Groundwater Risk Assessment

for

Llyn Gwynant Campsite Wastewater Treatment and Land Disposal System

- March 2024

Quality Control Sheet

TITLE	Groundwater Risk Assessment
CLIENT	Gwynant Ltd
ISSUE DATE	21 March 2024

Revision History

REV	Date	Status/Purpose	Prepared By	Approved
1	18/5/23	Consent	DG, TG	Peter Garden
2	21/3/24	Updated to include additional Groundwater and Phosphorus Assessment	DG, TG	Peter Garden

Table of Contents

Table of Figures

Table of Tables

Appendices

1.0 Introduction

1.1 Background

Public camping at the northern shore of Llyn Gwynant is recorded to have occurred since at least the early 1900s.

Llyn Gwynant Campsite has been operated by the current owners since 1980 and existing campsite infrastructure has been progressively upgraded since this time, including upgrades to the site wastewater collection, treatment and disposal systems. In 2019 planning permission was granted by Snowdonia National Park Authority for 'Extension to reception building, installation of underground waste treatment tanks and erection of agricultural style building for the processing of firewood' (NP2/11/715D). The installation of the underground treatment tanks was part of the planned upgrade of the existing campsite Wastewater Treatment Plant (WWTP).

This Groundwater Risk Assessment has been prepared in support of a discharge permit from Natural Resources Wales (NRW) for the continued operation of wastewater treatment and land treatment/disposal at the site.

1.2 Status

Revision 1 of this Groundwater Risk Assessment was prepared on 18/5/23.

As requested by NRW in the 'notice requiring further information' ref: PAN-022125 dated 22/2/24, this document has been updated to include:

1. Additional groundwater analysis, including a conceptual groundwater model derived from groundwater boreholes upgradient and downgradient of the site and groundwater quality data; and
2. An assessment of effects of phosphorus on the receiving environment.

This Revision 2 has also been updated for a peak daily flow rate of 60 m^3/d, increased from 50 m^3/d presented in Revision 1. This change was in accordance with changes made during the pre-screening process of the application where NRW noted the 50 m^3/d figure was exceeded in the monitoring data provided on one occasion (refer to Section 3.2 for further details). This updated flow rate is in-line with the design capacity of the WWTP.

1.3 Objectives

The objectives of this report are to:

- Provide an overview of the site setting, including characteristics of the landform, soils, geology and hydrogeology;
- Outline the proposed wastewater treatment and discharge regime including quantifying discharge flows and loads;
- Identify receptors and risks;
- Make recommendations for monitoring.

2.0 Site Setting

2.1 Location

Llyn Gwynant Campsite ('the site') is located in North Wales in Eryri National Park (formerly Snowdonia National Park) adjacent to the northern shore of Llyn Gwynant, Caernarfon, Gwynedd, LL554NW. The Grid Reference for the site is SH649524 and a site location plan is shown in Figure 1.

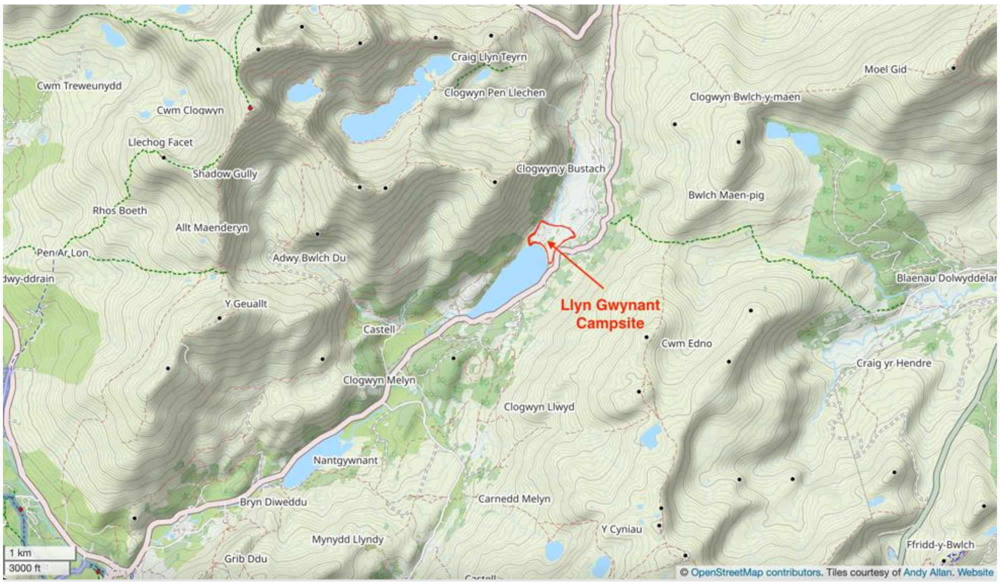


Figure 1: Site Location Plan

2.2 Landform

The site is located in an area of low-lying ground within a valley on the northern shore of Llyn Gwynant east of the Afon Glaslyn.

Retreating glaciers carved out the U-shaped valley and formed the lake, with the site generally situated on glacial deposits and younger alluvium, with elevations from 66.5 m above ordnance datum (m AOD) at lake level, gently sloping up the valley floor to 70 m AOD at the northern site boundary.

Yr Wyddfa (Mount Snowdon) lies approximately 2.5 miles to the NW at an elevation of 1085 m AOD. The peaks east of the site range in elevation from 500 to 70 0m AOD.

2.3 Soil Characteristics

Investigation using the Soilscapes Website[1] as shown in Figure 2 classify the site subsoil as "Loamy and clayey floodplain soils with naturally high groundwater". The adjacent soil type up valley comprises of "Freely draining slightly acid but base-rich soils".

[1] https://www.landis.org.uk/soilscapes/

Test pits dug in 2018 confirmed loamy topsoil extending 0.5 m below ground level over top of layers of silty and clay soils. In some eastern parts of the site there is a peat layer extending from 0.5 m bgl to 1.0 to 2.0 m bgl. Groundwater was measured at 1.0 to 2.0 m bgl across the site.

Percolation testing was undertaken from 6 - 14 May 2023 on three holes 0.3 x 0.3 m in area and 0.5 m deep. The results of the testing together with photographs of the test pits are included in Appendix A. The average percolation value (V_p) from the three holes was 26.7 seconds/mm, indicating that the soils are generally favourable for disposal.

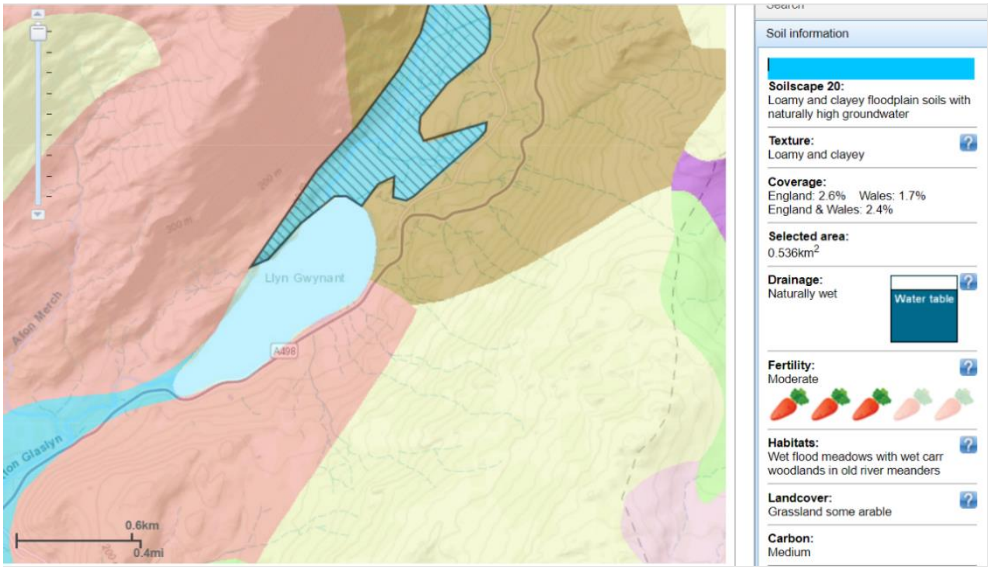


Figure 2: Soil Characteristics

2.4 Geology

The bedrock geology of the site consists of Ordovician volcanic rocks of the Lower Rhyolitic Tuff Formation and the Bedded Pyroclastic Formation, which are part of the Snowdon Volcanic Group. The Snowdon Volcanic Group is complexly deformed in the area around the site, and two inferred faults are mapped as crossing Llyn Gwynant and the campsite (Figure 3).

The superficial geology of the site is mapped as alluvium (Figure 3). Test pits excavated on site to 2 m bgl indicate that the shallow alluvium largely consists of silt and clay (see Appendix B). Areas of glacial deposits (till) and peat are mapped immediately up-valley from the site, while the hillslopes on either side of the valley are mapped as 'head' hillwash and colluvium.

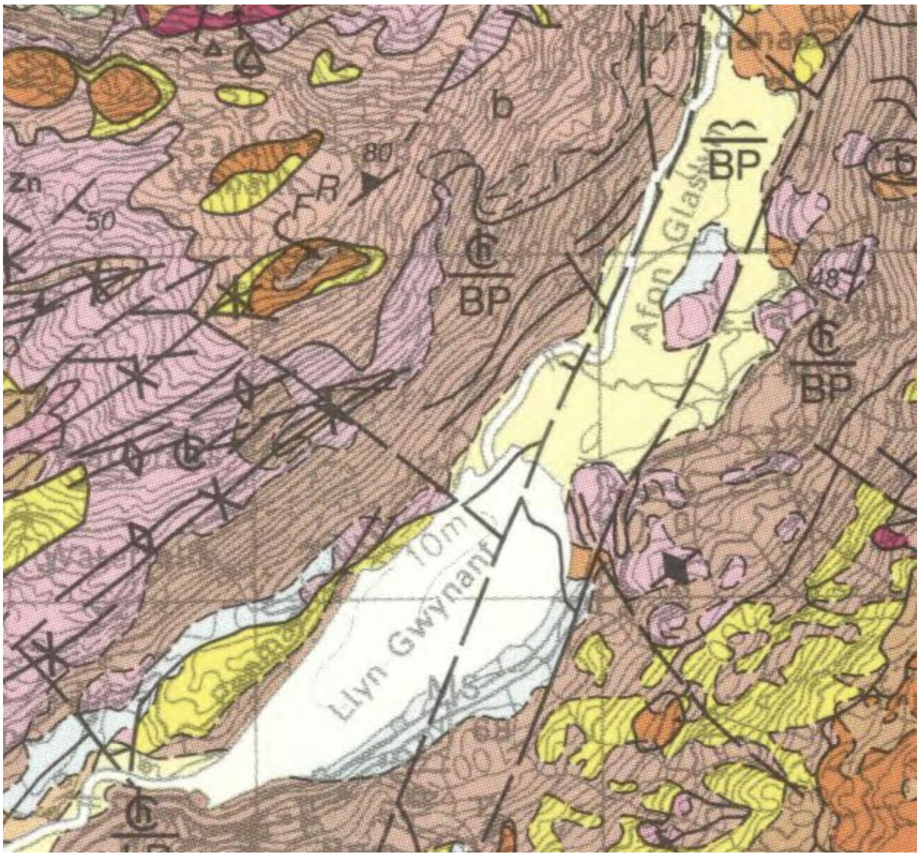


Figure 3: Excerpt from BGS 1:50,000 Series England and Wales Sheet 119, Snowdon, Solid and Drift Geology. Lithologies are coloured as follows: Light yellow – alluvium, blue – till, light brown – head, red – bedded pyroclasitic formation (BP) bedrock, yellow – lower rhyolitic tuff formation (LR) bedrock.

2.5 Hydrology

The site is located within the 66.8 km^2 Afon Glaslyn catchment, where river flows are monitored by the NRW Station 65001 at Beddgelert as shown in Figure 4.

The UK Centre for Ecology & Hydrology's National River Flow Archive[2] describes the catchment as a '…very wet, upland catchment draining southern flanks of Snowdonia with much bare rock exposure (impermeable Silurian volcanics). Otherwise, land use is mostly grassland and rough moorland grazing. Some forest.'

Key hydrological information for NRW's Station 65001 at Beddgelert is presented in Table 1.

[2] https://nrfa.ceh.ac.uk/data/station/meanflow/65001

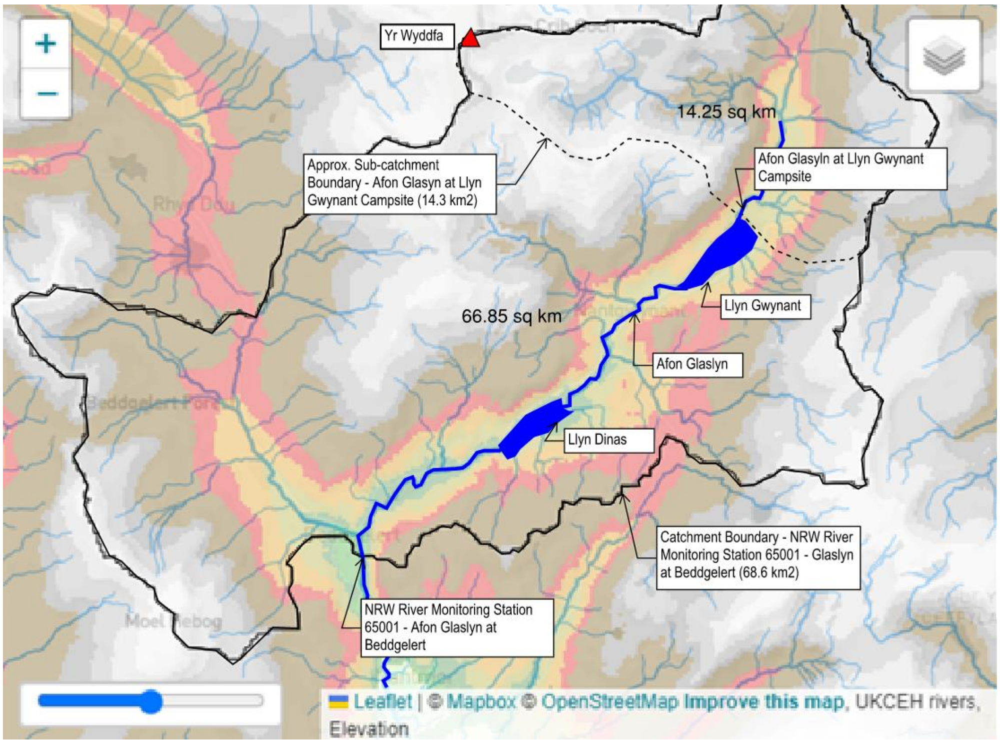


Figure 4: Afon Glaslyn - Catchment Boundary

Table 1: Catchment and Flow Data for NRW River Monitoring Station 65001 – Glaslyn at Beddgelert	
Grid Reference	SH591477
Minimum Altitude	36.60 mAOD
Maximum Altitude	1078.40 mAOD
Catchment Area	66.8 km^2
Station Operating Period	1961 - Present
Mean Flow	5.799 m^3/s
95% Exceedance (Q95)	0.578 m^3/s

The Afon Glaslyn at the site comprises of a 14.3 km^2 sub-catchment which comprises of generally steeper slopes extending up to the summit of Yr Wyddfa. This sub-catchment comprises approximately 21% of the total area of the wider Glaslyn catchment which is also demarcated in Figure 4.

The NRFA web portal includes spatial rainfall data for the catchment as shown in Figure 5. This indicates that the sub-catchment at the site experiences higher average rainfall than the remainder of the Afon Glaslyn catchment. Given the land coverage of the sub-catchment is similar and given the steeper slopes and higher average rainfall of the sub-catchment compared with the wider catchment, applying the 21% coverage area factor to estimate statistical river flows of the Afon Glaslyn at the site provides a conservative (i.e. lower) estimate of river flows. On this basis, the mean and Q95 river flow at the site is conservatively estimated to be 1.2 m^3/s and 0.12 m^3/s respectively.

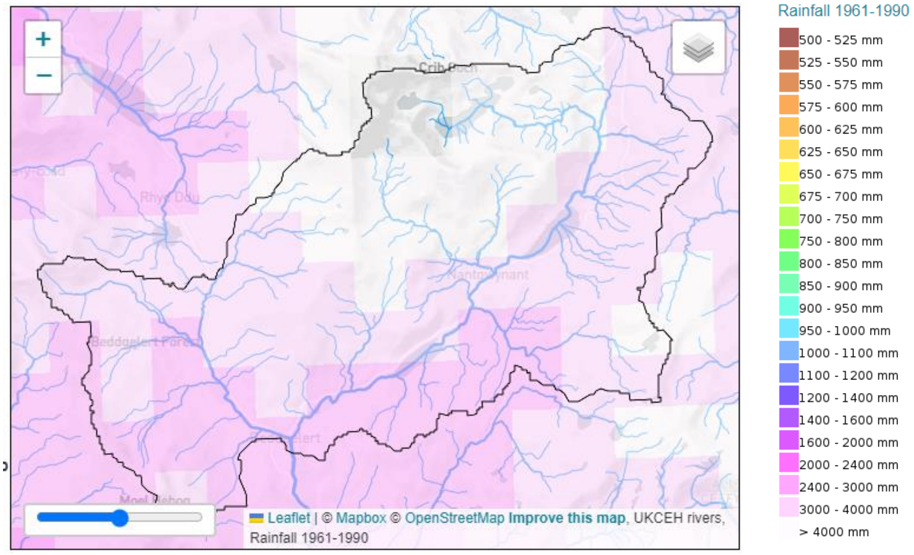


Figure 5: Afon Glaslyn - Catchment Rainfall

2.6 Hydrogeology

Based on the topography of the site, groundwater is expected to generally flow towards Llyn Gwynant, with local variation in the shallow groundwater flow direction due to the presence of drains and streams. A piezometric survey was conducted in May 2023 by concurrently measuring groundwater levels in three monitoring wells in the vicinity of the irrigation area. The survey measured groundwater levels of 0.45 – 1.25 m bgl, and indicated that the groundwater flow direction at the irrigation area is towards the north-west, i.e. towards the Afon Glaslyn. The site-specific hydrogeological setting and conceptual model is discussed in more detail in Section 4.0.

A test pit to 2 m bgl showed that the soils at the irrigation area consist of interbedded silt and clay, which would be expected to be of low permeability. This is generally consistent with other test pits that have been conducted across the wider campsite area. The groundwater level was measured at approximately 1 m bgl in this test pit, the location of which is shown in the Site Plan provided in Appendix B.

Using NRW Mapping, the following was determined for the site location.

2.6.1 Aquifer Maps

The British Geological Survey defines superficial aquifers as “permeable, unconsolidated (loose) deposits, e.g. sands and gravels”. The Superficial Aquifers map shows the site and the remainder of the alluvial valley floor mapped as a

Secondary A aquifer. Secondary aquifers are defined as comprising permeable layers that can support local water supplies and may form an important source of base flow to rivers.

The Bedrock Aquifers map also shows the site and the surrounding area mapped as a Secondary A aquifer.

2.6.2 Source Protection Zones

The mapping shows no Source Protection Zones or Groundwater Safety Zones in the surrounding areas.

2.7 Phosphorus Sensitive Special Area of Conservation (SAC)

The site is located within the upper headwaters of the Afon Glaslyn catchment (Meririonnydd Oakwoods, sub-catchment 'upstream Colwyn') as shown in Figure 6. The site is shown with blue marker. The catchment has been designated as a Special Area of Conservation (SAC) under the Conservation of Habitats and Species Regulations 2017.

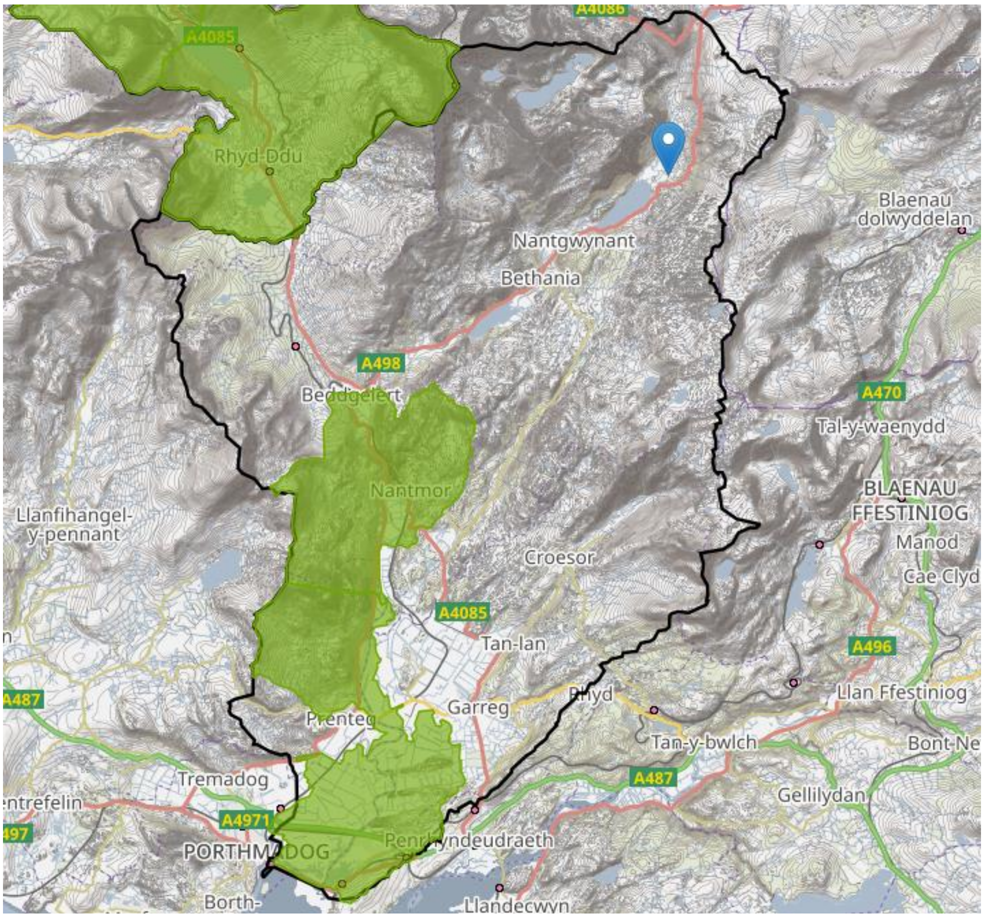


Figure 6: Meirionnydd Oakwoods SAC Catchment[3]

[3] https://datamap.gov.wales/maps/new?layer=inspire-nrw:ComplianceAssessmentOfWelshRiverSacsAgainstPhosphorusTargets#/

In 2021 NRW published a report[4] presenting an assessment of phosphorus loading within SAC rivers, including the Afon Glaslyn, together with proposed phosphorus targets.

This report included the following commentary with regard to the Afon Glaslyn catchment:

> *This is a predominantly terrestrial SAC in northwest Wales. It includes three water bodies in the Afon Glaslyn. The uppermost water body [upstream Colwyn] overlaps only marginally with the site and although a draft target has been set, it may not be required.*
>
> *Data is relatively limited from this site, with only one water body having a large dataset. Insufficient data was available for the Glaslyn – upstream Colwyn water body to make an assessment.*
>
> *There are no phosphorus failures in the Meirionnydd Oakwoods SAC, which therefore **passes** its phosphorus target.*

The NRW report proposes a draft phosphorus target of 5 µg/L orthophosphate as P for the Afon Glaslyn monitoring site 'upstream Colwyn', albeit NRW has noted that this target may not be required. While no annual mean monitoring P data is presented in the report, presumably due to insufficient data, a value of 2 µg/L is presented for the downstream waterbody 'Glaslyn - Nanmor to Colwyn'. This suggests that P loading in the upstream Colwyn water body is likely well within the proposed target.

Conversely, the 2021 NRW report indicates various Welsh SAC rivers which are failing phosphorus targets, and which have been identified for phosphorus neutrality status as discussed in the following section.

2.7.1 Phosphorus Neutrality

As stated on the NRW website[5]:

> *Applicants for Environmental Permits for a water discharge must demonstrate that their proposals are nutrient neutral where they could increase the amount of phosphorus in Special Areas of Conservation (SAC) river and water quality targets for phosphorus are already being exceeded.*

While nutrient neutrality is required for at-risk catchments identified by NRW, the Afon Glaslyn / Meirionnydd Oakwoods catchment is not identified for nutrient neutrality in the NRW published list. This is consistent with the findings of the January 2021 NRW report as described above which suggest in-river P is within target limits.

[4] Natural Resources Wales (2021) Compliance Assessment of Welsh River SACs against Phosphorus Targets, Report No: 489, January 2021

[5] https://naturalresources.wales/guidance-and-advice/business-sectors/planning-and-development/our-role-in-planning-and-development/principles-of-nutrient-neutrality-in-relation-to-development-or-water-discharge-permit-proposals/?lang=en

3.0 Proposal

Llyn Gwynant Campsite is a seasonal operation which typically runs from mid-March to the end of October each year.

The site is licensed for 460 pitches. Wastewater is generated from the onsite toilet blocks as well as from the showers and laundry, kitchen/bar (Cegin), kitchen wash sinks and a campervan waste dump station.

3.1 Wastewater Treatment Plant

The Llyn Gwynant Campsite Wastewater Treatment Plant (WWTP) was upgraded in 2022 and comprises of primary sedimentation, Sequencing Batch Reactor (SBR) activated sludge treatment (i.e. secondary biological treatment), reedbed polishing and UV disinfection.

Design of the plant has been based on process engineering calculations and has used the BioWin software package Version 5.2. Details of the WWTP are outlined in the document Llyn Gwynant Campsite WWTP Site Management Plan (V1, 2023) which was provided together with the discharge permit application.

3.2 Influent Flows and Loads

To reduce the impact on the environment (both water take and discharge) the Campsite uses various water conservation initiatives, including low-volume flush urinals, low-volume flush toilets, push-activation hand basins and timer control of shower duration.

Cooking facilities and kitchen wash-up sinks are limited for the number of tent pitches provided, with much cooking and washing-up taking place on the undeveloped pitches which have local standpipes. Consequently, historical flow monitoring has shown that the volume of wastewater generated at Llyn Gwynant Campsite is less than the default 100 L/person/day as per the British Water Code of Practice Flows and Loads – 4 (COP-4)[6]. Therefore, to accurately size and optimise the performance of the new WWTP and land treatment (irrigation) system the design flows and loads have been based on actual historical flow monitoring and raw influent wastewater characterisation.

Wastewater flows have been recorded since 2019 via a turbine type flow meter and data logger. Figure 7 shows actual daily treated wastewater flows for 2023, with the peak discharge of 51 m^3/d occurring on Saturday 27th August (bank holiday weekend). There were 814 people (adults and children) on site that day. This equates to 63 litres per person per day.

6 https://cdn.ymaws.com/www.britishwater.co.uk/resource/resmgr/publications/codes_of_practice/flows_and_loads___bw_cop_18.pdf

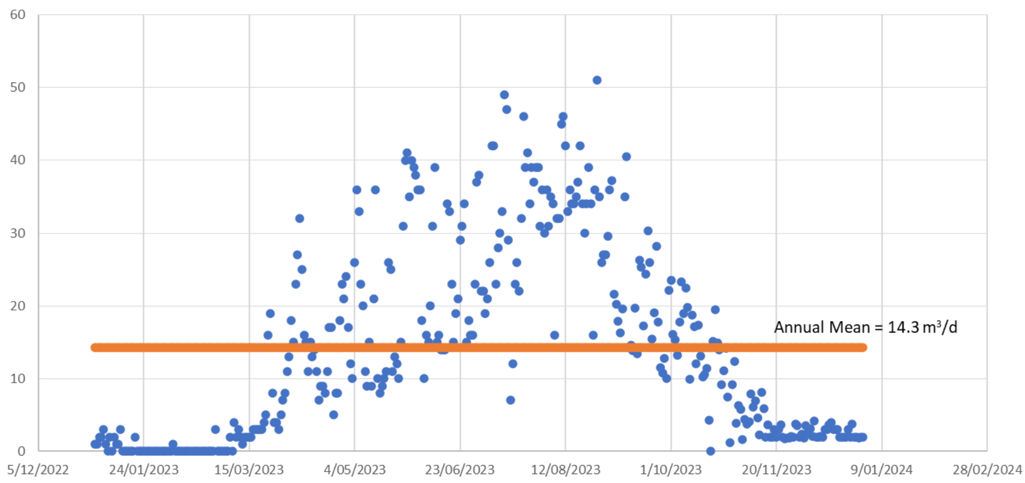


Figure 7: Daily Wastewater Flows (m^3/d) (2023)

As shown on Figure 7, from 1 November through to mid-March wastewater generation is very low, typically < 1 m^3/day. To provide a conservative WWTP design capacity basis, a peak daily flow rate of 60 m^3/d has been allowed.

A raw influent wastewater sampling and analysis programme has been undertaken to characterise influent contaminant concentrations and loads. Samples were collected and sent to ALS Laboratories Ltd for analysis and this data is presented in Appendix D. Grab samples were collected from the first primary sedimentation tank (Primary Tank 1).

The data shows that wastewater concentrations increase during peak occupancy periods. The design basis influent Total Nitrogen (TN) concentration and associated load for sizing purposes has been adopted from the calculated 95th percentile concentration from this dataset. Sampled influent Biochemical Oxygen Demand (BOD) concentrations were lower than the default COP-4 value, which is assumed to be because samples were collected from Primary Tank 1 where some BOD removal has taken place. Therefore, to ensure a conservative design the same % increase over and above the default COP-4 values as was assessed for the TN concentration was applied to the BOD influent concentration. The results of this analysis are summarised in Table 2.

Table 2: Design Influent Loads			
Peak Daily Flow	60 m^3/day		
Average Daily Flow	22 m^3/day during operating season[1] 14 m^3/day annual basis		
Parameter	**Concentration (mg/L)**	**Peak Load During Operating Season (kg/day)**	**Average Load During Operating Season (kg/day)**
BOD	731[2]	44	16.1
TN	152[3]	9.1	3.3
TP	20	1.2	0.4

Notes:

1. *The campsite operating season typically operates from 15 March through to 31 October each year (i.e. 229 days of the year, or 63% of the time).*
2. *Sampled influent BOD concentrations was lower than the default COP-4 value due to the fact that samples were collected from Primary Tank 1 where some BOD removal will have taken place. Therefore, to ensure a conservative design a 46% increase over the COP-4 BOD influent concentration has been applied, to be consistent with the TN analysis as discussed below.*
3. *The sampled TN concentration of 152 mg/L is high compared with COP-4 value of 104 mg/L (46% higher), which is not unexpected given waterless urinals and other water reduction initiatives are practiced at Llyn Gwynant Campsite.*

3.3 Treated Effluent Flows and Loads

The WWTP has been designed to achieve the treated effluent quality and loading limits outlined in Table 3.

As discussed in the Site Wastewater Management Plan, a key feature of the WWTP is that it has been designed for TN removal via an anoxic treatment step using biological denitrification, as opposed to ammoniacal-nitrogen (NH_4-N) removal only via nitrification to nitrate-nitrogen (NO_3-N) as is typical for proprietary packaged onsite wastewater treatment systems. TN removal is provided to further reduce potential adverse impact on the receiving environment as further discussed in Section 4.2.2.

Following secondary wastewater treatment in the SBR activated sludge based WWTP, further treatment is provided via a 200 m^2 vertical flow reed bed (designed and constructed in accordance with BRE Good Building Guide No. 42[7]), 130-micron automated backwashing screen/strainer and UV disinfection. While not typically required for onsite WWTPs in the UK of this size, UV disinfection has been included as a multiple-barrier approach to further reduce public health risks of contact recreation at the Afon Glaslyn and Llyn Gwynant as discussed further in Section 4.3.1.

[7] Good Building Guide 42 Part 2 Reed beds: design, construction and maintenance (2000), BRE.

Table 3: Treated Effluent Loads

Peak Daily Flow	60 m^3/day			
Average Daily Flow	22 m^3/day during operating season[1] 14 m^3/day annual basis			
Parameter	**Concentration Limit (mg/L)**	**Peak Daily Load (kg/day)**	**Average Daily Load During Operating Season (kg/day)**	**Average Annual Load (kg/yr)**
BOD	< 20	1.2	0.44	103
TSS	< 30	1.8	0.66	155
NH_4-N	< 20	1.2	0.44	103
TN	< 50	3.0	1.10	259
TP	< 12	0.7	0.26	62

Notes:

1. *Campsite Operating Season typically operates from 15 March through to 31 October each year (i.e. 229 days per year, or 63% of the time).*

It should be noted that the average annual loads are conservative load estimates which do not account for expected reduced effluent contaminant concentrations during low occupancy periods.

3.4 Land Treatment and Disposal

While Building Regulations H Drainage and Waste Disposal (2010)[8] permits direct discharge of secondary treated effluent from a reedbed/constructed wetland to a watercourse for flows < 20 m^3/d, irrigation to land as proposed provides for further removal of microbial, nitrogen and phosphorus contaminates via land treatment of the discharge within the irrigation area system.

Beneficial reuse of the treated wastewater as irrigation to land provides for nitrogen (N) and phosphorus (P) uptake in the form of grass production within the irrigation area. This beneficial reuse philosophy is consistent with the sustainability strategy of Llyn Gwynant Campsite.

Figure 8 shows a photograph of the land treatment / irrigation area with the downgradient monitoring well in the foreground (right image) and haymaking following mowing (left).

[8] H2 - Wastewater Treatment Systems and Cesspools

Figure 8: Land Treatment System, showing the downgradient MW 3 in the foreground (left), and haymaking (right)

3.4.1 Land Irrigation Infrastructure and Management

Details of the proposed land irrigation infrastructure are summarised in Table 4.

Table 4: Land Disposal System Design Parameters	
Irrigation Area	0.5 ha (5,000 m^2) comprising of 5 No. 1,000 m^2 zones
Irrigation System Design and Construction	Network of Netafim Bioline pressure compensating drip emitter pipes installed 200 mm below ground. Each of the 5 No. zones comprise of 5 No. 100 m long drip lines (0.6 GPM at 0.3 m emitter spacing) installed as per the manufacturer's instructions[9]. Irrigation is controlled by a series of solenoid valves which automatically sequence between zones allowing intermittent irrigation and resting periods. Treated wastewater is supplied to the irrigation area via a below ground wetwell adjacent to the reedbed which is fitted with duty/standby submersible irrigation pumps which deliver flows to the irrigation area at a flow rate of approximately 1 L/s.

The irrigation area is vegetated with grass which is typically cropped once per year and bailed as hay and carted offsite (refer Figure 8). No stock grazing of the irrigation area is proposed, to mitigate against pugging and damage to the soil structure (which could result in enhanced P losses via sediment runoff) as well as damage to subsurface drip line infrastructure. Stock exclusion will further minimise N and P losses associated with livestock urine patches and excrement.

[9] https://www.netafimusa.com/bynder/41497DDE-82FB-4B06-A9F71DCCBA8B4F6B-tdg-techline-design-guide.pdf

3.4.2 Hydraulic Loading

As per the assessment included as Appendix A, percolation testing has demonstrated an average Vp of 27 seconds/mm which indicates that the site is suitable for a conventional drainage field as per the guidelines outlined in Section 1.27 to 1.44 of H2 (i.e. requiring 15 <Vp<100).

Based on the calculation method outlined in the Building Regulations Approved Document H, applying a design population of 800 people, secondary treated effluent, and a Vp of 27 s/mm, the required drainage field size is 4,272 m^2. Therefore, the proposed 5,000 m^2 land treatment area is greater than the minimum sizing in accordance with the above method. Proposed peak daily and average annual hydraulic loading rates are outlined in Table 5.

Table 5: Hydraulic Loading Rates	
Peak Daily Flow[1]	60 m^3/day
Peak Daily Hydraulic Loading Rate[2]	12 mm/day
Average Daily Flow[1]	22 m^3/day during operating season[1] 1 m^3/day when closed[1] 14 m^3/day annual basis
Average Annual Hydraulic Loading Rate[3]	2.8 mm/day (1,020 mm/year)

Notes:
1. *As per the design flows outlined in Table 2.*
2. *By calculation, applying the peak daily flow and an irrigation area of 5,000 m^2.*
3. *Applying the mean annual daily flow of 14 m^3/day and an irrigation area of 5,000 m^2.*

3.4.3 Nutrient Loading

Applying the proposed treated effluent loads outlined in Table 3, and the irrigation field/ land treatment system area of 5,000 m^2, the proposed nutrient loading rates are outlined in Table 6. As stated in Section 3.3, it should be noted that these are conservative load estimates which do not account for expected reduced effluent concentrations during low occupancy periods.

Table 6: Nutrient Loading Rates	
Annual Nitrogen Load[1]	259 kgN/yr
Annual Phosphorus Load[1]	62 kgP/yr

Notes:
1. *Based on the annual treated effluent nutrient loads outlined in Table 2*
2. *Applying the proposed annual treated effluent nutrient loads and an irrigation area of 5,000 m^2 (0.5 ha)*

4.0 Site Conceptual Model

A site conceptual model of the site has been developed using geological, hydrological and hydrogeological data from the site, as well as characterisation of the effluent treatment and land irrigation. The site conceptual model is described using a source – pathway – receptor approach to understand the site, with the land treatment system described to characterise expected contaminant concentrations at the source, a conceptual groundwater model used to determine contaminant pathways, and receptors identified and assessed.

4.1 Land Treatment System

The key potential contaminants of concern for a domestic wastewater discharge such as that at the site are generally microorganisms (with *E.* coli typically used as an indicator organism), nitrogen and phosphorus. Pathogenic microorganisms have the potential to impact human health while nitrogen and phosphorus can potentially cause adverse ecological impacts to surface waterbodies.

The seasonal nature of the proposed treated wastewater discharge from Llyn Gwynant Campsite is well suited for land treatment, as the period of maximum vegetation growth, soil biological activity, reduced precipitation and evapotranspiration coincides precisely with the proposed period of treated wastewater irrigation.

The following sections outline further details regarding removal of specific microbial and nutrient contaminants via the land treatment system.

4.1.1 Microorganisms

Wastewater treatment includes a UV disinfection unit located downstream of secondary (activated sludge) treatment, reedbed polishing and 130-micron automated backflushing filter/strained. This treatment will achieve *E.* coli <1,000 cfu/100mL as confirmed by sampling and analysis of the UV treated effluent in 2023.

4.1.2 Nitrogen Removal

Total nitrogen (TN) within the treated effluent will primarily be in the form of ammoniacal-nitrogen (NH_4-N) and nitrate-nitrogen (NO_3-N), with a smaller fraction of particulate organic-nitrogen and nitrite-nitrogen (NO_2-N). The design effluent NH_4-N and TN concentrations and associated mass loads are outlined in Table 3.

When sufficiently sized to provide sustainable hydraulic and nitrogen loading rates in accordance with the proposed land use, N will be further removed via uptake to vegetation (i.e. grass) within the irritation area. The proposed hydraulic and nitrogen loading rates outlined in Table 5 are considered appropriate to mitigate the risk of effluent ponding on the land. For comparison, the Environmental Agency permits nitrogen loading rates on grass crops up to 300 kgN/ha/year within a nitrate vulnerable zone (NVZ), or 340 kg/ha/yr if the grass is cut at least 3 times in a year[10]. It should be noted however that the Afon Glaslyn is not designated an NVZ.

4.1.3 Phosphorus Removal

Provided the land system is adequately sized, then phosphorus (P) will be further removed within the land treatment system via adsorption to soil particles and via offsite removal associated with the cut-and-carry grass crop.

As discussed in Section 2.7.1, while the discharge is not required to demonstrate phosphorus neutrality, a high-level assessment has nonetheless been undertaken as presented in Table 7.

Table 7: Phosphorus Land Treatment Capacity Assessment

Land Treatment Area[1]	5,000 m^2 (0.5 ha)
Minimum Depth to Groundwater[2]	0.5 m
Mass of unsaturated soil within Land Treatment System[3]	3,750 t
Sorption Capacity of Soil[4]	500 mgP/kg of soil
Sorption Capacity of Land Treatment System[5]	1.9 t P
Annual P Loading Rate[6]	62 kgP/yr
P removal via cut-and-carry operation[7]	9 kgP/yr
Annual P accumulation rate in land[8]	53 kgP/yr
Time period to reach P soil saturation and P breakthrough to groundwater[9]	36 years

Notes:

1. *Proposed irrigation area.*
2. *Based on measured depth to groundwater as per the onsite testing outlined in Appendix B, and applying a conservative estimate of the worst case minimum seasonal groundwater depth*
3. *By calculation, applying the land treatment area, minimum depth to groundwater and an unsaturated soil density of 1,500 kg/m^3.*
4. *Based on literature suggested values for Loamy and clayey floodplain soils[11] as described in Section 2.3 and Appendix B.*
5. *By calculation, applying the mass of unsaturated soil within the land treatment system and the sorption capacity of the soil.*
6. *Loading rate as per Table 5.*
7. *By calculation, assuming a grass production rate of 6 tonnes of dry matter (DM) per hectare per year, and grass P concentration of 0.3% DM*
8. *By calculation, subtracting the annual plant update rate from the annual P load.*
9. *By calculation, applying the sorption capacity of the 0.5 ha land treatment system and the annual P accumulatio rate.*

[10] https://www.gov.uk/guidance/using-nitrogen-fertilisers-in-nitrate-vulnerable-zones

[11] Harrison, A. F.; Howard, D. M.; Lawson, G. J. 1988. *UK Soils: their phosphorus sorption capacity and potential for P removal from sewage effluents in emergent hydrophyte treatment systems.* NERC/Institute of Terrestrial Ecology, 179pp. (ITE Project No: T01014a5)

The assessment outlined in the table above suggests that based on the proposed P loading and soil properties, P losses from the land treatment system to surface water are not predicted to occur for a 36-year period.

On this basis, after 36 years of loading at the proposed rate then the soils underlying the land treatment system will be saturated with P and breakthrough via leaching to groundwater may occur, with P loading to down-gradient surface water. To mitigate against P breakthrough in order to maintain P neutrality of the Afon Glaslyn catchment (albeit this is not strictly required under the existing NRW plan), prior to this time, either an expansion (or replacement) of the land treatment area will be required, or upgrading of the WWTP to reduce effluent P loading. Upgrading of the WWTP to reduce effluent P could include adding chemical dosing (e.g. metal salt such as aluminium sulphate or ferric chloride) for phosphorus precipitation). The design of the WWTP has provisioned for this future upgrade via the installation of underground dosing pipework and spare capacity in the installed PLC control system.

It should be noted that based on this assessment, the proposed land irrigation is reducing the P load to surface water in the order of 62 kgP/yr compared to the alternative of a direct surface water discharge.

4.2 Conceptual Groundwater Model

As discussed in Section 2.6, the site is located in a glacially carved valley that has been infilled by glacial sediments (e.g. till), fine-grained alluvial flood plain sediments (largely silt and clay) and peat deposits. The Afon Glaslyn drains the valley, while Llyn Gwynant is immediately downgradient of the campsite. The Afon Feingam (a tributary to the Afon Glaslyn) drains the hills to the east of the campsite, and flows towards the west, to the north of the disposal area. Various other drains are located across the campsite, the most significant of which is situated approximately 90 m south of the Afon Feingam and flows parallel to it, into the Afon Glaslyn. These features are shown on Figure 9 below.

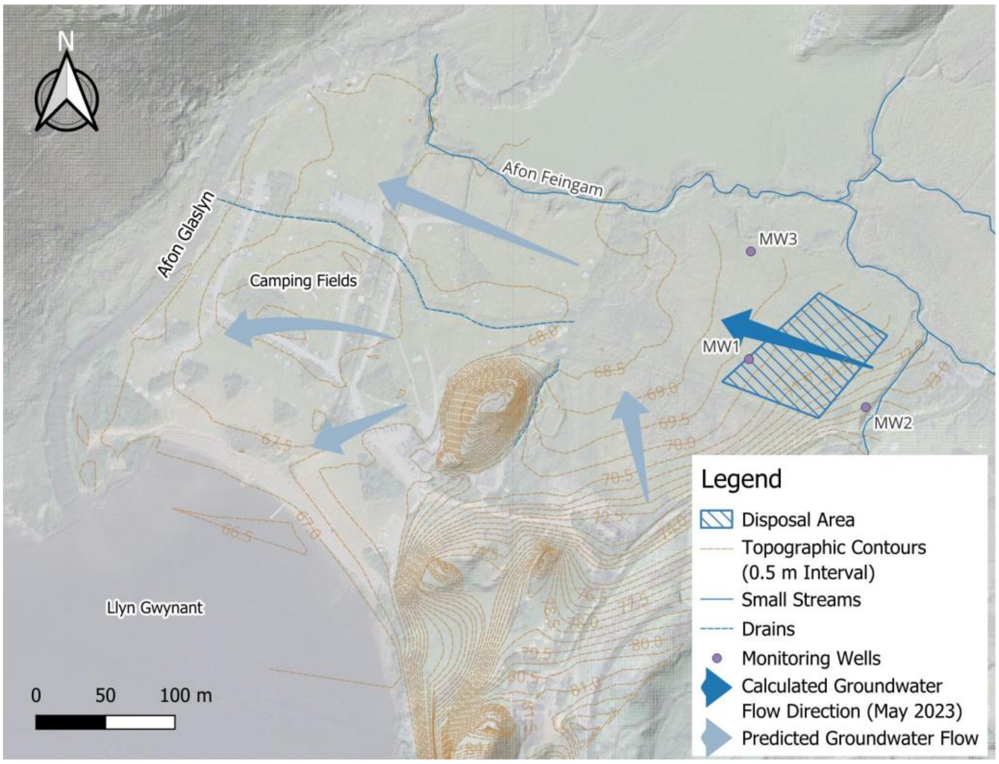


Figure 9: Plan showing key conceptual features relating to groundwater flow and contaminant transport at the site.

The Llyn Gwynant campsite itself (i.e. the camping fields) are located on the flood plain of the Afon Glaslyn, and most of the camping fields are less than two metres above the average level of the river, as indicated by topographic surveys conducted on the site (see topographic contours in Figure 9 above). It is expected that the Afon Glaslyn and Llyn Gwynant will act as near-constant head boundaries for groundwater, and the groundwater table is therefore expected to be shallow beneath the flat flood plain on which the campsite is situated.

The irrigation area is located to the east of the camping fields on topography that slopes towards the Afon Glaslyn, and has a steeper gradient (though still reasonably flat-lying) than the topography of the campsite proper. There are three monitoring wells near the irrigation area, which indicate that groundwater varies from approximately 0.45 – 1.25 m bgl, with generally shallower groundwater towards the west. A piezometric survey was conducted in May 2023 by concurrently measuring groundwater levels in each of the monitoring wells. The survey indicated that groundwater flows towards the northwest, with a relatively shallow hydraulic gradient (approximately 0.037). The calculated groundwater flow direction from the May 2023 survey is shown in Figure 9 above. It is expected that the bedrock mound east of the campsite reception and toilet block prevents groundwater from flowing directly to the lake from the irrigation area. Based on this conceptual understanding of the site, the following contaminant flow pathways from the disposal area are expected:

a. Groundwater flow directly to the Afon Glaslyn (approximately 300 m downgradient) of the disposal area, and surface flow thereafter from the Afon Glaslyn to Llyn Gwynant.

b. Groundwater flow to the Afon Feingam (approximately 100 m downgradient) and surface flow thereafter into the Afon Glaslyn and Llyn Gwynant.

c. Groundwater flow to the central campsite drain (approximately 120 m downgradient) and surface flow thereafter into the Afon Glaslyn and Llyn Gwynant.

4.2.1 Groundwater Velocity

Due to the relatively shallow hydraulic gradient and the silty and clayey soils observed beneath the disposal area (see Appendix A), the groundwater velocity is expected to be low, and relatively little dilution in groundwater due to background throughflow is expected.

An estimate of the groundwater velocity (v) can be made using Darcy's Law:

$$v = -\frac{K}{n_e}\frac{dh}{dl}$$

Where K is the hydraulic conductivity (in m/d), n_e is the effective porosity and dh/dl is the hydraulic gradient. If the fine grained soils beneath the disposal area are assumed to have a hydraulic conductivity of 0.1 m/d (towards the upper range of hydraulic conductivity for silt presented in Freeze and Cherry, 1979[12]) and an effective porosity of 0.01, and the hydraulic gradient is assumed to be 0.037 as described above, then the estimated groundwater velocity is 0.37 m/day. This is considered a conservatively high velocity, as a hydraulic conductivity of 0.1 is considered relatively high for clay or silt, and an effective porosity of 0.01 relatively low for these soils.

4.2.2 Microbial Die-off

Microbial die-off will occur as the treated wastewater travels vertically through the unsaturated soil zone (with unexpected removal rate in the order of 0.53 log_{10}/m as indicated by Pang (2009)[13] in sands), and thereafter via horizontal travel through the underlaying groundwater system before ultimately entering the Afon Glaslyn.

Pedley *et al* (2006)[14] suggests that *E. coli* decay rate in groundwater can be modelled as a first order rate process:

$$ln\left(\frac{C_t}{C_0}\right) = -\mu t$$

[12] Freeze, R.A. and J.A. Cherry, 1979. *Groundwater*. Prentice Hall, Englewood Cliffs, New Jersey, 604p.

[13] Pang, L. (2009). Microbial removal rates in subsurface media estimated from published studies of field experiments and large intact soil cores. *Journal of Environmental Quality*, *38*(4), 1531-1559.

[14] Pedley, S., Yates, M., Schijven, J., West, J., Howard, G., & Barrett, M. (2006). Protecting Groundwater for Health: Managing the Quality of Drinking-Water Sources.

Where *Co* is the initial concentration, *Ct* is the final concentration, *μ* is the inactivation rate, and *t* is time. Pedley *et al* (2006) indicate that *E. coli* inactivation rate can range from 0.32 d^{-1} to 0.84 d^{-1} in water temperatures from 3°C to 22°C. Ignoring any die-off in the unsaturated zone (given this is of limited depth) and applying a conservative inactivation rate of 0.32 d^{-1}, the above model suggests a 37-day decay period will achieve a further 4 log reduction in *E.* coli. Therefore, on this basis assuming *E.* coli in the treated effluent is initially <1,000 cfu/100mL, then by the time this enters surface water via the groundwater system *E.* coli will below the detection limit (i.e. < 1 cfu/100mL).

5.0 Risk Assessment

Based on the assessment above, the downstream receptors for any contaminants emanating from the proposed activity are:

a. Groundwater directly beneath and downgradient of the irrigation area; and

b. Surface Water within the Afon Glaslyn to the west of the irrigation area, upstream of Llyn Gwynant.

5.1 Existing Groundwater Users

NRW GIS mapping shows that the nearest groundwater supply bores are located 1,400 m to the NE at Gwastadannas (bore SH65SE1) and at Hafod Lwyfog (Campsite bore water supply) 300 m to the E (SH65SE2)[15]. The location of these bores in shown in Figure 10.

Figure 10: Map showing nearby groundwater supply bores at Gwastadannas (SH65SE1) and Hafod Lwyfog (SH65SE2).

As shown on Figure 10, the Campsite bore (SH65SE2) is upgradient of the disposal area and 120 m deep, extracting groundwater significantly deeper than the shallow groundwater under the irrigation area. The Gwastadannas bore (SH65SE1) is also upgradient and > 70 m deep.

The depth of these bores and their location upgradient of the site means the risk of impacting on existing groundwater users is expected to be very low.

[15] https://mapapps2.bgs.ac.uk/geoindex/home.html?layer=BGSBoreholes

5.2 Surface Water Receptors

The surface waters of the Afon Glaslyn and ultimately Llyn Gwynant are considered the ultimate receptor for all groundwater that flows from the disposal area. The closest surface water body downgradient of the disposal area is the Afon Feingam, a tributary to the Afon Glaslyn, which is approximately 100 m downgradient of the disposal area.

The Afon Glaslyn has a steep 14.3 km^2 catchment, and is conservatively estimated to have a mean flow of 1.2 m^3/s, as described in Section 2.5. Without accounting for evapotranspiration losses, the effluent discharge volume (an annual mean of 14 m^3/day or 0.16 L/s) is approximately 0.01% of the estimated mean flow of the Afon Glaslyn at the site. This means that significant mixing and dilution will occur of any contaminants (sourced from the irrigation area) present in groundwater that discharges to surface water along the lowest reaches of the Afon Glaslyn or its tributaries.

It should be noted that as the surface waters of the Afon Glaslyn and Llyn Gwynant are expected to be the ultimate receptor of all groundwater flow from the disposal area, analytical approaches used to estimate the concentration at a single point-source groundwater compliance point are not considered to be appropriate.

5.2.1 Microorganisms

As described in Section 4.2.2 above, microbial die-off will occur in groundwater prior to the discharge to surface water and E coli is likely to be undetectable by the time it enters surface water.

5.2.2 Nitrogen

As discussed in Section 4.1.2, the proposed hydraulic and N loading rate is not dissimilar to that typically applied to cut-and carry pasture systems within a nitrate sensitive groundwater zone. Furthermore, given the proposed period of loading will coincide with periods of maximum grass growth (i.e. spring and summer), N losses to groundwater and thereafter to the down gradient Afon Glaslyn is expected to be minor.

Notwithstanding, Table 8 provides a high-level mass-balance estimate of the potential nitrogen impact on the Afon Glaslyn at the site assuming zero N removal was provided by the land treatment system. As N will be removed in the proposed land treatment system as outlined in previous sections, this does not predict the impact on the Afon Glaslyn but rather provides a benchmark for comparison purposes.

Table 8: Hypothetical Nitrogen Impact on Afon Glaslyn Assuming no N Removal in Land Treatment System

Parameter	unit	Total Nitrogen
Annual Discharge Load[1]	kg/yr	259
Average Mass Flux to Surface Water via Ground Water Flow Path[2]	kg/s	8.2×10^{-6}
Predicted Increase in Contaminant Concentration at Average River Flow[3]	kg/m^3	6.8×10^{-6}
	µg/L	6.8

Notes:
1. *From Table 6*
2. *Assuming a mass flux to surface water averaged on an annual basis, with zero removal of N via the land system.*
3. *By calculation, applying the mass flux and the estimated mean annual river flow of 1.2 m^3/s as per Section 2.5.*

As shown in Table 8, with zero N removal via the land treatment system the predicted increase in N concentration in the Afon Glaslyn is in the order of 7 µgN/L. However, with the proposed land irrigation the nitrogen impact on the Afon Glaslyn will be significantly less.

5.2.3 Phosphorus

As outlined in Section 4.1.3, the land treatment system is expected have sufficient P sorption capacity to prevent phosphorus losses to groundwater and thereafter to the downstream surface water receptor for a period in order of 36 years based on the proposed loading. Therefore, the risk of P loading to surface water within this period is very low. This period could be extended with further upgrading of the wastewater treatment plant to remove additional P.

5.3 Public Access

The irrigation area is fenced-off to restrict public access.

Irrigation via sub-surface pressure compensating drippers is proposed in lieu of spray irrigation to reduce risks to the public associated with aerosols and spray drift.

6.0 Monitoring

The following monitoring is proposed:

6.1 Treated Effluent Monitoring

Monitor flow volumes (daily) and quarterly treated wastewater characteristics at the final sampling point within the UV shed, post SBR, reedbed and UV treatment.

Proposed quarterly monitoring would include sampling and laboratory testing for the following parameters:

1. Biochemical oxygen demand (BOD);
2. Total Suspended Solids (TSS);
3. Ammoniacal Nitrogen (NH_4-N);
4. Total Nitrogen (TN);
5. Total Phosphorus (TP); and
6. orthophosphate (reactive) as P.

6.2 Groundwater Monitoring

A series of groundwater monitoring wells have been installed within the land treatment / irrigation field, as well as downgradient and upgradient, which are labelled as follows:

- MW1: Within Land Treatment Area
- MW2: Downgradient
- MW3: Upgradient

The locations of these MWs are shown on the site plan provided as Appendix B and photographs are presented in Appendix C.

Biannual water level measurements and water quality sampling is proposed for each bore, which shall include laboratory testing for the following parameters:

1. NH_4-N
2. orthophosphate as P

Preliminary baseline groundwater water quality information for each groundwater monitoring well is provided as Appendix E.

MW2 could be used to set agreed trigger concentrations, at which point investigative action could be initiated.

6.3 Surface Water Monitoring

Proposed quarterly monitoring at the river and lake includes sampling and laboratory testing for the following parameters:

1. NH_4-N;

2. orthophosphate as P, and
3. E. coli.

Proposed monitoring sites are shown in the site plan provided as Appendix B and preliminary water quality data is presented in Appendix E.

This monitoring could be used to set agreed trigger concentrations, at which point investigative action could be initiated.

Appendix A: Test Pits and Percolation Testing

A 1.85 m deep test pit (TP1) was excavated (see location in Figure A1) on 15 May 2023 to assess the shallow soil profile at the site of the dripline effluent irrigation field. The soils were logged in accordance with the British Standard 5930:2015 and are described in Table 4 below. Photographs of the test pit are provided below (Figures B1 and B2).

Table 4: Soil Profile (TP1)

Depth (m bgl[1])	Description[2]
0.0 – 0.25	Dark brown organic SILT with some rootlets; moist. [TOPSOIL]
0.25 – 0.95	Brown, mottled orange-brown, sandy SILT with minor clay; moist.
0.95 – 1.05	Brown gravelly CLAY with some sand and silt; moist to wet; low to moderate plasticity.
1.05 – 1.85	Bluish grey silty CLAY with some sand and gravel; wet to saturated; low plasticity. At 1.8 m - Contains minor wood and organic silt. Small amount of water inflow at ~1.7 – 1.85 m bgl (<0.1 L/s).

Notes:
1. *Metres below ground level.*
2. *Described according to British Soil Classification System (BS 5930:2015).*

Previous excavations on the site for construction purposes indicate that the bluish grey clay at the bottom of TP1 likely extends to a depth of at least 4 m below ground level and is laterally continuous across the site.

Figure A1 - Excavation of test pit TP1

Figure A2 - Section of TP1

Percolation test results

Treated Wastewater Field Percolation Test and Groundwater Assessment

Job No.
Date
Client Gwynant Ltd
Address: Nant Gwynant, Caernarfon, Gwynedd, LL554NW

Test Hole

Weather conditions	See below for each date		
Ground Conditions	0.3m topsoil, 0.2m slightly clayey loam		
Hole Depth	0.5	m	
Hole Area	0.09	m2	300mm x 300mm
Estimated Groundwater Table Depth	0.7	m	

Saturated all holes to full depth on 6/5/23 - approx 3 to 4 hours to empty. Preliminary assessment of trial hole favourable? Yes
Filled each hole to 500mm then timed from 75% level (375mm) to 25% level (125mm) from bottom of hole

Hole No.	Test Date	Test No.	Time				Drop	Time of Drop	Time to Drop
			Date	Start	Finish	Duration	mm	sec	sec/mm
Hole 1		1	7/05/23	12:59:00	15:50:00	02:51:00	250	5940	23.8
53.05270N 4.01196W		2	9/05/23	15:25:00	19:55:00	04:30:00	250	7560	30.2
		3	14/05/23	11:54:00	16:47:00	04:53:00	250	8940	35.8
Hole 2		1	7/05/23	13:05:00	16:43:00	03:38:00	250	6600	26.4
53.05279N 4.01224W		2	9/05/23	15:35:00	20:15:00	04:40:00	250	8160	32.6
		3	14/05/23	11:57:00	16:31:00	04:34:00	250	7800	31.2
Hole 3		1	7/05/23	13:14:00	14:53:00	01:39:00	250	3780	15.1
53.05299N 4.01288W		2	9/05/23	15:40:00	18:55:00	03:15:00	250	5220	20.9
		3	14/05/23	12:02:00	14:55:00	02:53:00	250	6060	24.2
								Average	26.7

Average time of drop Vp 26.7 sec/mm
Vp > 15 and <100 sec/mm

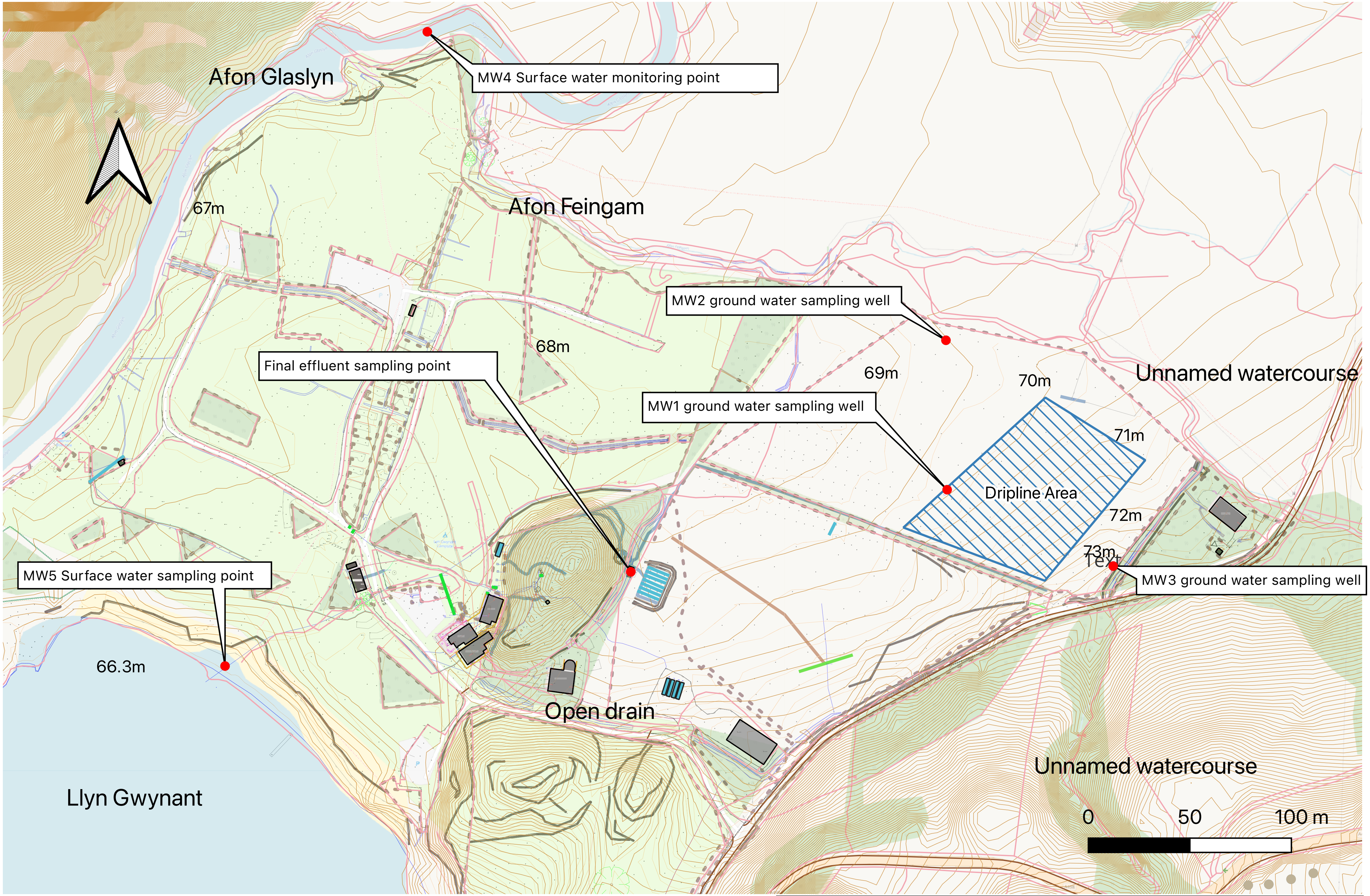
On 7/5 Zone 5 running (near hole 3) until 1pm then Zone 1 (near hole 1)

On 14/5 zone 2 (near hole 1) running until 3pm

Figure A3 - Percolation test hole 1

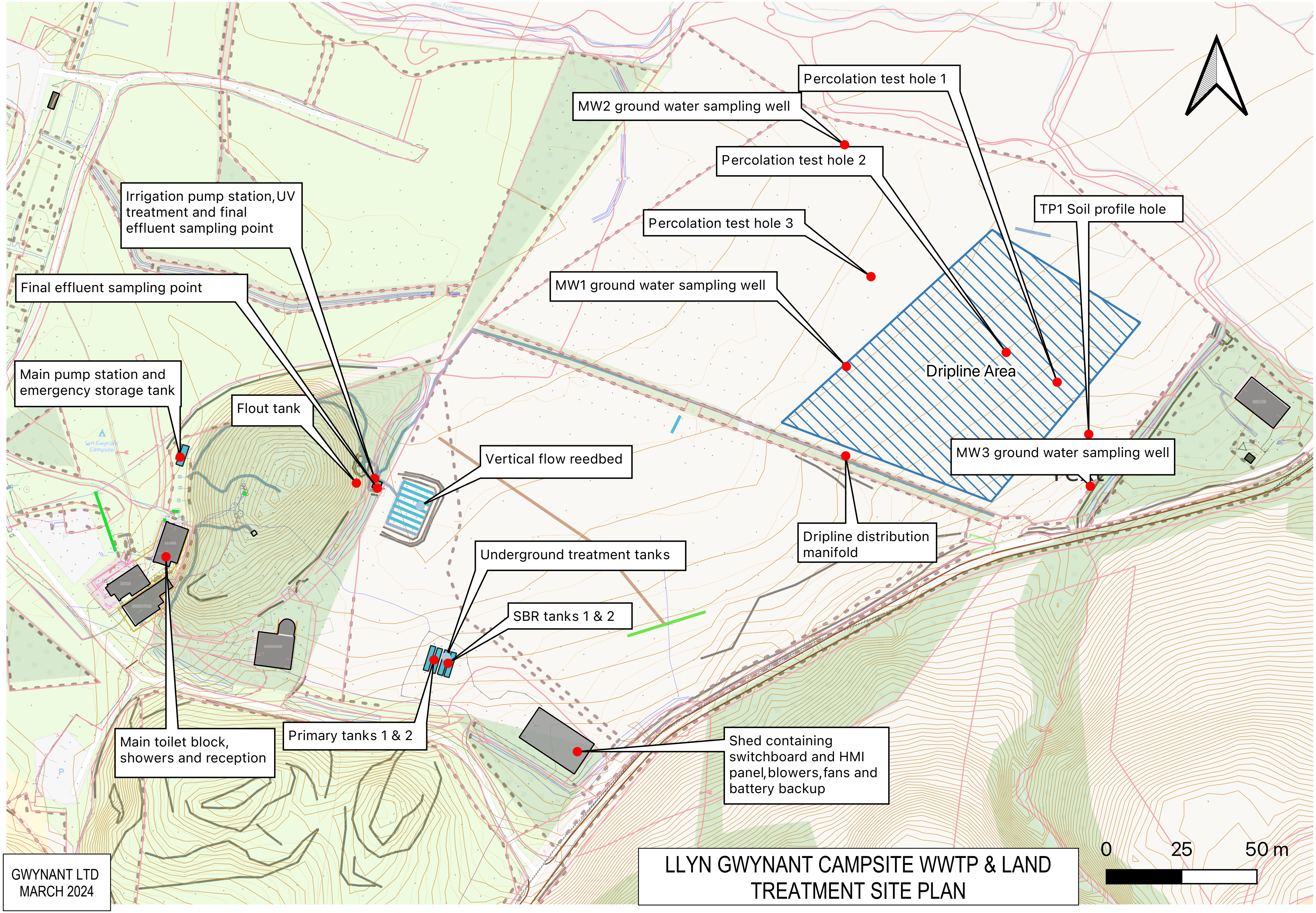
Figure A4 - Percolation test underway

Appendix B: Site Plan



GWYNANT LTD
MARCH 2024

LLYN GWYNANT CAMPSITE OVERALL SITE PLAN - SHOWING PROPOSED MONITORING SITES



LLYN GWYNANT CAMPSITE WWTP & LAND TREATMENT SITE PLAN

GWYNANT LTD
MARCH 2024

Appendix C: Groundwater Monitoring Well Details

Shallow groundwater monitoring wells have been installed in the vicinity of the land treatment / irrigation area. These comprise of DN 100 PVC riser with slotted screens at 2.0 m bgL and backfilled with drainage aggregate at depth and compacted clay soil around the upper 0.5 m. The PVC risers extend approximately 1 m above ground level and are fitted with screw caps.

The site plan provided as Appendix A shows the location of these wells.

Water quality samples can be collected using a 50 mm dia bailers, with samples sent to ALS laboratories for analytical analysis.

Photographs of the WMs is provided below in Figures C1 C2 and C3.

Figure C1 – MW1, within Land Treatment Area

Figure C2 – MW2, Downgradient of Land Treatment Area

Figure C3 – MW3, Upgradient of Land Treatment Area

Appendix D: Influent Characterisation

C 2360807 Gwynant Ltd: Gwynant LTD													
Laboratory Number	Test Ref	Units	21944913	22073124	22097104	22119055	22140828	22164698	Min	Mean	Median	95%ile	Maximum
Customer Sample Ref.			mary Tan	mary Tan	mary Tan	mary Tan	mary Tan	Primary					
Sample Date/Time			3/2022 17:	9/2022 11:4	0/2022 18:0	0/2022 11:3	0/2022 10:0	0/2022 10:4					
Sample Matrix			eated Sev	eated Sev	eated Sev	eated Sev	eated Sev	eated Sev					
pH	WAS039	pH units	7						7	7	7	7	7
Alkalinity as CaCO3	WAS025	mg/l	552						552	552	552	552	552
Ammoniacal Nitrogen as N	WAS036	mg/l	131						131	131	131	131	131
Nitrate as N	WAS036	mg/l	<0.7						1	0.7	1	1	0
Nitrogen as N (Kjeldahl) Calc	WAS022	mg/l	161						161	161	161	161	161
Nitrogen, Total as N	WAS022	mg/l	161	123	88.2	61	63.6	60.1	60	93	76	152	161
Phosphate, Ortho as P	WAS036	mg/l	18.1						18	18	18	18	18
Total Suspended Solids	WAS006	mg/l	158	96	100	105	66	75	66	100	98	145	158
BOD + ATU (5 day)	WAS001	mg/l	407	413	133	240	164	72	72	238	202	412	413
Phosphates, Total as P	WAS076	mg/l	21	17	14	12	10	14	10	15	14	20	21

Appendix E: Groundwater and Surface Water Quality Data

C 1223069 Gwynant Ltd: Llyn Gwynant Campsite

Laboratory Number			**14861392**	**14861395**	**14861396**	**14861397**
Customer Sample Ref.			**1**	**4**	**5**	**6**
Sample Matrix			**Anoxic tank Surface Water**	**Ddol Fawr ground Surface Water**	**River at bridge Surface Water**	**Lake 10m from outfall Surface Water**
Analyte	**Method**	**Units**				
E.coli presumptive	W10	cfu/100ml	N/S	9	11	12
Escherichia coli confirmed	W10	cfu/100ml	N/S	9	18	14
pH	WAS039	pH units	7.8	6.1	6.7	7.1
Alkalinity as CaCO3	WAS025	mg/l	413	N/S	N/S	N/S
Ammoniacal Nitrogen as N	WAS036	mg/l	N/S	<0.41	<0.41	<0.41
Nitrate as N	WAS036	mg/l	N/S	<0.7	<0.7	<0.7
Nitrogen as N (Kjeldahl) Calc	WAS022	mg/l	87.7	5	<0.9	<0.9
Phosphate, Ortho as P	WAS036	mg/l	N/S	<0.6	<0.6	<0.6
Phosphates , Total as P	WAS049	mg/l	N/S	0.93	<0.120	<0.120
Total Suspended Solids	WAS006	mg/l	120	2420	2	4
BOD + ATU (5 day)	WAS001	mg/l	101	103	N/S	N/S