefore represent less than 0.2% of average daily rainfall.*

5.2 Radius of influence

The Theis formula (Theis, 1935, see footnote #4), can be used to predict drawdown for an enlarged quarry using the parameters listed in Section 5.1 plus additional information: specific yield (groundwater storage) and time. A duration of one year is assumed, not because the quarry will expand to the full extent in one year, but because eventually groundwater recharge will balance drawdown on an annual basis. The background groundwater level (at which there is zero drawdown is assumed 55 m AOD).

The results are illustrated in Figure 5-1 for two values of groundwater storage (Low = 0.5% and High = 5%). The low storage profile, (orange in Figure 5-1), is considered more realistic along strike (SW-NE), and the high storage profile more realistic perpendicular to strike (SE-NW).

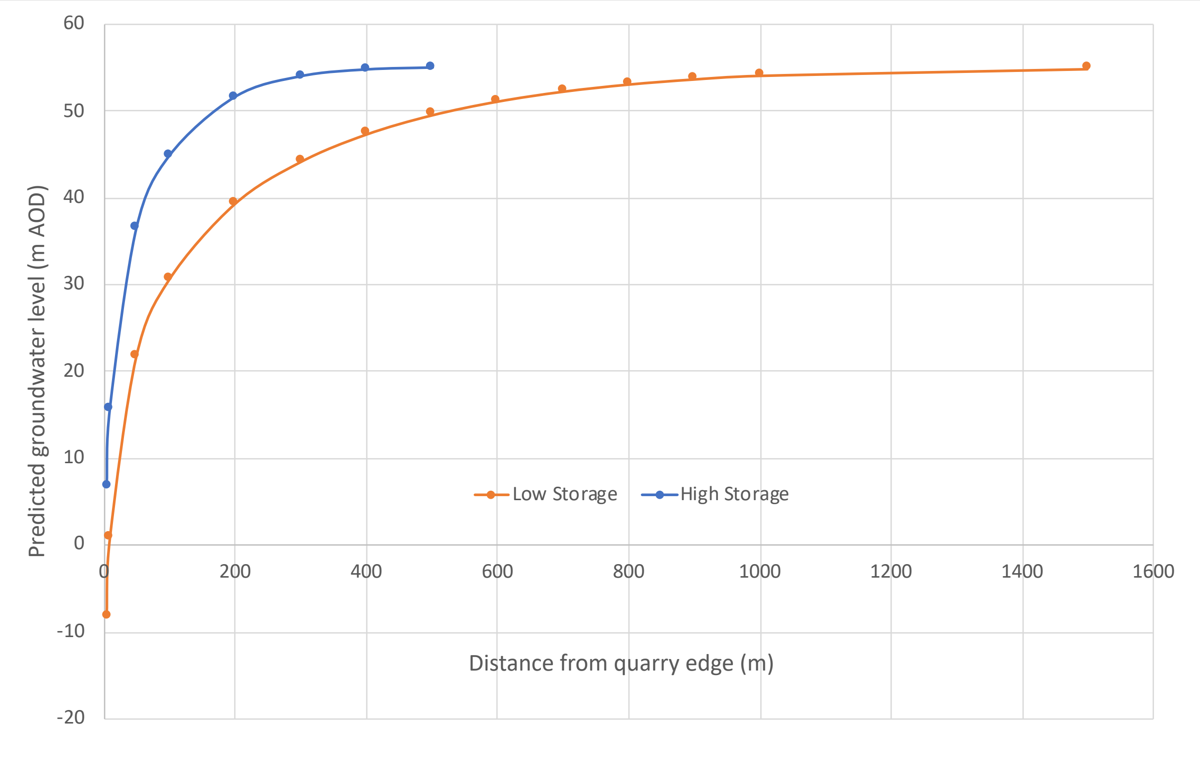


Figure 5-1. Predicted future drawdown profiles

The predicted maximum future radius of influence is 1,500 m. However, it is important to note that groundwater levels measured recently on site show that drawdown will not be equal in all directions.

The large-scale geological structure, i.e. the SW – NE strike of the granite is an influence on groundwater flow and drawdown now, and will be in the future. There will be more groundwater flow and greater drawdown along strike and less perpendicular to it.

5.3 Discussion of impacts

5.3.1 Catchment water balance

The low permeability of the granite means that it produces little water – it is a poor aquifer in terms of water resources – and the groundwater inflow to Gwyndy will be insignificant in terms of the local water balance. Future groundwater inflows are predicted to be approximately 0.18 % of rainfall occurring within the Afon Crigyll catchment, with impacts mitigated by discharge of groundwater into the surface water network.

5.3.2 Drawdown

Extending the quarry to depth and laterally will likely extend the influence on the water table. However, evidence from recent groundwater monitoring and analyses at Gwyndy suggest the additional drawdown will be limited by the low permeability of the granite and rainfall recharge. The high groundwater levels, (close to ground surface), and the rapid response to rainfall suggest that rainfall has the greatest influence on water levels and the relatively high groundwater levels near the quarry indicate little long-term impact from quarrying.

5.3.2.1 THE CURRENT SITUATION

A brief review of the current situation will help provide context to the impact assessment.

After 60 years of quarrying and a quarry floor at 20 m AOD, the water table in boreholes within 200m of the quarry is 53 – 55 m AOD, or 3 – 5 metres below ground level.

Local monitoring of groundwater levels does not prove conclusively the absolute extent, however, the information can be extrapolated using simple analytical groundwater model, e.g. Figure 3-2. While it was not possible to fit the current drawdown profile exactly, modelling indicates zero drawdown is currently likely at distances from the quarry of approximately 200 m (to the NW and SE) and 500 m (to the NE and SW).

5.3.2.2 THE POTENTIAL FUTURE SITUATION

The area of influence, i.e. the area of land below which water table drawdown occurs as a result of groundwater flow to the Quarry, will grow as the quarry is enlarged. It will stabilise as eventually the amount of rainfall captured increases and balances the groundwater draining.

We know from monitoring data at site that drawdown is likely to be at a maximum along strike and lower, approximately half perpendicular to it.

Analysis using the Theis equation and calibrated hydraulic parameters suggests the worst case scenario for a quarry at full extent, is zero drawdown at 1,500 m. To determine an area of significant influence it is more helpful to consider drawdown in the context of the saturate thickness of the shallow aquifer that might be utilised locally by wells. Based on the drilling results at Gwyndy, (Table 4-1), the superficial aquifer is typically 4 – 7 m thick and the groundwater level is c. 3 m BGL, meaning that the saturated thickness is 1- 3 m. In this context, drawdown of 1 m is potentially significant to nearby wells. In this 'worst-case scenario' 1m of drawdown is predicted at 1,000m from the quarry along strike and 500m perpendicular to strike.

Figure 5-2 shows the areal extent of predicted future drawdown – the pink area is where 1 m or more drawdown is possible. The figure also shows the location of private wells and boreholes as provided by Anglesey Council. Two boreholes and three wells are within the area of potentially significant impact.

Records from Anglesey council show that all boreholes are no longer used (**Appendix A**). Hogan Group has contacted the owners of the three wells and has confirmed that the properties are on mains water (and that the three wells are no longer in use).

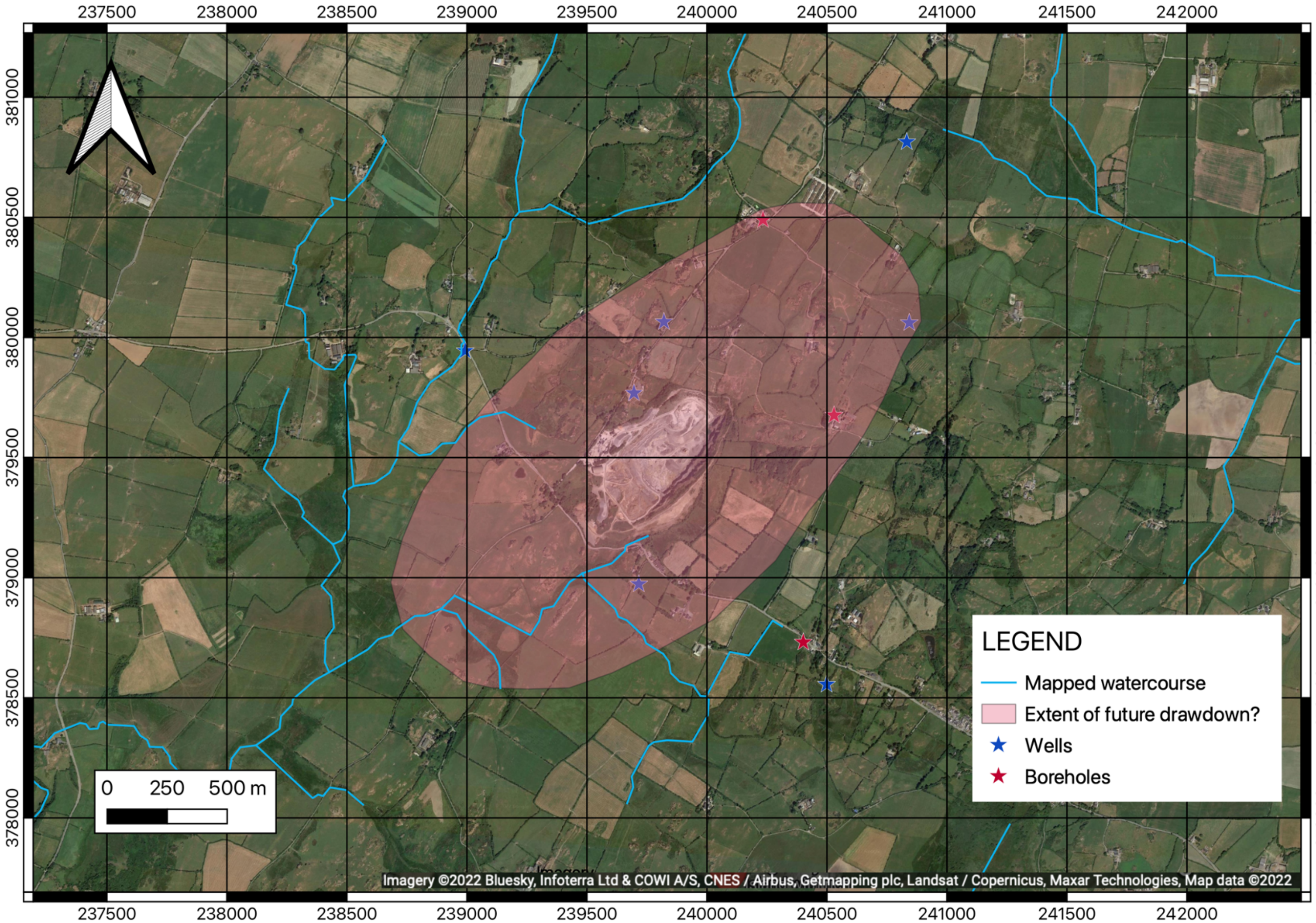


Figure 5-2 Predicted extent of future drawdown (1 m below current levels)

6 CLOSURE AND QUARRY LAKE FORMATION

6.1 Introduction to analyses method

Following quarry closure, as long as water inflows are greater than evaporation, a lake will form within the quarry void. The speed at which the void will fill with water is dependent on three factors: Direct effective rainfall, i.e. the amount of rainfall directly entering the void less evaporation, groundwater inflow, and surface water inflow.

A water balance equation that combines the above terms the best way to calculate the future lake water level. The equation is as follows:

Equation 4. Quarry void lake water balance

Lake water level = starting water level + effective rainfall + groundwater inflow + surface water inflow

6.2 Key variables

Effective rainfall: This is calculated using the 91 years of measured rainfall data from RAF Valley (1931 – 2021), and 57 years of Potential Evapo-Transpiration calculated by the Centre for Ecology and Hydrology (1961 – 2017).

Groundwater inflow: This is calculated using Equation 2. The hydraulic conductivity used is 0.04 m/d. The effective radius (rq) is as per that used in Section 5 – equivalent to the extraction permit area. ho remains the base of the quarry, the starting water level in the quarry (hq) is zero on day 1 of the first month. Thereafter, the water level calculated each month is used as the starting water level (hq) for the following month. The radius of influence cannot be calculated reliably without a numerical model. Therefore two versions of the equation were implemented, (ro = 200 m and 500 m), the two values justified on the basis that the current quarry for which the ro is 200 – 500 m, is about midway between the pre-quarrying water level and -10m AOD.

Surface water inflow: As per Section 3.2, the maximum surface water catchment calculated for the current quarry, c. 70,000 m^2, is applied. Also, as noted in Section 3.2, it is possible that there the surface water catchment will be close to zero.

For the purpose of the calculation, quarrying is assumed to stop on December 31 2029 and recovery start on 1st January 2030. The results of the two monthly calculations are presented in Figure 6-1. The two lines plotted relate to the two values input for ro (known as radius of influence, RoI). Fixing this value controls the hydraulic gradient, a smaller RoI, e.g. 200 m, means a steeper gradient, more groundwater inflow and therefore a more rapid rise in the lake water level.

6.3 Results

Based on this simple water balance analysis, the lake water level is predicted to return to the pre-quarrying groundwater level, e.g. 55 m AOD after 36 years, (i.e. January 2066) for an average radius of influence (RoI) of 200 m.

- The rate of water level rise slows as a result of decreasing groundwater input – as the water level rises, the hydraulic gradient reduces driving less water towards the quarry void. To illustrate the effect, the first and last 10 m of the void will fill with water in 3 years 3 months and 12 years, respectively.

- Results presented include a small surface water catchment, recovery will be slower if no run-off enters the quarry, and more rapidly if the surface water catchment is larger than calculated in Section 3-2. The water balance model assumes that there is no surface water run-off between the months of April and July when evaporation is historically greater than rainfall.

- The rainfall input and surface water input are constant on an annual basis, with average monthly values repeated January – December. Natural changes in rainfall and climate change may increase or decrease the time frame for pit lake formation.

- As noted previously in the report evaporation is difficult to calculate. Here evapo-transpiration has been used, evaporation from open water will be different, but whether it is significantly different when methods of calculating evaporation from open water vary by up to 30%, is debatable.

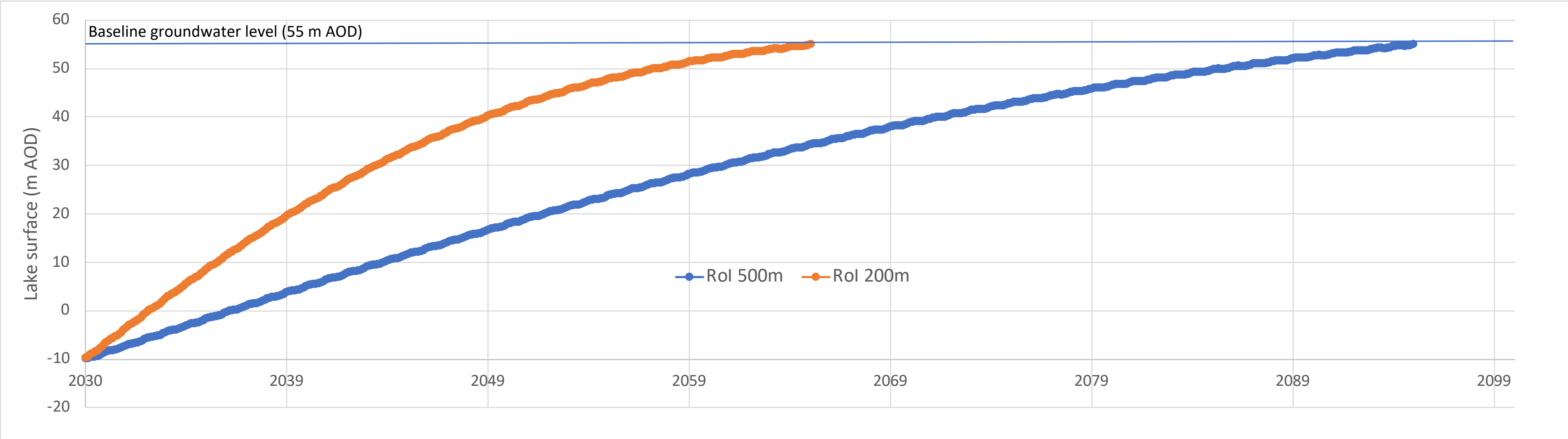


Figure 6-1.Predicted recovery in quarry lake water levels.

7 SUMMARY AND CONCLUSIONS

Like granite elsewhere in the UK and around the world the granite at Gwyndy Quarry is generally very hard and low permeability. It is because of this inherent low permeability and low water storage that the British Geological Survey classify the granite as a low productivity aquifer. It is also why groundwater inflows will be low throughout the life of the quarry, drawdown away from the quarry will be limited in extent, and it will take decades for a quarry lake to fully form.

7.1 Permeability and groundwater flow

Water strikes during drilling indicate groundwater flow generally within 15 m of ground surface. Seepages in the quarry coincide with weathered and fractured areas of granite – with occasional open fractures seeping at depth (below 15 m BGL).

Site investigations and subsequent groundwater level monitoring has demonstrated very little drawdown within 200 m of the quarry edge - a sign of the low permeability. There is evidence from borehole water levels that permeability is greater in the direction of geological strike and less perpendicular to it, which would be consistent with fracturing orientated preferentially in the direction of strike., i.e. SW-NE. The difference in permeability can be observed in the quarry walls, the granite of the west wall is sparsely fractures by comparison with the south wall where relatively deep weathering can be observed.

The permeability (hydraulic conductivity) of the granite was calculated using two methods: 1) a the quarry discharge and groundwater flow equation were used to 'back-calculate' a bulk hydraulic conductivity, and 2) hydraulic tests were performed in the three boreholes. The two methods agree well and prove the granite at Gwyndy to be low permeability. The hydraulic conductivities are applied in 'lumped parameter' analytical models, the models are suitable for whole quarry calculations, but do not represent vertical and spatial differences in hydraulic properties. For this reason model predictions should be considered in the context of the conceptual model and our understanding of groundwater flows developed from direct observation.

7.2 Water quality

Water samples from the boreholes, which are constructed to c. 25 m below sea level, were analysed for minor and major ion chemistry (a water type suite). The results indicate borehole water is fresh. A borehole, (BH1), that penetrated different type of bedrock at approximately 74 m BGL on the western margin of the quarry is higher permeability and contained different type of water to the other boreholes (and the quarry sump). The quarry sump and lagoon water is similar in composition to borehole BH2 and BH3. The water in borehole BH1 is high in iron and shows a recharge signature suggesting there may be preferential groundwater flow along the western contact of the granite that could lead to a change in discharge quality if it was penetrated by quarry excavations.

The low groundwater inflow means there is significant dilution in the quarry sump. Water samples taken near the end of a two-week dry period suggested a ratio of rainfall to groundwater of 3:1. The high dilution is potentially related to recirculation of discharge water that occurs along the eastern wall. A water balance for the wet period at the end of September 2022 , where rainfall input was c. 10 times that of groundwater, suggests dilution closer to 10:1 during periods of rainfall. Under such conditions, should the sediments contribute water to the quarry sump, dilution would lower the iron concentration well below drinking water standards.

Water quality sampling of the boreholes and quarry discharge should continue, frequency to be determined.

7.3 Impact on catchment water balance

Groundwater inflows to the quarry are estimated currently at approximately 100 m^3/day, equivalent to 0.09 % of rainfall in the Afon Crigyll catchment. Groundwater inflows are predicted to increase to approximately 200 m^3/day. Two-hundred cubic metres per day equates to approximately 0.18 % of average annual rainfall within the Afon Crigyll catchment.

Not all groundwater seepages to the quarry are lost from the catchment water balance. Groundwater flowing into the quarry is discharged to a field drain, a distant tributary of Afon Crigyll, and returned to the catchment during all but the driest of periods of the year, (when groundwater seepages may evaporate in the quarry floor). The impact of the quarry on catchment water resources is therefore much less than the sum of seepages.

7.4 Impact on nearby users

Details of private water supplies within 2 km of Gwyndy Quarry were provided by Anglesey Council (three boreholes and seven wells). The wells presumably target water at the base of the superficial deposits and potentially the top of weathered granite, e.g. are approximately 4-7 m deep, the boreholes are likely to extend deeper to the base of the weathered zone, 7-15 m BGL, or target deeper fractures. Records show that all three boreholes are no longer in use.

An analytical model of future water table drawdown, combined with observations of drawdown at the monitoring boreholes, are used to identify an area around the quarry within which potentially significant drawdown impacts may be experienced in the future. The model indicates that, in a worst-case scenario, there could be 1 m drawdown at a distance of 1,000 m from the quarry, (in a direction parallel to strike, SW-NE). Differential drawdown observed in monitoring boreholes suggests the drawdown impacts will extend less than half this distance perpendicular to geological strike, (1 m drawdown at 500 m to the SE and NW).

Three wells are identified within an oval area defined by the conditions described above. The owners of the relevant properties have been contacted by Hogan Group and confirmed that the properties are on mains water (and the wells are not used for water supply).

7.5 Closure

A closure water balance model was developed to predict the recovery of the water levels within the quarry void. The model, which was based on average climatic conditions and required assumptions regarding groundwater flow system and surface water catchment, predicts at least 36 years for the formation of a quarry lake to pre-existing groundwater levels. A longer time frame is considered likely.

The long duration is principally a function of the low permeability of the granite and the small surface water catchment. However, the steeper the hydraulic gradient towards the quarry, the faster a lake will form. Water level recovery will, therefore, be greatest in early years. For example, depending on hydraulic and climatic variables, between 15 and 30 m of water level recovery is predicted within the first 10 years.

A more accurate estimate of lake recovery might be possible using a combination of numerical groundwater model and stochastic modelling of climate and surface water inputs. However, the low permeability of the granite, which has been well established in this study, will be the controlling factor regardless of the computational methods applied, and improved simulations will still be limited by uncertainty around the key parameters of evaporation and future rainfall.

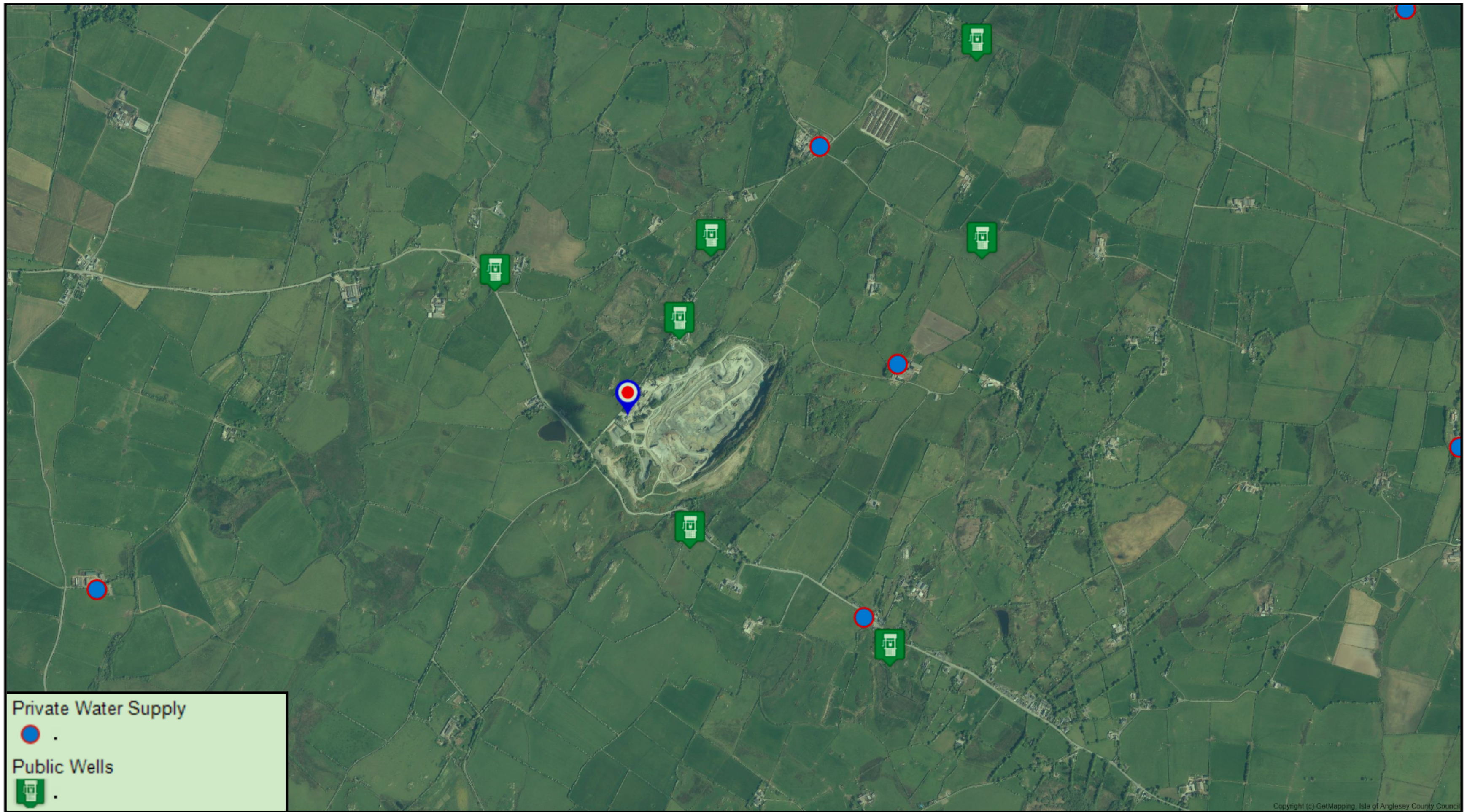
Appendix A – Anglesey Council private water supply records

Boreholes

Reference	Address 1	Address 2	Address 3	Postcode	Usage	Type of Usage	sucodea	Easting	Northing
EZ1ANTYNLO/2	Bryn Tirion	Tynlon	Holyhead	LL65 3BJ	EZ1	No Longer Farming	Non Longer in Use (PWS)	240402	378731
EZ1ANLLAND/7	Waen Y Graig	Llandrygan	Llanerchymedd	LL71 7AN	EZ1	No Longer Farming	Non Longer in Use (PWS)	240234	380490
E10ANTYNLO/3	Foel	Tynlon	Holyhead	LL65 3BQ	E10	Farm - Dairy	Non Longer in Use (PWS)	240530	379676

Wells

Name	Village	Town	ogc_fid
BRYNGORS	LLANDDYFNAN		30
CAERGOLL	LLANDRYGARN		58
GLANGORS		LLANERCHYMEDD	125
MAES Y LLAN BACH	BODWROG		172
PENRHOS	BODWROG		219
PENTREFELIN	LLANDRYGARN	LLANERCHYMEDD	226
TANRALLT	LLANDRYGAN	LLANERCHYMEDD	293



Hydro Technica 2km Gwndy Quarry

N Scale: 1:20000

CYNGOR SIR YNYS MÔN ISLE OF ANGLESEY COUNTY COUNCIL

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Appendix B – Quarry photographs

The east wall above and below – a close up of water seepage

The west wall, largely devoid of seepages.

The south wall showing contrast between very hard granite (rhs) and more readily weathered, fractured granite (lhs). Minor seepages observed at the contact between them.

Appendix C – Single borehole hydraulic tests

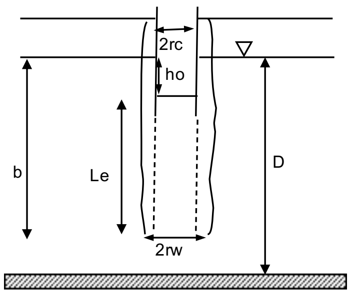
Borehole BH1 rising head test 21 July 2022

Bouwer and Rice - Steady-State Flow (Confined / Unconfined Aquifer)

Does filter pack span the water table (Y/N)? No

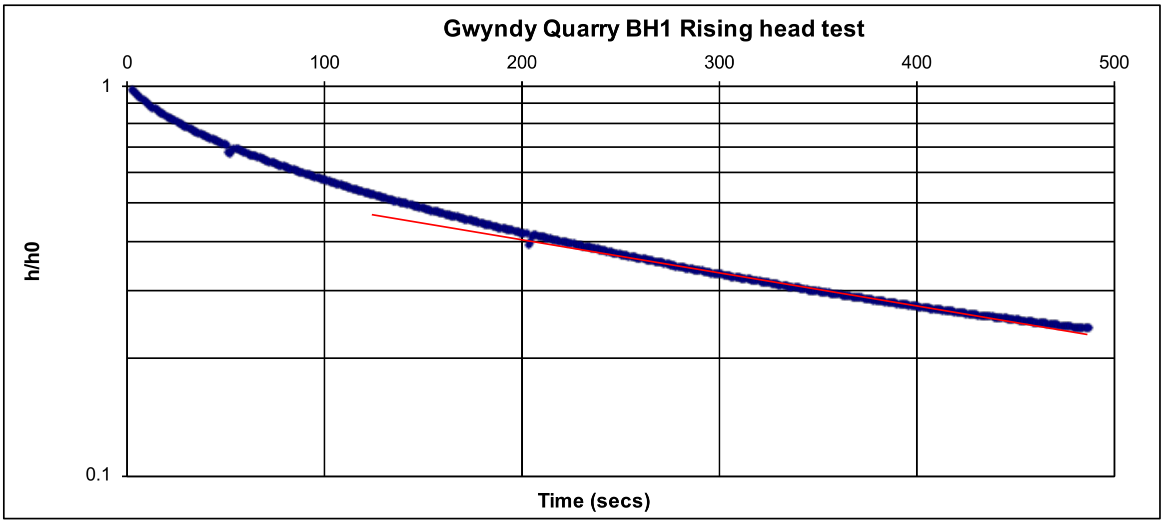
Length of screen Le (m)	48.00
Drilled diameter 2rw (m)	0.15
Saturated thickness D (m)	78.00
Water column height b (m)	78.00
Casing diameter 2rc (m)	0.05
Filter pack porosity (-)	0.3
Effective casing diameter	0.050

Le/rw =	640
A (Constant) =	8.530853636
B (Constant) =	2.436497689
C (Constant) =	11.32570871
ln(Re/rw) =	5.7



K = **1.25E-07** m/sec **0.0108** m/d

Static water level (mbtc)	6.11
Slug volume (l)	1.00
Initial displacement, h0 (m)	0.780
Slope (log_{10}/sec)	0.00085



Borehole BH2 rising head test 21 July 2022

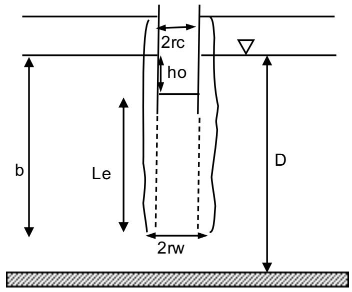
Bouwer and Rice - Steady-State Flow (Confined / Unconfined Aquifer)

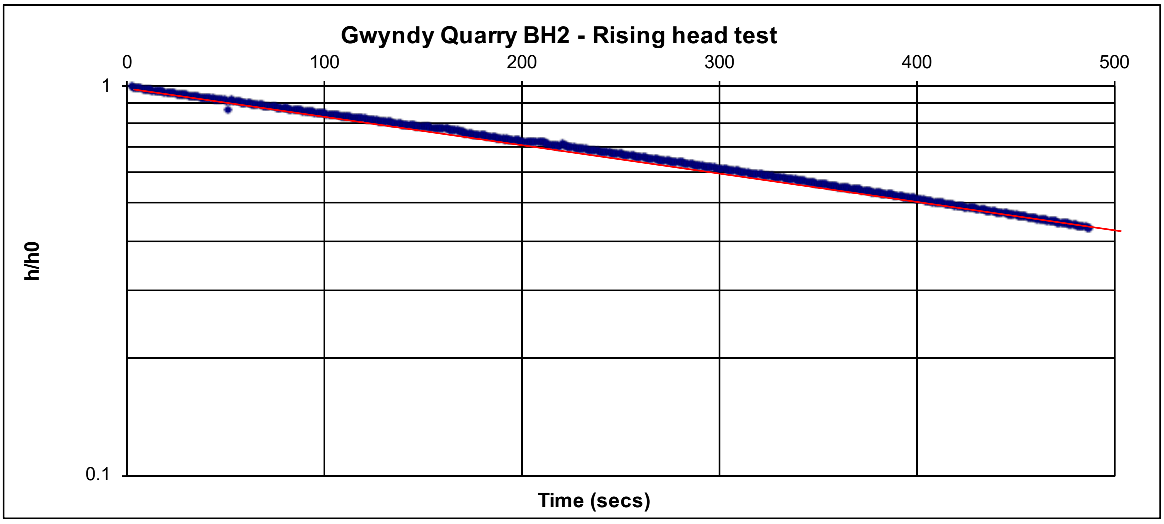
Does filter pack span the water table (Y/N)? No

Length of screen Le (m)	60.00	Le/rw =	800
Drilled diameter 2rw (m)	0.15	A (Constant) =	8.878193008
Saturated thickness D (m)	80.00	B (Constant) =	2.66541148
Water column height b (m)	80.00	C (Constant) =	11.87814976
Casing diameter 2rc (m)	0.05	ln(Re/rw) =	5.8
Filter pack porosity (-)	0.3		
Effective casing diameter	0.050		

K = **8.78E-08** m/sec **0.0076** m/d

Static water level (mbtc)	3.99
Slug volume (l)	1.00
Initial displacement, h0 (m)	0.804
Slope (log_{10}/sec)	0.00073





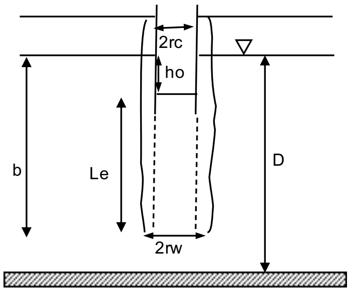
Borehole BH3 rising head test 21 July 2022

Bouwer and Rice - Steady-State Flow (Confined / Unconfined Aquifer)

Does filter pack span the water table (Y/N)? No

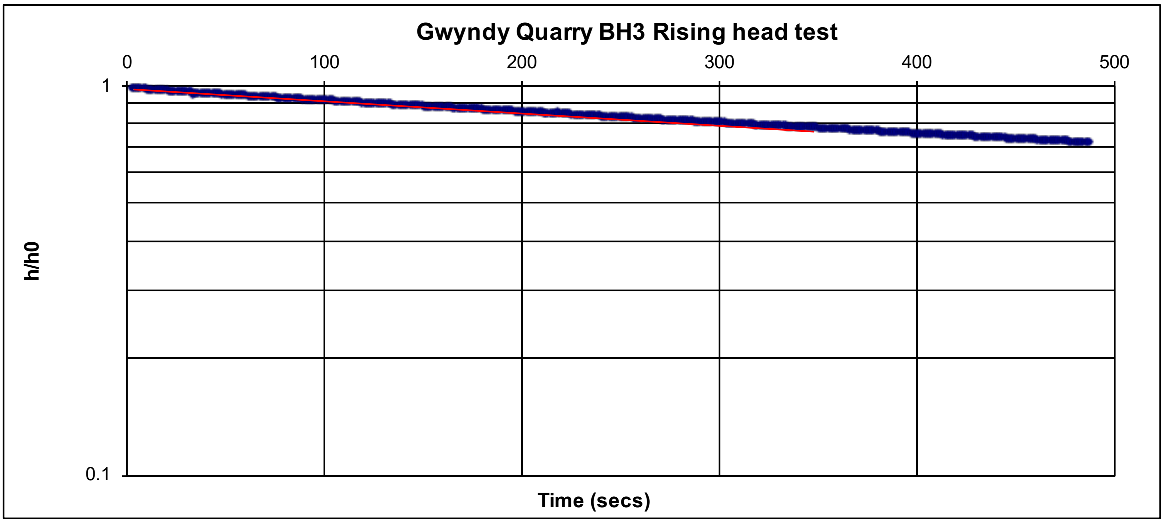
Length of screen Le (m)	60.00
Drilled diameter 2rw (m)	0.15
Saturated thickness D (m)	80.00
Water column height b (m)	80.00
Casing diameter 2rc (m)	0.05
Filter pack porosity (-)	0.3
Effective casing diameter	0.050

Le/rw =	800
A (Constant) =	8.878193008
B (Constant) =	2.66541148
C (Constant) =	11.87814976
ln(Re/rw) =	5.8



K = **3.79E-08** m/sec **0.0033** m/d

Static water level (mbtc)	4.195
Slug volume (l)	1.00
Initial displacement, h0 (m)	1.397
Slope (log_{10}/sec)	0.00031



Appendix D – Laboratory analyses of water samples

ALS Laboratories (UK) Limited
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www.alsenvironmental.co.uk

F.A.O Gallagher
Hydrotechnica
27 High Street,
Kinglsey,
Stoke on Trent, ST10 2AF
Staffordshire

16 November 2022

Test Report: COV/2396999/2022

Dear F.A.O Gallagher

Analysis of your sample(s) submitted on 04 November 2022 is now complete and we have pleasure in enclosing the appropriate test report(s).

An invoice for the analysis carried out will be sent under separate cover.

Should you have any queries regarding this report(s) or any part of our service, please contact Customer Services on +44 (0)24 7642 1213 who will be happy to discuss your requirements.

If you would like to arrange any further analysis, please contact Customer Services. To arrange container delivery or sample collection, please call the Couriers Department directly on 024 7685 6562.

Thank you for using ALS Laboratories (UK) Limited and we look forward to receiving your next samples.

Yours Sincerely,

Signed:

Name: P. Patel

Title: Inorganics Chemistry Manager

UKAS TESTING 1314 | bsi ISO 14001 Environmental Management CERTIFIED EMS675527 | ISO 45001 Occupational Health and Safety Management CERTIFIED OHS 542058 | MCERTS THE ENVIRONMENT AGENCY'S MONITORING CERTIFICATION SCHEME

This communication has been sent to you by ALS Laboratories (UK) Limited. Registered in England and Wales. Registration No.02391955.
Registered Office: ALS Laboratories (UK) Limited, Torrington Avenue, Coventry, CV4 9GU.

Report Summary

ANALYSED BY

F.A.O Alex Gallagher
Hydrotechnica
27 High Street,
Kinglsey,
Stoke on Trent,
Staffordshire
ST10 2AF

UKAS TESTING 1314

Date of Issue: **16 November 2022**

Report Number: **COV/2396999/2022** Issue **1** This issue replaces all previous issues

Job Description: Ground Water Analysis

Job Location: Gwyndy Quarry

Number of Samples included in this report **5**

Job Received: **04 November 2022**

Number of Test Results included in this report **90**

Analysis Commenced: **08 November 2022**

Signed: [signature]

Name: **P. Patel** Date: **16 November 2022**

Title: **Inorganics Chemistry Manager**

ALS Laboratories (UK) Limited was not responsible for sampling unless otherwise stated.

Information on the methods of analysis and performance characteristics are available on request.
Opinions and interpretations expressed herein are outside the scope of UKAS accreditation. The results relate only to the items tested and where relevant sampled.
Tests marked 'Not UKAS Accredited' in this Report/Certificate are not included in the UKAS Accreditation Schedule for our laboratory.
This test report is not a statement of conformity to any specification or standard.

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Certificate of Analysis

ANALYSED BY

Report Number:	**COV/2396999/2022**	Issue	**1**
Laboratory Number:	**22202429**	Sample	**1** of **5**

Sample Source:	**Hydrotechnica**	
Sample Point Description:		
Sample Description:	**BH1**	
Sample Matrix:	**Ground Water**	
Sample Date/Time:	**21 July 2022**	**08:30**
Sample Received:	**04 November 2022**	
Analysis Complete:	**14 November 2022**	

Test Description	Result	Units	Analysis Date	Accreditation		Method
pH	7.7	pH units	08/11/2022	Y	Cov	WAS039
Bicarbonate Alkalinity	245	mg/l	08/11/2022	N	Cov	WAS025
Chloride as Cl	55.9	mg/l	08/11/2022	N	Cov	WAS036
Sulphate as SO4	52.1	mg/l	08/11/2022	N	Cov	WAS036
Solids, Tot Dissolved 180 DegC	472	mg/l	09/11/2022	Y	Cov	WAS010
Boron, total as B (mg/l)	<0.06	mg/l	10/11/2022	Y	Cov	WAS076
Sodium, total as Na (mg/l)	40	mg/l	10/11/2022	Y	Cov	WAS076
Magnesium, total as Mg (mg/l)	15	mg/l	10/11/2022	Y	Cov	WAS076
Potassium, total as K (mg/l)	1.9	mg/l	10/11/2022	Y	Cov	WAS076
Calcium, total as Ca (mg/l)	96.5	mg/l	10/11/2022	Y	Cov	WAS076
Chromium, total as Cr (mg/l)	0.0053	mg/l	10/11/2022	Y	Cov	WAS076
Iron, total as Fe (mg/l)	1.5	mg/l	10/11/2022	Y	Cov	WAS076
Nickel, total as Ni (mg/l)	0.0048	mg/l	10/11/2022	Y	Cov	WAS076
Copper, total as Cu (mg/l)	0.0097	mg/l	10/11/2022	Y	Cov	WAS076
Zinc, total as Zn (mg/l)	0.022	mg/l	10/11/2022	Y	Cov	WAS076
Strontium, total as Sr (mg/l)	0.43	mg/l	10/11/2022	Y	Cov	WAS076
Cadmium, total as Cd (mg/l)	<0.00007	mg/l	10/11/2022	Y	Cov	WAS076
Lead, total as Pb (mg/l)	0.0040	mg/l	10/11/2022	Y	Cov	WAS076

Analyst Comments for 22202429:

This sample has been analysed for pH, Chloride as Cl, Sulphate as SO4, Solids, Tot Dissolved 180 DegC, Boron, total as B(mg/l), Sodium, total as Na(mg/l), Magnesium, total as Mg(mg/l), Potassium, total as K (mg/l), Calcium, total as Ca(mg/l), Chromium,total as Cr(mg/l), Iron, total as Fe(mg/l), Nickel, total as Ni (mg/l), Copper, total as Cu(mg/l), Zinc, total as Zn(mg/l), Strontium, total as Sr(mg/l), Cadmium, total as Cd (mg/l), Lead, total as Pb(mg/l), Bicarbonate Alkalinity outside recommended stability times. It is therefore possible that the results provided may be compromised.

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Analysed at: CHE = Chester(CH5 3US), COV = Coventry(CV4 9GU), OTT = Otterbourne(SO21 2RU), S = Subcontracted, TRB = Subcontracted to Trowbridge(BA14 0XD), WAK = Wakefield(WF5 9TG), F = Data supplied by customer.
For Microbiological determinands 0 or ND=Not Detected, For Legionella ND=Not Detected in volume of sample filtered.
I/S=Insufficient sample   For soil/sludge samples: AR=As received, DW=Dry weight.

Signed:	Name: **P. Patel**	Date: **16 November 2022**	
	Title: **Inorganics Chemistry Manager**		

Certificate of Analysis

ANALYSED BY

UKAS TESTING 1314

ALS

Report Number:	**COV/2396999/2022**		Issue	**1**
Laboratory Number:	**22202430**		Sample	**2** of **5**

Sample Source: **Hydrotechnica**
Sample Point Description:
Sample Description: **BH2**
Sample Matrix: **Ground Water**
Sample Date/Time: **21 July 2022** **08:55**
Sample Received: **04 November 2022**
Analysis Complete: **14 November 2022**

Test Description	Result	Units	Analysis Date	Accreditation		Method
pH	7.9	pH units	08/11/2022	Y	Cov	WAS039
Bicarbonate Alkalinity	137	mg/l	08/11/2022	N	Cov	WAS025
Chloride as Cl	105	mg/l	08/11/2022	N	Cov	WAS036
Sulphate as SO4	46.2	mg/l	08/11/2022	N	Cov	WAS036
Solids, Tot Dissolved 180 DegC	552	mg/l	09/11/2022	Y	Cov	WAS010
Boron, total as B (mg/l)	<0.06	mg/l	10/11/2022	Y	Cov	WAS076
Sodium, total as Na (mg/l)	25	mg/l	10/11/2022	Y	Cov	WAS076
Magnesium, total as Mg (mg/l)	26	mg/l	10/11/2022	Y	Cov	WAS076
Potassium, total as K (mg/l)	1.6	mg/l	10/11/2022	Y	Cov	WAS076
Calcium, total as Ca (mg/l)	70.3	mg/l	10/11/2022	Y	Cov	WAS076
Chromium, total as Cr (mg/l)	0.00070	mg/l	10/11/2022	Y	Cov	WAS076
Iron, total as Fe (mg/l)	0.202	mg/l	10/11/2022	Y	Cov	WAS076
Nickel, total as Ni (mg/l)	0.0014	mg/l	10/11/2022	Y	Cov	WAS076
Copper, total as Cu (mg/l)	<0.0018	mg/l	10/11/2022	Y	Cov	WAS076
Zinc, total as Zn (mg/l)	0.011	mg/l	10/11/2022	Y	Cov	WAS076
Strontium, total as Sr (mg/l)	0.49	mg/l	10/11/2022	Y	Cov	WAS076
Cadmium, total as Cd (mg/l)	<0.00007	mg/l	10/11/2022	Y	Cov	WAS076
Lead, total as Pb (mg/l)	0.0006	mg/l	10/11/2022	Y	Cov	WAS076

Analyst Comments for 22202430:

This sample has been analysed for pH, Chloride as Cl, Sulphate as SO4, Solids, Tot Dissolved 180 DegC, Boron, total as B(mg/l), Sodium, total as Na(mg/l), Magnesium, total as Mg(mg/l), Potassium, total as K (mg/l), Calcium, total as Ca(mg/l), Chromium,total as Cr(mg/l), Iron, total as Fe(mg/l), Nickel, total as Ni (mg/l), Copper, total as Cu(mg/l), Zinc, total as Zn(mg/l), Strontium, total as Sr(mg/l), Cadmium, total as Cd (mg/l), Lead, total as Pb(mg/l), Bicarbonate Alkalinity outside recommended stability times. It is therefore possible that the results provided may be compromised.

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For Microbiological determinands 0 or ND=Not Detected, For Legionella ND=Not Detected in volume of sample filtered.
I/S=Insufficient sample   For soil/sludge samples: AR=As received, DW=Dry weight.

Signed:	Name: **P. Patel**	Date: **16 November 2022**	
	Title: **Inorganics Chemistry Manager**		

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ANALYSED BY

UKAS TESTING 1314

Report Number:	**COV/2396999/2022**	Issue	**1**
Laboratory Number:	**22202431**	Sample	**3** of **5**

Sample Source: **Hydrotechnica**
Sample Point Description:
Sample Description: **BH3**
Sample Matrix: **Ground Water**
Sample Date/Time: **21 July 2022** **09:21**
Sample Received: **04 November 2022**
Analysis Complete: **14 November 2022**

Test Description	Result	Units	Analysis Date	Accreditation		Method
pH	8.0	pH units	08/11/2022	Y	Cov	WAS039
Bicarbonate Alkalinity	141	mg/l	14/11/2022	N	Cov	WAS025
Chloride as Cl	84.6	mg/l	08/11/2022	N	Cov	WAS036
Sulphate as SO4	112	mg/l	08/11/2022	N	Cov	WAS036
Solids, Tot Dissolved 180 DegC	485	mg/l	09/11/2022	Y	Cov	WAS010
Boron, total as B (mg/l)	<0.06	mg/l	10/11/2022	Y	Cov	WAS076
Sodium, total as Na (mg/l)	56	mg/l	10/11/2022	Y	Cov	WAS076
Magnesium, total as Mg (mg/l)	9.7	mg/l	10/11/2022	Y	Cov	WAS076
Potassium, total as K (mg/l)	3.5	mg/l	10/11/2022	Y	Cov	WAS076
Calcium, total as Ca (mg/l)	81.2	mg/l	10/11/2022	Y	Cov	WAS076
Chromium, total as Cr (mg/l)	0.00055	mg/l	10/11/2022	Y	Cov	WAS076
Iron, total as Fe (mg/l)	0.333	mg/l	10/11/2022	Y	Cov	WAS076
Nickel, total as Ni (mg/l)	0.0014	mg/l	10/11/2022	Y	Cov	WAS076
Copper, total as Cu (mg/l)	0.0041	mg/l	10/11/2022	Y	Cov	WAS076
Zinc, total as Zn (mg/l)	0.009	mg/l	10/11/2022	Y	Cov	WAS076
Strontium, total as Sr (mg/l)	0.29	mg/l	10/11/2022	Y	Cov	WAS076
Cadmium, total as Cd (mg/l)	<0.00007	mg/l	10/11/2022	Y	Cov	WAS076
Lead, total as Pb (mg/l)	0.0007	mg/l	10/11/2022	Y	Cov	WAS076

Analyst Comments for 22202431:

This sample has been analysed for pH, Chloride as Cl, Sulphate as SO4, Solids, Tot Dissolved 180 DegC, Boron, total as B(mg/l), Sodium, total as Na(mg/l), Magnesium, total as Mg(mg/l), Potassium, total as K (mg/l), Calcium, total as Ca(mg/l), Chromium,total as Cr(mg/l), Iron, total as Fe(mg/l), Nickel, total as Ni (mg/l), Copper, total as Cu(mg/l), Zinc, total as Zn(mg/l), Strontium, total as Sr(mg/l), Cadmium, total as Cd (mg/l), Lead, total as Pb(mg/l), Bicarbonate Alkalinity outside recommended stability times. It is therefore possible that the results provided may be compromised.

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For Microbiological determinands 0 or ND=Not Detected, For Legionella ND=Not Detected in volume of sample filtered.
I/S=Insufficient sample   For soil/sludge samples: AR=As received, DW=Dry weight.

Signed:	Name: **P. Patel**	Date: **16 November 2022**	
	Title: **Inorganics Chemistry Manager**		

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Report Number:	**COV/2396999/2022**		Issue	**1**
Laboratory Number:	**22202432**		Sample	**4** of **5**

Sample Source: **Hydrotechnica**
Sample Point Description:
Sample Description: **Sump**
Sample Matrix: **Ground Water**
Sample Date/Time: **21 July 2022** **10:30**
Sample Received: **04 November 2022**
Analysis Complete: **14 November 2022**

Test Description	Result	Units	Analysis Date	Accreditation		Method
pH	8.2	pH units	08/11/2022	Y	Cov	WAS039
Bicarbonate Alkalinity	120	mg/l	08/11/2022	N	Cov	WAS025
Chloride as Cl	31.8	mg/l	08/11/2022	N	Cov	WAS036
Sulphate as SO4	52.2	mg/l	08/11/2022	N	Cov	WAS036
Solids, Tot Dissolved 180 DegC	287	mg/l	09/11/2022	Y	Cov	WAS010
Boron, total as B (mg/l)	<0.06	mg/l	10/11/2022	Y	Cov	WAS076
Sodium, total as Na (mg/l)	22	mg/l	10/11/2022	Y	Cov	WAS076
Magnesium, total as Mg (mg/l)	10	mg/l	10/11/2022	Y	Cov	WAS076
Potassium, total as K (mg/l)	2.2	mg/l	10/11/2022	Y	Cov	WAS076
Calcium, total as Ca (mg/l)	52.3	mg/l	10/11/2022	Y	Cov	WAS076
Chromium, total as Cr (mg/l)	<0.00051	mg/l	10/11/2022	Y	Cov	WAS076
Iron, total as Fe (mg/l)	0.035	mg/l	10/11/2022	Y	Cov	WAS076
Nickel, total as Ni (mg/l)	<0.0010	mg/l	10/11/2022	Y	Cov	WAS076
Copper, total as Cu (mg/l)	<0.0018	mg/l	10/11/2022	Y	Cov	WAS076
Zinc, total as Zn (mg/l)	<0.006	mg/l	10/11/2022	Y	Cov	WAS076
Strontium, total as Sr (mg/l)	0.27	mg/l	10/11/2022	Y	Cov	WAS076
Cadmium, total as Cd (mg/l)	<0.00007	mg/l	10/11/2022	Y	Cov	WAS076
Lead, total as Pb (mg/l)	<0.0003	mg/l	10/11/2022	Y	Cov	WAS076

Analyst Comments for 22202432:

This sample has been analysed for pH, Chloride as Cl, Sulphate as SO4, Solids, Tot Dissolved 180 DegC, Boron, total as B(mg/l), Sodium, total as Na(mg/l), Magnesium, total as Mg(mg/l), Potassium, total as K (mg/l), Calcium, total as Ca(mg/l), Chromium,total as Cr(mg/l), Iron, total as Fe(mg/l), Nickel, total as Ni (mg/l), Copper, total as Cu(mg/l), Zinc, total as Zn(mg/l), Strontium, total as Sr(mg/l), Cadmium, total as Cd (mg/l), Lead, total as Pb(mg/l), Bicarbonate Alkalinity outside recommended stability times. It is therefore possible that the results provided may be compromised.

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For Microbiological determinands 0 or ND=Not Detected, For Legionella ND=Not Detected in volume of sample filtered.
I/S=Insufficient sample   For soil/sludge samples: AR=As received, DW=Dry weight.

Signed:	Name: **P. Patel**	Date: **16 November 2022**	
	Title: **Inorganics Chemistry Manager**		

Certificate of Analysis

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Report Number:	**COV/2396999/2022**	Issue	**1**
Laboratory Number:	**22202433**	Sample	**5** of **5**

Sample Source: **Hydrotechnica**
Sample Point Description:
Sample Description: **Discharge**
Sample Matrix: **Ground Water**
Sample Date/Time: **21 July 2022** **10:21**
Sample Received: **04 November 2022**
Analysis Complete: **14 November 2022**

Test Description	Result	Units	Analysis Date	Accreditation		Method
pH	8.0	pH units	08/11/2022	Y	Cov	WAS039
Bicarbonate Alkalinity	123	mg/l	09/11/2022	N	Cov	WAS025
Chloride as Cl	31.9	mg/l	08/11/2022	N	Cov	WAS036
Sulphate as SO4	53.9	mg/l	08/11/2022	N	Cov	WAS036
Solids, Tot Dissolved 180 DegC	299	mg/l	09/11/2022	Y	Cov	WAS010
Boron, total as B (mg/l)	<0.06	mg/l	10/11/2022	Y	Cov	WAS076
Sodium, total as Na (mg/l)	22	mg/l	10/11/2022	Y	Cov	WAS076
Magnesium, total as Mg (mg/l)	11	mg/l	10/11/2022	Y	Cov	WAS076
Potassium, total as K (mg/l)	2.2	mg/l	10/11/2022	Y	Cov	WAS076
Calcium, total as Ca (mg/l)	53.1	mg/l	10/11/2022	Y	Cov	WAS076
Chromium, total as Cr (mg/l)	<0.00051	mg/l	10/11/2022	Y	Cov	WAS076
Iron, total as Fe (mg/l)	0.027	mg/l	10/11/2022	Y	Cov	WAS076
Nickel, total as Ni (mg/l)	<0.0010	mg/l	10/11/2022	Y	Cov	WAS076
Copper, total as Cu (mg/l)	<0.0018	mg/l	10/11/2022	Y	Cov	WAS076
Zinc, total as Zn (mg/l)	<0.006	mg/l	10/11/2022	Y	Cov	WAS076
Strontium, total as Sr (mg/l)	0.28	mg/l	10/11/2022	Y	Cov	WAS076
Cadmium, total as Cd (mg/l)	<0.00007	mg/l	10/11/2022	Y	Cov	WAS076
Lead, total as Pb (mg/l)	<0.0003	mg/l	10/11/2022	Y	Cov	WAS076

Analyst Comments for 22202433:

This sample has been analysed for pH, Chloride as Cl, Sulphate as SO4, Solids, Tot Dissolved 180 DegC, Boron, total as B(mg/l), Sodium, total as Na(mg/l), Magnesium, total as Mg(mg/l), Potassium, total as K (mg/l), Calcium, total as Ca(mg/l), Chromium,total as Cr(mg/l), Iron, total as Fe(mg/l), Nickel, total as Ni (mg/l), Copper, total as Cu(mg/l), Zinc, total as Zn(mg/l), Strontium, total as Sr(mg/l), Cadmium, total as Cd (mg/l), Lead, total as Pb(mg/l), Bicarbonate Alkalinity outside recommended stability times. It is therefore possible that the results provided may be compromised.

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This issue replaces all previous issues
Accreditation Codes: Y = UKAS / ISO17025 Accredited, N = Not UKAS / ISO17025 Accredited, M = MCERTS.
Analysed at: CHE = Chester(CH5 3US), COV = Coventry(CV4 9GU), OTT = Otterbourne(SO21 2RU), S = Subcontracted, TRB = Subcontracted to Trowbridge(BA14 0XD), WAK = Wakefield(WF5 9TG),
F = Data supplied by customer.
For Microbiological determinands 0 or ND=Not Detected, For Legionella ND=Not Detected in volume of sample filtered.
I/S=Insufficient sample   For soil/sludge samples: AR=As received, DW=Dry weight.

Signed: [signature]	Name: **P. Patel**		Date: **16 November 2022**
	Title: **Inorganics Chemistry Manager**		

ANALYST COMMENTS FOR REPORT COV/2396999/2022 **Issue 1**

This issue replaces all previous issues

Date of Issue: **16 November 2022**

Sample No	Analysis Comments
22202429	This sample has been analysed for pH, Chloride as Cl, Sulphate as SO4, Solids, Tot Dissolved 180 DegC, Boron, total as B(mg/l), Sodium, total as Na(mg/l), Magnesium, total as Mg(mg/l), Potassium, total as K(mg/l), Calcium, total as Ca(mg/l), Chromium,total as Cr(mg/l), Iron, total as Fe(mg/l), Nickel, total as Ni(mg/l), Copper, total as Cu(mg/l), Zinc, total as Zn(mg/l), Strontium, total as Sr (mg/l), Cadmium, total as Cd(mg/l), Lead, total as Pb(mg/l), Bicarbonate Alkalinity outside recommended stability times. It is therefore possible that the results provided may be compromised.
22202430	This sample has been analysed for pH, Chloride as Cl, Sulphate as SO4, Solids, Tot Dissolved 180 DegC, Boron, total as B(mg/l), Sodium, total as Na(mg/l), Magnesium, total as Mg(mg/l), Potassium, total as K(mg/l), Calcium, total as Ca(mg/l), Chromium,total as Cr(mg/l), Iron, total as Fe(mg/l), Nickel, total as Ni(mg/l), Copper, total as Cu(mg/l), Zinc, total as Zn(mg/l), Strontium, total as Sr (mg/l), Cadmium, total as Cd(mg/l), Lead, total as Pb(mg/l), Bicarbonate Alkalinity outside recommended stability times. It is therefore possible that the results provided may be compromised.
22202431	This sample has been analysed for pH, Chloride as Cl, Sulphate as SO4, Solids, Tot Dissolved 180 DegC, Boron, total as B(mg/l), Sodium, total as Na(mg/l), Magnesium, total as Mg(mg/l), Potassium, total as K(mg/l), Calcium, total as Ca(mg/l), Chromium,total as Cr(mg/l), Iron, total as Fe(mg/l), Nickel, total as Ni(mg/l), Copper, total as Cu(mg/l), Zinc, total as Zn(mg/l), Strontium, total as Sr (mg/l), Cadmium, total as Cd(mg/l), Lead, total as Pb(mg/l), Bicarbonate Alkalinity outside recommended stability times. It is therefore possible that the results provided may be compromised.
22202432	This sample has been analysed for pH, Chloride as Cl, Sulphate as SO4, Solids, Tot Dissolved 180 DegC, Boron, total as B(mg/l), Sodium, total as Na(mg/l), Magnesium, total as Mg(mg/l), Potassium, total as K(mg/l), Calcium, total as Ca(mg/l), Chromium,total as Cr(mg/l), Iron, total as Fe(mg/l), Nickel, total as Ni(mg/l), Copper, total as Cu(mg/l), Zinc, total as Zn(mg/l), Strontium, total as Sr (mg/l), Cadmium, total as Cd(mg/l), Lead, total as Pb(mg/l), Bicarbonate Alkalinity outside recommended stability times. It is therefore possible that the results provided may be compromised.
22202433	This sample has been analysed for pH, Chloride as Cl, Sulphate as SO4, Solids, Tot Dissolved 180 DegC, Boron, total as B(mg/l), Sodium, total as Na(mg/l), Magnesium, total as Mg(mg/l), Potassium, total as K(mg/l), Calcium, total as Ca(mg/l), Chromium,total as Cr(mg/l), Iron, total as Fe(mg/l), Nickel, total as Ni(mg/l), Copper, total as Cu(mg/l), Zinc, total as Zn(mg/l), Strontium, total as Sr (mg/l), Cadmium, total as Cd(mg/l), Lead, total as Pb(mg/l), Bicarbonate Alkalinity outside recommended stability times. It is therefore possible that the results provided may be compromised.

Signed: P. Patel

Name: **P. Patel** Date: **16 November 2022**

Title: **Inorganics Chemistry Manager**

DETERMINAND COMMENTS FOR REPORT COV/2396999/2022

ISSUE 1

This issue replaces all previous issues

Date of Issue: 16 November 2022

Sample No	Description	Determinand	Comments

Signed:

Name: **P. Patel**

Date: **16 November 2022**

Title: **Inorganics Chemistry Manager**

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