Spink Quarry, Knockbaun, Abbeyleix, Co. Laois

Spink Quarry

Environmental Impact Assessment Report

Section 7

Water

2021

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7 WATER

7.1 INTRODUCTION

This section of the EIAR assesses the impact on the hydrological and hydrogeological environment of the proposed continuation and extension of hard rock quarrying at an existing quarry at Knockbaun, Spink, Co. Laois. The quarry will be referred to as 'the site' for ease of reference throughout this chapter.

The hydrogeological regime of the site is influenced by its position on the north-western periphery of the Castlecomer Plateau. Almost the entire site is underlain by the Castlecomer Groundwater Body (GWB). However, a very small area (approximately 5 %) of the north-western corner of the site is mapped by the GSI as being within the Ballingarry GWB. In order to maintain a dry working subsurface environment on the floor of the quarry, some rainfall-runoff and groundwater will need to be transferred across the site boundary. Such waters will enter local surface waters. In terms of local hydrology, the Water Framework Directive (WFD) sub catchments delineate a surface water divide running broadly north-south through the centre of the site with the Clogh River to the east and the Owveg River (also known as the Owenbeg or Ouveg River) to the west. The Clogh River rises at the site and travels in an easterly direction. The mapped area of the River Barrow and River Nore Special Area of Conservation (SAC; Site Code 002162) commences at 1 km, approximately, NW of the site's most western boundary. All surface waters in this headwater segment of the landscape ultimately drain to the River Nore SAC, which is home to the Freshwater Pearl Mussel (*Margartifera durrovensis*). The significance of hydrological and hydrogeological setting is therefore acknowledged.

Waters leaving the site will be managed by way of a Discharge Licence. An existing Discharge Licence is attached to the site (ENV2 WP27) although a new application will be submitted to Laois County Council because the existing Licence is in the previous owner's name. Lagan Materials Ltd (Lagan) who are part of the Breedon Group, acquired the site in 2014 and there has been no quarrying of rock at this location since then. The hydrological and hydrogeological appraisals and the impact assessment presented in this work support the case for a new Discharge Licence for the site. In terms of water quality and flow, the proposed surface water management system has been designed cognisant of the relevant national assessment guidelines (DoEHLG 2011, EPA 2011) and Regulations, namely the Groundwater Regulations (2010, as amended 2011, 2012, 2016), Surface Water Regulations (2009, as amended 2019), Freshwater Pearl Mussel Regulations (2009, as amended 2018), and Birds and Natural Habitats Regulations (2011).

7.1.1 PLANNING CONTEXT

The quarry is currently permitted under P.A. Ref. 10/383 which is for a 10 year period to work the quarry, plus two years for final re-instatement works, unless, prior to the end of the period, planning permission has been granted for its extension for a further period.

The site or permitted area for quarrying under PA. Ref. 10/383 covers c. 26.6 ha. Part of the unworked permitted area to the northwest has been sold and the revised landholding and quarry now covers c. 20 ha., which is in the ownership of the applicant. Figure 7.1 presents the site area and its regional setting.

7.1.2 PROPOSED DEVELOPMENT

The development will consist of the continued use and operation of the existing quarry including deepening of the quarry. Extraction will be confined to the existing permitted quarry area (P.A. Ref. 10/383) comprising an extraction area of c. 14.5 ha within an overall application area of c. 19.6 ha. The development will include provision of new site infrastructure, including portacabin site office, canteen, toilets, concrete batching plant and truck washdown facility, hydrocarbon interceptors, mobile crushing and screening plant, upgrading of the water management system, provision of holding tank for wastewater, and other ancillaries. The proposed development will utilise/upgrade the existing in-situ quarry infrastructure, including site access, internal roads, storeroom, wheel wash, weighbridge, aggregate storage bays, refuelling hard stand, water settlement pond system, and other ancillaries (Refer to Figure 1.3).

It is proposed that the quarry will be worked in a series of benches (typically 10 to 20 metres) down to a final depth of 200 m AOD in the western quarry area and 190 m in the eastern quarry area (Refer to Figures 3.1 and 3.3). The development will see the extraction of both the Clay Gall Sandstone Formation and Coolbaun Formation, which overlies the Clay Gall sandstones to the east of the existing quarry sump.

There will be no changes to the method of extraction and processing as a result of this planning application. Drilling and blasting will continue to be utilised with processing of extracted rock using mobile crushing and screening plant located within the quarry void. The broken rock will be excavated by a combination of either a wheeled loading shovel and/or excavator. Once loaded, the excavated rock will be taken directly to the mobile crushing plant. Processed material will be sold as aggregate or used on-site to manufacture concrete, or off-site to manufacture asphalt products.

Plant and machinery that operate at the application area will consist of tracked excavators, wheeled loaders and mobile processing plant. Ancillary plant, such as a drilling rig and a water bowser, will be deployed on an intermittent basis.

A series of established settlement ponds and a discharge area are specified in the site's existing Discharge Licence, ENV2 WP27. The Water Management Plan, capacity of the settlement ponds and mechanisms of discharge are presented in this EIAR chapter.

A Restoration & Landscape Plan for the site has been compiled. Full details for the Restoration Plan are presented in Section 3.4 of this EIAR. The final site restoration will contain a landscaped woodland / amenity with water feature.

The intention is to create a habitat suitable for aquatic life and birds, such that the disused workings will eventually become of considerable amenity value. Some of the methods to be employed are detailed on the Restoration Plan Figure 7.2.

In summary, the final restoration will consist of the following:

- Landscaping works will be undertaken during the working life of the quarry, where required;
- At the end of quarrying, all plant and machinery will be removed off the site;
- All site boundaries will be secured;
- Additional planting of trees and shrubs may be necessary in some areas; and
- The water abstraction pumps will be switched off and groundwater levels will be allowed to return to the current inactive regime at which sump water levels will be maintained by way of an existing overflow to natural existing drainage channels.

7.1.3 STATEMENT OF EXPERTISE

The Water Chapter of the EIAR has been completed collaboratively between Dr. Pamela Bartley (Hydro-G) and Dr. Colin O'Reilly (Envirologic).

Dr. Pamela Bartley is a water focussed civil engineer with 24 year's field-based practice in groundwater, surface water and wastewater. Upon completion of a Diploma in Water and Wastewater Technology at Sligo RTC, Pamela completed her primary degree in Civil Engineering at Queen's University, Belfast, followed by postgraduate education at the School of Civil Engineering at Trinity College, Dublin. While a postgraduate at TCD, she completed a MSc. in Environmental Engineering at the School of Civil Engineering, with geotechnical, hydrogeological, legislation and water specialities, and later a hydrogeologically focussed Ph.D. As a result of her work in evaluating planning appeals, Pamela has become a specialist in quarry and discharge evaluations in the context of enacted Irish Regulation and EU Directives concerning the environment, such as the Groundwater Regulations (2010, 2011, 2012, 2016), Surface Water Regulations (2009, 2012, 2015), EU (Birds and Natural Habitats) Regulations (2011), and Water Framework and Habitats' Directives. She has completed hydrologically focussed impact assessments for many regionally important quarries in SAC settings, including catchments with habitats for the designated species pearl mussel and vertigo. Pamela's significant quarry assessments of note include Bennettsbridge Limestone, Co. Kilkenny, McGrath's Limestone of Cong, Cos. Galway and Mayo, Cassidy's of Buncrana, Co. Donegal, Harrington's of Turlough, Co. Mayo, Ardgaineen, Co. Galway and Mortimer's of Belclare, Co. Galway. Each of these quarries operate within SAC catchments and have successfully managed their discharge, under licence, for many years.

Pamela's key work areas include the development of large-scale public supply water boreholes, surface water and groundwater assessments with a discharge focus, soil systems, soil hydrology and hydrogeological evaluations for quarries with a specific regulatory focus on water and ecological constraints. Pamela is qualified and IOSH certified to act as Project Supervisor Design Phase (PSDP) and Project Supervisor Construction Stage (PSCS) as defined in the Construction Regulations. The company is a registered Irish Water Supplier (no. 1855), Pamela Bartley is HSQE approved within Irish Water and is one of their Hydrogeologist service providers. She is a professional member of Engineers Ireland and International Hydrogeologists (Irish Group).

Dr. Colin O'Reilly has over 15 years of professional experience as a hydrogeologist coupled with a doctorate degree in hydrology, awarded by the Centre for Water Resources Research, School of Architecture, Landscape and Civil Engineering, UCD, while a recipient of a Teagasc Walsh Fellowship. Colin's company is Envirologic, which has key competencies in hydrogeology and hydrology with expertise in flood assessments in addition to assessment of quarries across a range of diverse hydrogeological conditions across Ireland. Colin is a current and active member of Engineers Ireland and International Association of Hydrogeologists (Irish Group). Pat Breheny MSc (Hydrogeology) PGeo. Works with Colin O'Reilly in Envirologic. Pat completed much of the monitoring, sampling, hydrogeological response investigation works and the analysis and interpretation of the field data at Spink Quarry. Patrick Breheny has 12 years of post-graduate experience in environmental consultancy having worked extensively in Ireland and the UK, with a background specialising in hydrogeology, hydrology and contaminated land. Patrick holds a Master of Science Degree (MSc) in Hydrogeology which he attained at the University of Leeds, UK. He is a member of the International Association of Hydrogeologists (IAH) and is a Chartered Geologist, as awarded by the Institute of Geologist Ireland (IGI). Working as a senior hydrogeologist, Patrick's key skills and experience include site investigation, groundwater resources, risk assessment, groundwater remediation, environmental permitting and management and liability assessment for soil and groundwater remediation projects.

Examples of recent relevant projects completed by Envirologic include:

- Hydraulic capacity assessment and flood risk assessment relating to six crossings on R181 prior to road upgrade works, Shantonagh, Co. Monaghan (client: Monaghan County Council);
- Hydrological assessment relating to proposed drainage channel upgrade and maintenance works on a 5.3 km stretch of a river and its tributaries, Oranmore, Co. Galway (client: Galway County Council); and
- Design and specification of a flood alleviation scheme to include a new quarry discharge route from an active limestone quarry, Co. Galway.

Both Hydro-G and Envirologic hold the required Professional Indemnity Insurances, Employers and Public Liability Insurances.

7.1.4 OBJECTIVES

The objectives of this 2021 assessment are to:

- Provide baseline hydrogeological and hydrological conditions for the site and the surrounding area, within the footprint of the site and update previous assessments based on additional drilling, aquifer testing, water quality monitoring and discharge route assessments;
- Assess the potential impact of the proposed development on the underlying groundwater aquifer and associated surface water bodies, including assimilation capacity simulations with respect to the proposed quarry water's arisings that will require discharge licensing;
- Identify potential risks and impacts and provide appropriate mitigation measures for any identified potential impacts, as deemed necessary; and
- Consider and address hydrological & hydrogeological issues raised in scoping consultations returned by all competent authorities and historic items identified in considerations by NPWS and An Bord Pleanála.

7.1.5 PLANNING GUIDANCE DOCUMENTS & LEGISLATIVE REQUIREMENTS

This report was prepared with consideration of the following guidance documents and ensuring compliance with Irish Regulations, listed as follows:

- River Barrow and River Nore SAC 002162 Conservation Objectives (NPWS 2011);
- Groundwater Regulations: European Communities Environmental Objectives (Groundwater) Regulations, 2010. S.I. No. 9 of 2010, as amended 2019 as S.I. No. 366 of 2019;
- European Communities (Birds and Natural Habitats) Regulations, 2011. S.I. No. 477 of 2011;
- European Communities Environmental Objectives (Surface Waters) Regulations 2009 Statutory Instruments S.I. No. 272 of 2009, as amended 2012 (S.I. No. 327 of 2012), 2015 (S.I. No. 386 of 2015) and 2019 (S.I. No. 77 of 2019);
- Guidance on the Authorisation of Discharges to Groundwater (EPA 2011);
- Guidance on Licensing of discharges to Surface Waters by Local Authorities (LASNTG 2011);
- Guidelines on the information to be contained in Environmental Impact Statements (EPA 2002);
- Geology in Environmental Impact Statements: A Guide (IGI 2002);
- Guidelines for the Preparation of Soils, Geology & Hydrogeology Chapters of Environmental Impact Statements, Institute of Geologists of Ireland (IGI 2013);

- Revised guidelines on the information to be contained in Environmental Impact Statements. Environmental Protection Agency (2015);
- Guidelines on the information to be contained in Environmental Impact Assessment Reports. Environmental Protection Agency (2017);
- Guidelines for Planning Authorities and An Bord Pleanála on carrying out Environmental Impact Assessment. Department of Housing, Planning and Local Government (2018);
- Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes, NRA @ https://www.tii.ie/technical-services/environment/planning/Guidelines-on-Procedures-for-Assessment-and-Treatment-of-Geology-Hydrology-and-Hydrogeology-for-National-Road-Schemes.pdf;
- Environmental Management Guidelines for the Extractive Industry (Non-Scheduled Minerals) (EPA 2006);
- Quarries and Ancillary Activities – Guidelines for Planning Authorities, Dept. of Environment, Heritage and Local Government (2004);
- Lyons, M.D. & Kelly, D.L. (2016) Monitoring guidelines for the assessment of petrifying springs in Ireland. Irish Wildlife Manuals, No. 94. National Parks and Wildlife Service, Department of Arts, Heritage, Regional, Rural and Gaeltacht Affairs, Ireland:
  - National Parks and Wildlife Service (NPWS). Database of Special Areas of Conservation, National Heritage Areas, National Parks, Special Protection Areas including site synopsis reports;
  - WFD Working Group (2004) Guidance document no. GW3: The Calcareous/Non-calcareous ("siliceous") Classification of Bedrock Aquifers in the Republic of Ireland;
  - WFD Working Group (2004) Guidance document no. GW5: Guidance on the Assessment of the Impact of Groundwater Abstractions;
  - Using Science to create a better place: hydrogeological impact appraisal for dewatering abstractions. Environment Agency, Science Report – SC40020/SR1. Bristol, UK, 2007. Authors: Boak, R. et al;
  - Reclamation Planning in Hard Rock Quarries. University of Sheffield (2004). Department of Civil & Structural Engineering. Edge Consultants, Mineral Industry Research Organisation; and
  - A Quarry Design Handbook. 2014 Edition. GWP Consultants and David Jarvis Associates Limited, UK.

7.2 IMPACT ASSESSMENT METHODOLOGY

In the course of this assessment, we have considered and integrated information relating to the region, local area and site, as follows:

- Desk study;
- Site walkover and local area visual survey;
- Site investigations including piezometer installations with continuous water level data loggers, drilling of large diameter wells for aquifer pumping tests, groundwater and surface water quality sampling for hydrochemical evaluations, groundwater and surface water level recording, flow measurements and cross-sectional survey of receiving survey waters; and
- Data analysis including quantification of aquifer characteristics to inform potential future dewatering requirements, establishment of groundwater and surface water level and flow regimes, design specifications for effective mitigation measures, e.g., settlement pond system, determination of hydraulic capacity of receiving waters, determination of chemical status of receiving waters and ability to assimilate discharge waters.

Ultimately, each of the components listed above were used to develop a hydrogeological Conceptual Site Model for the site and the local surrounding area. The hydrogeological Conceptual Site Model was then used to populate a hydrogeological Risk Assessment Framework.

The assessment of impacts within this chapter was carried out with respect to the hydrogeological and hydrological environment. Within this chapter, potential impacts were considered to be the effects resulting from changes to the environment by the proposed development. Impacts were assessed in terms of scale, i.e., imperceptible, not significant, slight, moderate, etc., and mitigation measures were proposed, if necessary.

The significance of potential impacts on geological, hydrogeological and hydrological sensitive receptors was estimated by implementing an assessment as per the Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes (NRA 2008) and the Guidelines for the Preparation of Soils, Geology & Hydrogeology Chapters of Environmental Impact Statements (IGI 2013). Those assessment frameworks require input of the project's groundwater and geological type attributes and measures to determine the magnitude of the impact on the attribute.

In the absence of Irish Competent Authority guidance specific to hydrogeological impact assessment and quarry dewatering appraisals, the UK practical guidance as published by the UK Environment Agency (the public body equivalent of the Irish EPA) has been adopted in this work: that guidance document is cited as Boak et al. (2007) Using Science to create a better place: hydrogeological impact appraisal for dewatering abstractions. (Environment Agency, Science Report – SC40020/SR1) and the approach is succinctly outlined by the EA (2007) as follows:

"The methodology for hydrogeological impact appraisal (HIA) is designed to fit into the Environment Agency's abstraction licensing process. It is also designed to operate within the Environment Agency's approach to environmental risk assessment, so that the effort involved in undertaking HIA in a given situation can be matched to the risk of environmental impact associated with the dewatering. The HIA methodology can be summarised in terms of the following 14 steps:

- ***Step 1:*** Establish the regional water resource status.
- ***Step 2:*** Develop a conceptual model for the abstraction and the surrounding area.
- ***Step 3:*** Identify all potential water features that are susceptible to flow impacts.
- ***Step 4:*** Apportion the likely flow impacts to the water features.
- ***Step 5:*** Allow for the mitigating effects of any discharges, to arrive at net flow impacts.
- ***Step 6:*** Assess the significance of the net flow impacts.
- ***Step 7:*** Define the search area for drawdown impacts.
- ***Step 8:*** Identify all features in the search area that could be impacted by drawdown.
- ***Step 9:*** For all these features, predict the likely drawdown impacts.
- ***Step 10:*** Allow for the effects of measures taken to mitigate the drawdown impacts.
- ***Step 11:*** Assess the significance of the net drawdown impacts.
- ***Step 12:*** Assess the water quality impacts.
- ***Step 13:*** If necessary, redesign the mitigation measures to minimise the impacts.
- ***Step 14:*** Develop a monitoring strategy.

The steps are not intended to be prescriptive, and the level of effort expended on each step can be matched to the situation. Some steps will be a formality for many applications, but it is important that the same thought-process occurs every time, to ensure consistency. The methodology depends heavily on the development of a good conceptual model of the dewatering operation and the surrounding aquifer. The steps of the methodology are followed iteratively, within a structure with three tiers, and the procedure continues until the required level of confidence is achieved. Advice is also given on how to undertake HIA in karstic aquifers and fractured crystalline rocks." Boak et al. (2007).

While there are the Irish EPA's 'Environmental Management Guidelines for the Extractive Industry (Non-Scheduled Minerals)' (EPA 2006), Hydro-G and Envirologic also employ hard rock specific guidance, as follows:

- **Reclamation Planning in Hard Rock Quarries.** University of Sheffield (2004). Department of Civil & Structural Engineering. Edge Consultants, Mineral Industry Research Organisation; and
- **A Quarry Design Handbook.** 2014 Edition. GWP Consultants and David Jarvis Associates Limited, UK.

Hydro-G has adopted and applied the thought process and applied knowledge of how groundwater moves in Irish aquifers in order to present a reasoned assessment of the potential for impact that might arise in response to deepening excavations at the site.

7.2.1 STUDY METHODOLOGY

For additional detail, the study areas listed above are comprised of the following components:

1. Comprehensive desk study including as follows:
    i. Review of all EPA, GSI and NPWS information for the local area and wider region;
    ii. Review of detailed Geological Assessment Report including rotary core borehole logs (4 no.) reported by SLR (2020);
    iii. Water quality and discharge volume records for the existing Discharge Licence ENV2 WP27;
    iv. Available flow and level data from EPA/OPW hydrometric stations;
    v. Information relating to Public and Group Water Schemes;
    vi. Evaluation of groundwater usage and water supplies in the area using Laois County Council's ePlanning system which provides comprehensive information of local houses and their water supply (Covid lockdown restricted some aspects of house to house surveys);
    vii. Historical assessments under previous planning applications, evaluation by the Board under planning reference PL 11.130640 and any other information of note locally, for example, applications to Laois County Council for Wind Farms in the wider area;
2. Site walkover and local area visual survey. A walkover survey of the application site and surrounding area was undertaken by Hydro-G and Envirologic on multiple occasions between Winter 2020 and Summer 2021. Assessment of the landscape position, surrounding lands and dwellings was undertaken to better understand topography and geological patterns. Features of hydrological and hydrogeological significance were identified and used as a basis for discussing sources, pathways and receptors that the study should focus on. The local area and locations of water schemes in the wider regional context was evaluated and the mapped Source Protection Zone for the Swan Water Supply was visited;
3. With respect to hydrology and hydrogeology, Hydro-G and Envirologic completed a field programme that involved surveying and description of groundwater and surface water systems in the vicinity of the site. Field-gathered information was combined with available State hydrometric and hydrochemical data. Site investigations were undertaken between December 2020 and June 2021, and involved the following key components:
    i. In 2020, SLR completed a Geological and Resource Assessment for the site (Appendix 6). Four rotary core boreholes were drilled and the lithology

logged and described. Two of the rotary core boreholes were converted to long-term monitoring piezometers and water level dataloggers were permanently installed;

ii. Upon review of the SLR Site Investigation borehole logs and the numerous mapped local domestic wells, Hydro-G designed a production well drilling programme to truly test, by pumping test, the potential for future dewatering needs and local area impact. That drilling programme was completed in February 2021. Three 8" diameter 'Production Wells' were drilled in three working days of the 18th, 19th and 22nd February 2021. The results of the Production Well drilling and BH logs and field collected information of note are presented in Appendix 7.1;

iii. Pumping tests were performed on each of the large diameter wells to characterise the bedrock aquifer in terms of hydraulic conductivity and transmissivity. These values were used to inform future potential dewatering requirements;

iv. Sequential water quality sampling and analysis was done to inform baseline condition and assimilative capacity of receiving waters. Historically, the site was required to sample waters as part of the Conditions of the Discharge Licence ENV2 WP 27. In response to a request to Laois County Council's Environment Section, the historic data were not available for the site. With respect to the quality of the water environment, Hydro-G commenced water sampling and quality evaluations in December 2020 and these continued into Spring/Summer 2021;

v. Design and specification of a surface water management plan to include settlement ponds, treatment of discharge waters, and process water management; and

vi. Survey and record flow characteristics in the local streams and surface water drainage networks in order to create a hydrological model to quantify the hydraulic capacity and headspace to accommodate and convey the envisaged discharge from the site.

With respect to site investigations informing future management proposals for the site, it is noted that the site has previously operated with a Discharge Licence limited to 8,000 litres/day and discharge was to groundwater (ENV2 WP27). The appropriateness of this 8,000 l/d estimated limiting value (ELV) for volumetric discharge will be evaluated in this chapter. In the context of site area, hydrogeological characteristics and rainfall, design proposals shall be informed by new evaluations.

There is no historical information available from Laois County Council describing rates and quality of water's arising during the site's operation prior to the current owner's (Lagan) acquisition of the site. Lagan are applying for planning permission for continuance of use and deepening of the existing quarry at the site.

7.2.2 DESK STUDY SITE INFORMATION RESOURCES

The following sources of information relating to mapped information for the site and its region were used in the compilation of this assessment:

- Ordnance Survey of Ireland, Sheets No. 61 & 60, 1:50,000;
- GSI (1994) Geology of Carlow – Wexford. A Geological Description to Accompany Bedrock Geology Sheet 19, 1:100,000 Map Series. Geological Survey of Ireland;
- GSI (1994) Geology of Kildare – Wicklow. A Geological Description to Accompany the Bedrock Geology Sheet 16, 1:100,000 Map Series. Geological Survey of Ireland;
- GSI (2000) Swan Water Supply Scheme Groundwater Source Protection Zone Report;
- GSI (2004a) Laois Groundwater Protection Scheme;
- GSI (2004b) Castlecomer GWB Report 1st Draft;
- GSI (2004c) Ballingarry GWB Report 1st Draft;
- GSI (2004d) Assessment of the Quality of Public and Group Scheme Groundwater Supplies in County Laois;
- GSI On-line Groundwater database. Aquifer Classification, Aquifer Vulnerability, Teagasc Soil Classification. https://dcenr.maps.arcgis.com/apps/MapSeries/;
- EPA online Water Quality Mapping, Catchments.ie online monitoring records for regional GWBs & historical monitoring records for the site's water quality. https://gis.epa.ie/EPAMaps/;
- Teagasc (1987) Soils of Co. Laois;
- National Parks and Wildlife Service (NPWS). Database of Special Areas of Conservation, National Heritage Areas, National Parks, Special Protection Areas including Site Synopsis and Conservation Objectives reports including the 2010 Freshwater Pearl Mussel, Second Draft, Nore Sub-Basin Management Plan;
- STRIVE (2007–2013) report entitled A Review of Groundwater Levels in the South-East of Ireland (TCD 2011) provides useful information on the Hydrogeology of the Castlecomer Plateau;
- Previous assessment completed by An Bord Pleanála for the original planning for the site (An Bord Pleanála PL 11. 130640, 2003 Inspector's Report);
- Geological Assessment Report for the site including Rotary Core Borehole Logs (4 no) reported by SLR (2020);
- Evaluation of groundwater usage and water supplies in the area using Laois County Council's ePlanning system which provides comprehensive information of local houses and their water supply (Covid Lockdown restrictions preclude house to house surveys), and any other information of note locally, for example, applications to Laois County Council for Wind Farms in the wider area;

- EPA online Water Quality Mapping, Catchments.ie online monitoring records for regional GWSs and historical monitoring records for the site's water quality. https://gis.epa.ie/EPAMaps/Water; and
- National Parks and Wildlife Service (NPWS). Database of Special Areas of Conservation, Special Protection Areas, National Heritage Areas, National Parks, including Site Synopsis and Conservation Objectives Reports, particularly the 2010 Freshwater Pearl Mussel, Second Draft, Nore Sub-Basin Management Plan.

7.2.3 CONSULTATION

7.2.3.1 Mandatory Stakeholders

J Sheils Planning & Environmental Ltd. circulated a scoping document to all mandatory stakeholders in May 2021. Information on the scoping and responses is presented in Section 1.5.1 of the EIAR. The GSI's response raised no issues for concern for the Water Section. The ecologist for the project conveyed ecological constraints as informed by their review of published NPWS information. Hydro-G consulted with the GSI Groundwater Section querying the availability of updated information regarding the Swan PWS, and while the scheme was more recently reviewed, they have not changed the mapping (Taly Hunter Williams, pers. comm. 2021).

7.2.3.2 Laois County Council Planning Section

A meeting between the project team and Laois County Council took place by way of virtual video conference call on the 11th February 2021. The proposed development was presented by Project Team Leader and EIAR coordinator Mr. John Sheils, J Sheils Planning & Environmental Ltd., to representatives from Laois County Council's Planning (Mr. David O'Hara), Roads (Mr. Patrick Murphy) and Environment (Mr. Liam Rabbitte). Representatives from Lagan's Property Management and Environmental Management sections were in attendance, as was Pamela Bartley of Hydro-G.

Laois County Council responded to the pre-planning information and presentation on the day with feedback relating to the existing conditions of the current planning permission on the site (PA. Ref. 10/383) and considerations for ongoing compliance with road safety plus contributions from the Environment representative.

At the end of the meeting, Hydro-G raised questions regarding any information on file at Laois County Council for monitoring information for the Discharge Licence (ENV2 WP27) and direction regarding Laois County Council's position of the streams and rivers rising in the immediate vicinity of the site. The Environment Section representative at the pre-planning meeting referred Hydro-G to their colleague Ann Marie Callan for surface water and Discharge Licence queries.

7.2.3.3 Laois County Council Environment Section

Historically, the site was required to sample waters as part of the Conditions of the Discharge Licence ENV2 WP 27. Upon consultation with Laois County Council's Environment Section, Ann Marie Callan suggested that little information existed on file with respect to compliance with the Conditions of the Discharge Licence in terms of return of monitoring data.

Hydro-G consulted with the aforementioned personnel overseeing water issues in the local authority.

"From: Pamela Bartley (Hydro-G) <pamela@hydro-g.com>
Sent: Friday 12 February 2021 08:51
To: 'amcallan@laoiscoco.ie' <amcallan@laoiscoco.ie>
Cc: 'lrabitte@laoiscoco.ie' <lrabitte@laoiscoco.ie>; 'Colin O'Reilly' <colin@envirologic.ie>; 'John Sheils' <jsheils@jspe.ie>; 'John Fennell' <john.fennell@breedongroup.com>; 'brian.downes@breedongroup.com' <brian.downes@breedongroup.com>

Subject: Quarry @ Knockbaun, Spink Co. Laois

Hello Ann Marie

Colin O Reilly (Envirologic) and I (Hydro-G) will be doing the 'Water' Section of the EIAR for the application for continued use of a quarry (currently dormant but still in lifetime of permission) @ Knockbaun, Spink Co. Laois. John Sheils is the Project Manager, EIAR compiler and all discipline scientific team leader. John Fennell and Brian Downes are Lagan (Breedon Group)'s Property and Environmental Managers, respectively. I have cc'd all here and I have included your colleague in Environment, Liam. Liam and David from Planning and Paddy from Roads represented Laois Coco @ the introductory 1st Planning interaction between our team and yours.

Ann Marie, I am writing to you this morning because Liam suggested that you were the person who could best answer the questions I raised about water, rising streams and discharge licencing at the end of our meeting. My queries relate to following and I wonder if you could assist?

1. *David asked us to make sure the site was compliant in the parent permission conditions – Amongst other things, I am working on the water management systems and the future discharge route. I am aware of the Discharge Licence ENV2 WP27, attached. I believe you sent it last year to John Fennell of Lagan.*
    a. *Ann Marie, is there a record of the specified discharge quality sampling and volumes recorded on site?*
    b. *Are there 'as built drawings' of the settlement ponds and discharge zone on file in your department?*
    c. *Do you have any experience or concerns regarding the site/systems/their efficacy?*
2. *With respect to future discharge licencing: if our upcoming hydrogeological assessments suggest that dewatering will be part of the future of the quarry AND IF other discharge routes need to be considered, could I please discuss the Clogh_010's rising on the site and potential for discharge at the headwaters there?*

I need to establish a connection in Environment who deals with Water. Liam deals primarily with Waste he told us. I obviously have the WFD Subcatchment Report for the Dinin subcatchment: half our site is in this catchment and half is in the Nore_SC_060. I would appreciate if we could schedule a call at any time that suits you. Maybe next week sometime? Whenever suits you. I also attach John Shiel's pre-planning information circulated to your colleagues for yesterday's meeting.

All the best

Pamela

Dr Pamela Bartley
B.Eng., M.Sc., Ph.D.
Hydro-G
50 Henry St
Galway
H91 FA 4X
087 8072744

Hydro-G is the registered trading name of Bartley Hydrogeology ltd., a limited company registered to trade in Galway, Ireland. Company number 437572."

7.2.3.4 Laois County Council Environment Section Site Meeting

In response to our consultations with the Environment Section of Laois County Council and subsequent discussions, Ann Marie Callan met with Mr. John Fennell of Lagan, Dr. Pamela Bartley and Dr. Colin O'Reilly at the site on 2nd March 2021.

The existing Discharge Licence was discussed, the existing settlement ponds were observed, and the discharge zone was evaluated by means of visual examination. In addition, the watercourse that commences at the site and feeds the Clogh River was observed and discussed with respect to discharge feasibility. Ann Marie Callan noted that the Clogh River was designated under WFD characterisations as 'At Risk' from agricultural pressures and as such any proposals should not add to the pressures in that catchment. It was agreed that the proposals presented would comply with all requirements of the Surface Water, Groundwater and Birds and Habitats Regulations.

It was noted that a significant water management network of ponds and vegetated wetland settlement system existed in the western portion of the site and the intention would be to recommission and enhance necessary water management infrastructure in this area. It was suggested that feasibility of discharge to both surface water and groundwater be considered, with the latter potentially supporting retention of water on site.

7.2.3.5 Laois County Council Roads Section

During assessments of potential discharge routes to the east and west, both potential discharge routes were surveyed for cross sectional geometry and slopes to the west towards the Owveg River and east to the Clogh stream for the purposes of assessing the hydraulic and assimilative capacity of each.

An issue arose regarding the ability to access the piped culvert beneath the R430 outside the north-western zone's boundary of the quarry. The culvert was buried and inaccessible. To confirm the pipe diameter and invert level on the northern and southern side of the road, Envirologic consulted with the roads section of Laois County Council.

Mr. Wes Wilkinson, Senior Executive Engineer, Portlaoise Municipal District Roads Office, Laois County Council, responded to enquiries in an email Tuesday, 11 May 2021 at 14:02, that the Portlaoise MD Office does not have any mapping/data relating to the pipe diameter or invert levels for this culvert. Laois County Council advised that the hydrologists should make arrangements their own arrangements to carry out works to survey/obtain the information on site.

The team decided that rather than carry out any intrusive works near the culvert, which may have undermined the county council's road, the work at this stage could be progressed using a series of simulations based on varying possibilities for this culvert. An approach was taken to work backwards, insofar as knowing the proposed discharge volume and controls that would be put in place, what size culvert might be necessary in the future?

7.2.3.6 Consultation with EPA, Water Matters, Catchments.ie, LAWPRO, Inland Fisheries Ireland

Following on from consultation with the Environment Section at the site meeting on the 2nd March 2021, Ann Marie Callan suggested that when the project team had a draft discharge licence proposal on the table, Laois County Council would consult with LAWPRO, Fisheries Board, EPA etc.

7.2.3.7 Project Ecologist and NPWS:

The ecologist for the project is Ger O'Donohoe of Moore Consulting. He briefed the scope of the hydrological and hydrogeological assessment from the perspective that the site straddles the Margaritifera SAC Catchment to the west and Margaritifera Sensitive Area to the east (Plate 7.1 and Plate 7.2). The ecologist and project team are aware that management of discharge and suspended solids is critical and that any Water Management System on site must ensure that the discharge of suspended solids from site is controlled to ensure no impact on the Pearl Mussels.

It is also important to note that consideration needs to be given to impact on Salmonids because the Pearl Mussel and Salmonids are symbiotic.

The project's ecologist requested that our works design for no resultant impact on the River Barrow & Nore SAC with respect to groundwater volume or electrical conductivity.

7.2.3.8 Pearl Mussel Expert

An Bord Pleanála's Inspector's Report for the site in case number PL 11. 130640 (2003) reproduced information from the original application (Laois County Council PA. Ref. 10/383):

- 'Freshwater mussels' sensitivity will not be compromised by proposed development: the sensitive zone of the River Nore lies more than 10 kilometres upstream of the confluence of the main Nore channel with its tributary (River Dinin) serving the catchment, including the appeal site. Spawning grounds as far upstream as the village of Swan on the River Nore tributary system will be protected by the mitigation measures of oil interceptor and siltation traps. There will be ongoing monitoring of surface waters. The requirements of the Southern Regional Fisheries Board will be met.'

Dr. Pamela Bartley has worked collaboratively on projects with the Pearl Mussel expert Dr. Evelyn Moorkens.

In the course of previous projects, Dr. Bartley has previously been advised by Dr. Moorkens that:

1. The headwaters of any pearl mussel catchment are extremely important.
2. It is imperative that Suspended Solids concentrations shall not change as a result of any proposal.

The discharge assessment and assimilation capacity simulation work completed for the site shall ensure those, and other, design caveats are ensured. All discharge evaluations are completed cognisant of the requirements of the Surface Water Regulations (2009, as amended). This assessment will also include the requirements of the Pearl Mussel Regulations (2009 as amended 2018).

Dr. Evelyn Moorkens advised Dr. Pamela Bartley that the point of interest for the Pearl Mussel populations closest to the proposed development site is in the vicinity of Ballyragget, Co. Kilkenny.

Utilising EPA mapping tools (https://gis.epa.ie/EPAMaps/Water) allows measurement confirming that there is 20 km, approximately, of stream length between the proposed development site in county Laois and the Pearl Mussel point of interest in Ballyragget, Co. Kilkenny. Hydro-G notes that there are also four other rivers that confluence in advance of Ballyragget. There is an OPW hydrometric station upstream of Ballyragget (Station number, 15012, Station name, BALLYRAGGET) and the reported catchment area is 1056.80 km² (https://epawebapp.epa.ie/hydronet/#15012). There is an EPA HydroTOOL model node (15_1157) on one of the River Nore's upland tributaries 1.7 km east of the quarry on the Owveg (Nore)_010 and the cited catchment is 14.506 km². It is therefore calculated that the catchment in which the quarry sits is ((14.506/1056.80)*100) = 1.4% of the land area upgradient of the Pearl Mussel point of interest. The importance of maintaining the Environmental Quality Objectives of the Surface Water Regulations and the Pearl Mussel requirements for no change is Suspended Solids is also acknowledged as crucial for all waters at all parts of the catchment. The assimilation capacity simulations for the proposed discharge will ensure compliance in that regard. However, it is of significance that a ~1% proportion is miniscule in the context of the ~1000 km ² surface water catchment upgradient of the Pearl Mussels.

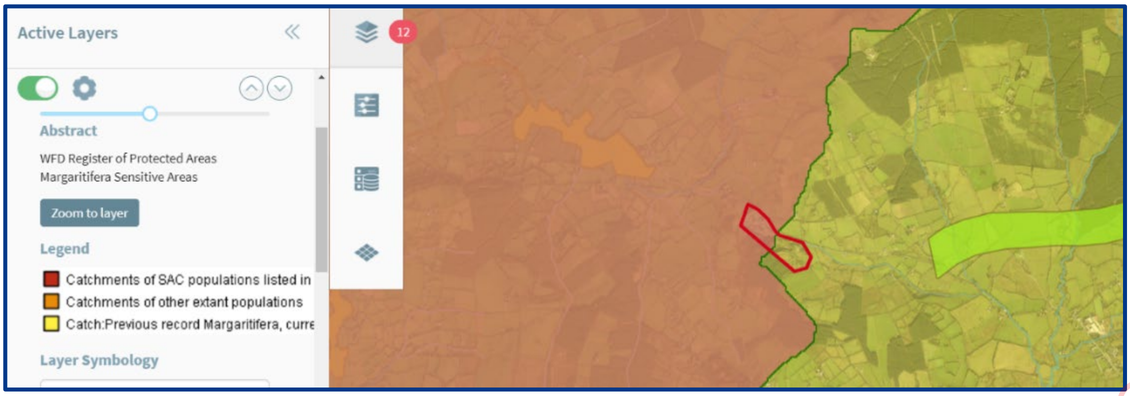


Plate 7.1 WFD Register of Protected Areas and Margaritifera Sensitive Areas (www.epamaps.ie).

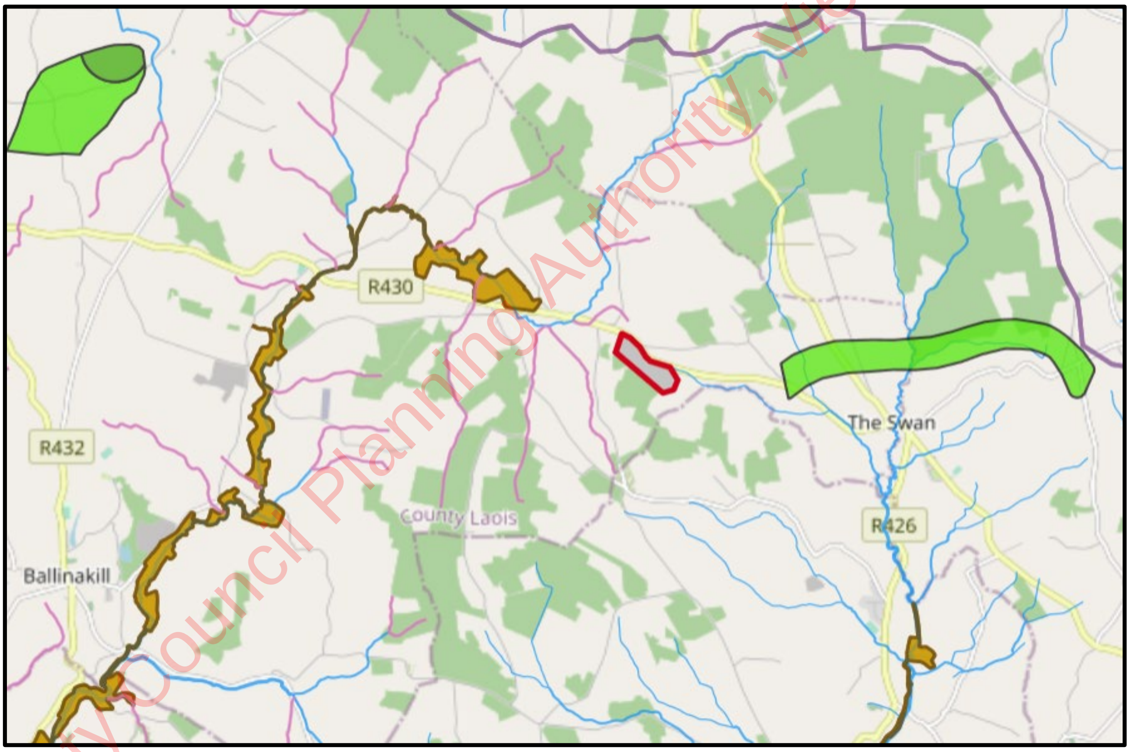


Plate 7.2 Site outlined in Red with Margaritifera First Order Rivers (Purple) - To the West (Margaritifera SAC Catchment (www.epamaps.ie).

7.3 SITE DESCRIPTION

7.3.1 SITE LOCATION & TOPOGRAPHY

The site is located within the townland of Knockbaun, 3 km west of Swan, 7 km south of Timahoe and 9 km east of Abbeyleix (see Figure 7.1). The quarry is located on the southern side of Regional Road R430, which connects Abbeyleix with Swan.

Regional topography is heavily influenced by the Castlecomer Plateau, an elevated saucer-shaped upland area. The plateau has a north-south length of approximately 30 km, and is widest through the central axis which extends to 20 km. The upland area is hilly with peaks reaching 300–350 m OD. The centre of the raised plateau is depressed relative to the periphery with elevations falling to 130 m OD. The site itself is located at the northern end of the plateau, positioned on the southern side of a small, raised valley that runs northwest-southeast between hills 1,300 m to the north (290 m OD) and 130 m to the south (261 m OD). The valley falls naturally to lower grounds to the east and west. The 1:50,000 OSI Discovery maps show elevations at the site to be in the order of 230–261 m OD.

7.3.2 LAND USE

Land in the area typically supports moderate-intensity agricultural grassland supporting livestock production. A forestry plantation abuts the site to the south and this is consistent with land use on higher ground in the wider area. There is a relatively low density of one-off single residences in the area, with some of these attached to farmsteads. A small cluster of residential dwellings is located to the northwest of the site, notably at Larkin's Cross, with the closest of these being 175 m, approximately, west of the site. A search of planning files on the Laois online planning system suggests that potable water supply to all houses in the vicinity of the quarry is sourced from private domestic wells. Historical land uses were reviewed using maps and aerial photography, which are detailed in Table 7.1.

Table 7.1 Historical Land-use at the Site and its Surroundings

Ordinance Survey Map Reference and/or dates	On Site	Immediate Surroundings
OS 6 inch colour (1837-1842)	Small agricultural land parcels, small structures shown at current location of sump, entrance, outfall pond. Local road mapped as extending through northwest corner of quarry no longer present.	Residential and small farm holding agglomeration of buildings. Low density development.
OS 6 inch Cassini (1845)	There are now only two houses or buildings of some sort mapped in the site, both close together and in the NW corner near the road. Spring rising shown opposite the gate to the site. Abundant marked Benchmarks on the boundaries of the site.	Still low-density houses and farms but slightly more of them. 6 houses/farms within 500 m of the boundaries in all directions.
OS 25 inch (1888-1913)	Spring indicated south of current entrance at corner of current sump.	Numerous springs mapped in locality.
Aerial Map (2000)	Greenfield, poor quality grassland and gorse. Very small borrow pit in north-western quadrant.	Farmyard opposite gate. Sparse density around but a new house to the west on the Larkins's Cross corner of the road with the R430 and 3rd class route going south (i.e., L77921). Plantation forestry just starting in the lands to the south of the quarry, uphill.
Aerial Map (2005)	Commencement of quarrying in north-western portion of application site	Construction of dwelling 170 m west of quarried area
Aerial Map (2009)	The entire western half is developed to a quarry void. Installation of settlement ponds, processing plant. Minor quarrying in eastern portion of application area.	Housing development has not changed since 2010 aerial photo. Plantation forestry well established in the lands to the south of the quarry, uphill.
Aerial Map (2018)	Current sump area excavated.	

7.3.3 SITE LAYOUT

The permitted area for quarrying under PA. Ref. 10/383 covers c. 26.6 ha. In the interim, ownership of part of the permitted, but unworked, area at the north-western end of the site has been transferred. The revised landholding and quarry now cover c. 19.6 ha (See Figure 7.2, refer also to Figure 1.2). The site is broadly rectangular in shape with a southeast-northwest length of 800 m parallel with, and adjacent to, the R430, and a perpendicular width of 200–250 m.

An aerial topographical survey was carried out by JSPE in 2021 and has been used to inform discussion of site topography. Pre-development topography falls from the hill to the south (261 m OD) into a minor, raised east-west valley that corresponds with the R430 routing. The high point on the road in front of the site is approximately 234 m OD and road elevations fall to the east and to the west from this point.

The site is accessed via an entrance midway along the northern boundary. For the purposes of site description, it is considered by the hydrogeological team to contain three distinct areas (See Figure 7.2): (i) south-eastern portion; (ii) central portion; and (iii) north-western portion.

The south-eastern portion is regarded as the area southeast of the site entrance. Ground in this area is uneven having been partially stripped of overburden in the past and used for the storage of overburden. It has mostly reverted to natural scrub. To the immediate south-east of the site entrance is a small area understood to have contained a bentonite-lined clarification pond and infiltration area which was probably for management of waters as per the historical Discharge Licence for the site.

The north-western portion of the site relates to the area excavated to a single bench and contains the previous processing area. The surface condition is generally competent bare rock, which has an elevation of c. 225 m OD. The processing area previously contained an asphalt plant, which has since been removed and will not be reinstated. Other existing site infrastructure remaining includes the site access, internal roads, storeroom, wheel wash, weighbridge, aggregate storage bays, refuelling hard stand. Constructed settlement ponds are present in the north-western and south-western corners. There is evidence of pumping infrastructure and equipment across this area. The sump occurs in the central portion of the site, which has a footprint of approximately 1 ha. Exposed faces around the sump perimeter have heights up to around 20 m above sump water level. There are several stockpiles of previously extracted and processed material to the west of the sump, which remain from the previous operator.

7.3.4 PREVIOUS SITE WATER MANAGEMENT

The sump contains a mixture of groundwater and rainfall due to excavation below existing perimeter ground level. Rainfall landing in the catchment upgradient of this area drains by gravity to the sump. Rainfall landing in the western half of the quarry drains by gravity either to the sump or towards the north-western corner of the site, which accommodates historic water management infrastructure.

It is understood that during previous operations, water was pumped initially from the sump to a series of four interconnected settlement ponds in the south-western corner of the site (referred to as 'Western Settlement Ponds' in Figure 7.2). These ponds remain in place and usable for the management of the quarry's waters in the future. Refer to Plate 7.3. All settlement system ponds at the site are lined with concrete and are impermeable. The dimensions, and consequent volumetric capacity, for the existing 'Western Settlement Ponds' are as follows:

- Pond Tank No. A = 62 m x 12 m x 1.0 m = 744 m^3 (surface area = 744 m^2)
- Pond Tank No. B = 72 m x 12 m x 1.0 m = 864 m^3 (surface area = 864 m^2)

Upon adequate retention time, clarified water left the south-western corner's settlement tank system by a high-level overflow and travelled by gravity flow via a constructed channel to two final concrete structured settlement ponds located in the north-western corner, these being referred to as:

- Pond Tank No. 2 = 541 m^3
- Pond Tank No. 1 = 541 m^3

It is understood that, under the Conditions of the previous Licence, water was to be pumped uphill from Pond Tank No. 1 to an excavated pond adjacent to the site entrance, referred to in previous planning documentation as the Discharge Pond (capacity = 1,941 m^3). This 'Discharge Pond' area appears to have contained two discrete excavated areas. Previous planning documents suggest that pumped water entered an initial settlement pond lined with bentonite at the site entrance. A small spring outflow from raised ground in the eastern half of the site follows the land gradients and is routed into this pond. This pond then overflowed to a second unlined pond from which it infiltrated to ground. A soakaway test was performed by Trinity Green, as part of the previous owner's applications in this area which returned a vertical infiltration rate of 1.5×10^{-6} m/s (*pers. comm.*, Mr. Eugene Bolton, Trinity Green). The assessor noted the upper 1.3 m of rock in the trial pit to be heavily fragmented and in our evaluation those results may not be a true representation of bedrock permeability.

(a) South-western Pond Tank System: Long Linear concrete lined Ponds with baffle walls.

(b) Secondary Pond Tank System in South-western corner of the site: Long Linear concrete lined Ponds with baffle walls.

(c) North-western Corner's Pond Tanks No. 1 and 2.

[Looking to the SW corner of the site]

(d) North-western Corner's Pond Tanks No. 1 and 2.

[Looking to the NW corner of the site & road boundary]

Plate 7.3 Settlement Ponds and Tanks at the site (July 2021).

The historic discharge licence (ENV2 WP27, dated 2009) for the site specified management of a discharge volume of 8,000 l/d, which is equivalent to 8 m^3/d, and discharge to groundwaters in the discharge pond immediately to the east of the site entrance. Historic records justifying the discharge do not seem to be currently accessible to the Environment Section of the Council. This may be a combination of archive and accessibility issues resulting from the limitations of working environments during the Covid Lockdown of 2020–2021 in combination with the fact that the person previously responsible for the licence is no longer in the Environment Section of Laois County Council. A flowmeter was reportedly fitted prior to waters entering the Discharge Pond, though flow records could not be sourced. Currently, rainfall in the south-eastern half of the quarry and the aforementioned spring flow also enter this excavated 'discharge' pond. While there may be some unquantified infiltration to ground, it appears from visual observation that there is a surface water outflow from this area which continues eastwards via a ditch that runs along the southern side of the R430. This flow was estimated as 0.5 l/s (43 m^3/d) in March 2021. This is the rising of the Clogh River. The proposed quarry design makes provision for a 50 m buffer zone set back from the boundary with the R430 Regional Road. There will be no quarrying and no construction activity in this area. The rising of the Clogh River is in this zone and is thereby protected.

Since cessation of activities at the site, the lack of pumping has resulted in the sump filling with water. The sump is maintained at a constant level by an overflow located on its lower western side. The overflow is channeled into Pond Tank No. 1. The northern wall of Pond Tank No. 1. has been altered such that a short section is made up of large boulders, facilitating a natural pond outflow. Water leaves through the northern edge of Pond Tank No. 1 and subsequently flows westwards through a channel excavated in stockpiled material that is part of the embankment with the adjacent road. This channel continued westwards and directs quarry water into a roadside gully. The channel has become overgrown due to lack of maintenance resulting in quarry water now emerging into a small roadside channel. Water flows westwards alongside the road until it enters the gully. This flow entering the gully was estimated as 1.5 l/s (130 m^3/d) in March 2021 and 2.5 l/s (216 m^3/d) in May 2021.

7.3.5 PREVIOUS PLANNING CONDITIONS

Historic planning reports, prior to the applicant's acquisition of the site, outlined how surface water from the entire site drained into the settlement pond system by a series of channels and drains. The design of the settlement ponds was such that overall pond capacity was sufficient to prevent overfilling of the Discharge Pond, even in the case of return period design floods, and this prevented flow of surface water from the site entrance onto the R430 (Byrne 2010a). There had reportedly been six settlement ponds, two silt and oil interceptors, a discharge pond, and a flow meter to ensure that the daily discharge limit of 8,000 litres of trade effluent from the discharge pond, established by Discharge Licence Ref. ENV2, WP27 from Laois County Council, was not exceeded. All clarified water was reportedly discharged to ground in the Discharge Pond near the site entrance, and was restricted to a suspended solids level of < 25 mg/l. The Licence to Discharge Trade Effluent (ENV2, WP27) to ground appears to relate specifically to PA. Ref. 09/384.

Under PA. Ref. 10/383, planning condition 8 (Water Quality Protection) and 12 (Groundwater, Surface water and Water Table) relate to water management, while Condition No. 11 (Environmental Management & Monitoring) in part relates to monitoring of surface and groundwater. Laois County Council also sought clarity on collection of surface water, operation of settlement ponds, and prevention of overfilling of the Discharge Pond. All waters were pumped from the 6 settlement ponds, via the silt and oil interceptors, to the Discharge Pond.

Furthermore, issues were identified by Laois County Council in relation to mains water, foul sewer and source protection. There is no mains water supply in the area, so the applicant was directed to provide water of adequate quality, and instructed that sewage treatment systems must comply to EN12566, with appropriate thickness of unsaturated subsoil below invert of percolation trench. The previous owners of the site were instructed regarding water, sewerage and oil storage bund capacity.

Hydro-G and Envirologic have determined, by exploration of levels and site boundaries, that there are currently two active surface water outfalls from the site: one to the eastern catchment and one to the western catchment. These findings are in agreement with the mapped surface water divide that runs north-south through the centre of the site. However, this is a local surface water divide. The mapped surface water division within the site is the natural separation between the River Clogh catchment to the east and the River Owveg to the west (Figure 7.1) but both of these are headwaters for the River Nore and both rivers ultimately contribute downstream to the River Nore at a distance of 22 km to the south to southwest of the site. The significance of local catchment divisions with respect to the entire Nore catchment will be considered in the evaluation of the most appropriate surface water management plan for the site.

7.4 RECEIVING ENVIRONMENT

7.4.1 GEOLOGY

7.4.1.1 Soils

Figure 7.3 shows that original soils at the application site are predominantly shallow and well-drained, consistent with other elevated surrounding lands. Soils on surrounding lands in the wider area tend to be deeper and less well-drained, with much unimproved land covered in rushes.

With the exception of field drains and first order streams, local river systems are underlain and flanked by narrow banks of alluvial deposits.

Soils of County Laois (Conry 1987) describes soils at the site as a Brown Earths belonging to the Ridge Stony Phase Soil Series. These tend to be characterised by a dark-brown, friable clay loam surface horizon overlying a yellowish-brown silt loam. A schematic representation is shown in Plate 7.4 with the target material shown as 'Flagstone'. Conry (1987) describes how soils on the Castlecomer Plateau are largely wet with rushes proliferating.

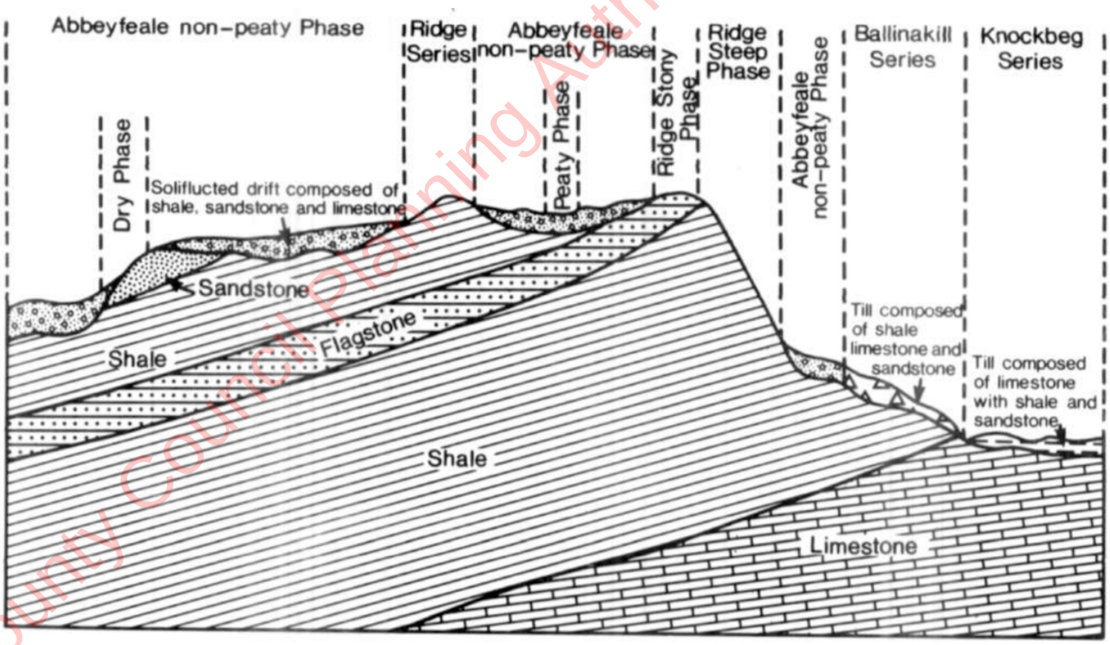


Plate 7.4 Schematic Cross-section of Soils and Geology on the Castlecomer Plateau (Conry 1987)

7.4.1.2 Quaternary Deposits

Parent material of the Ridge Stony Phase is a till derived from Namurian shale and sandstone bedrock (Figure 7.4). This till is described as a dense mantle of boulder clay which results in a low inherent permeability. The impermeable nature of the parent material is the cause of the proliferation of rushes. The better drained soils occur on higher or steeper lands where this till has been eroded and soils instead sit directly upon bedrock.

7.4.1.3 Bedrock Geology

The Castlecomer Hills are formed from relatively young Carboniferous rocks. The earliest of these rocks are black mudstones and thin limestones. On top of these lie Namurian sandstones and mudstones that were deposited by river delta and marine sands as sea levels receded. Similar sedimentation continued and the succeeding series of sandstones and mudstones contain thin coal seams, formed from buried organic matter which was subsequently compressed.

The Castlecomer Plateau is described as an undulating upland basin with a horseshoe-shaped high rim capped by tough sandstone. The softer underlying shales have been rapidly eroded to form a steep outer escarpment. Inside the rim the ground slopes gently down to the centre. The tough, coarse Clay Gall Sandstone, which is 40-60 m thick, can become exposed on elevated ground.

The GSI 1:100,000 Sheet 19 Map of the Geology of Carlow-Wexford shows the central area on the Castlecomer Plateau is mapped as being underlain by the Coolbaun Formation, described as shale and sandstone with thin coals. The basal unit of the formation is a 0.5 m thick coal seam, which is roofed by shales with up to 50 m of shale. Overlying this shale is a 5-20 m thick laminated dark-grey siliceous sandstone, known as the Swan Sandstone Member. The Swan Sandstone Member does not occur at the site. The report for the Swan PWS is presented in Appendix 7.2.

Bedrock exposed at the site belongs to the Clay Gall Sandstone Formation, and is composed of medium and fine quartz sand with some feldspar, which is well cemented by silica and gives a non-porous rock (Figure 7.5). The Clay Gall Sandstone ranges from 2 to 58 metres in thickness (GSI 2004). The Clay Gall Formation is overlain by the Coolbaun Formation, and underlain by the thick Moyadd Coal Formation, which itself sits on the flaggy sandstone of the Breguan Flagstone Formation.

7.4.2 HYDROGEOLOGY

7.4.2.1 Aquifer Classification

Figure 7.6 shows that two distinct aquifer units are mapped within the site boundary.

The shales belonging to the Coolbaun Formation, which underlie the eastern half of the site, and are mapped on the upper surface of the Castlecomer Plateau, are classified as a 'Poor Aquifer, Bedrock which is Generally Unproductive' (Pu). This is the least productive of all aquifer types in Ireland. This bedrock typically has few and poorly connected fractures, fissures and joints and the low fissure permeability tends to decrease further with depth. A shallow zone of slightly higher permeability may exist within the top few metres of more fractured/weathered rock. In general, the poor fissure network results in poor aquifer storage, short flow paths and low recharge acceptance. Groundwater discharge to streams ('baseflow') is very limited.

The thinner sandstone layers which become exposed at intervals on the peripheral slopes of the Castlecomer Plateau tend to be more productive and are classified as a 'Locally Important Aquifer, Bedrock which is Generally Moderately Productive' (Lm). This includes the Clay Gall Sandstones exposed in the western half of the site and the Swan Sandstone Member which outcrops further east of the site. There may be partial continuity between these sandstone units along structural faults. In this aquifer type, the network of fractures, fissures and joints is reasonably well connected and dispersed, giving moderate permeability and groundwater flow rates. Aquifer storage is moderate and groundwater flow paths can be up to several kilometres in length. There is likely to be a substantial groundwater contribution to surface waters ('baseflow') and large (> 2,000 m^3/d), and dependable springs may be associated with these aquifers. Although the aquifer may supply 'excellent' yields, the small size limits the amount of recharge available to meet abstractions.

The Moyadd Coal Formation which sits beneath the Clay Gall Sandstone, along with the Bregaun Flagstone Formation and Killeshin Siltstone Formation, which outcrop on lower lands to the northwest, are classified as a 'Poor Aquifer, Bedrock which is Generally Unproductive except for Local Zones (Pl).

The low permeability nature of the underlying (Moyadd Coal) and overlying (Coolbaun) aquifers means that groundwater within the Clay Gall Sandstones may be confined.

The hydrogeology of the Swan Member, which occurs km's to the east of the site, is reported by Fitzsimons (2004c) to be unique in Laois. The GSI SPZ Report for the hydrogeology of the Swan PWS cites the Swan Sandstone member as shallow at 28 m deep and artesian at the source BH on the outskirts of the village of Swan (GSI 2000, reproduced here as Appendix 7.2).

7.4.2.2 Groundwater Body Reports

The GSI maps the majority of the site as being underlain by the Castlecomer Groundwater Body (GWB) (GSI 2004), which has a groundwater flow regime of productive fissured bedrock (sandstone). The Castlecomer GWB is reported to have an approximate area of 224 km^2 with an outcrop area of 102 km^2. Its associated surface water features include the Castlecomer Stream, Clogh River, Dinin River (Nore) and Monefelim River. In areas where the rock is exposed at the surface the land is 'rushy', small springs are frequent at breaks-in-slope and drainage densities are high.

Most of the Castlecomer GWB is confined, the unconfined portion being a relatively narrow strip around the perimeter of the plateau. Rainfall recharge occurs only in the unconfined portion. Downward leakage from confining layers is unlikely because of artesian pressure. Groundwater flows through the GWB from the perimeter inwards, in line with contact plane angle, with the main baseflow sink being the Dinin River. Some potential recharge may be rejected at the margins.

A negligible area on the northwest corner of the site is mapped as being part of the Ballingarry GWB that extends northwest and within which the dominant groundwater flow regime is poorly productive bedrock. The same groundwater flow regime is applied to the Newtown GWB that covers that part of the Coolbaun Formation mapped on the upper part of the Castlecomer Plateau.

The GSI (2004b & c) Groundwater Body reports are included as Appendix 7.2.

7.4.2.3 Aquifer Properties

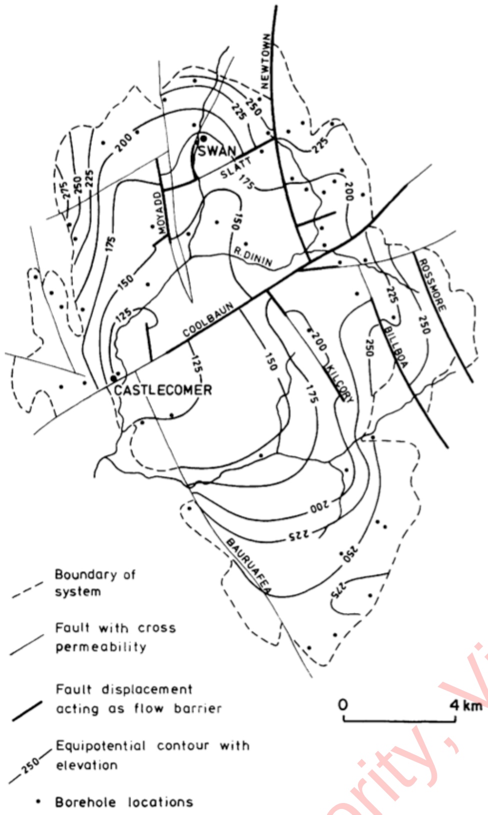
From the Castlecomer GWB report (GSI 2004):

- Most of the groundwater body is confined, the unconfined portion being a relatively narrow strip around the perimeter of the plateau;
- The rocks are folded into a syncline by at least one major phase of folding, causing considerable fracturing within the two sandstone formations, which reacted to the stress in a more brittle manner than the surrounding shales;
- The aquifer outcrops around the rim of the plateau, but dips down to depths of over 246 m below ground in the centre of the plateau;
- Away from the main recharge-outcrop area, the groundwater is confined by the overlying low permeability Westphalian shales. This is reflected by artesian pressures in wells drilled closer to the centre of the plateau (e.g., the Swan public supply in County Laois);
- Several important faults cross the body. Some of these juxtapose the two sandstones and allow flow between them. Some faults act as barriers to flow;
- Well testing (Misstear et al. 1980) suggests transmissivities in the order of 10 m^2/d (range 1 m^2/d – 500 m^2/d) and permeabilities in the order of 0.1 m/day (range 0.01 m/d – 50 m/d).
- Permeability and Transmissivity are sometimes enhanced near faults;
- The Clay Gall Sandstone ranges from 2 m to 58 m in thickness;
- Moyadd Coal (MC): Black shale, siltstone and minor sandstone, typically 55 m thick;
- Water infiltrates at the exposed areas around the perimeter. Some will discharge outwards to the surrounding basins. The remainder flows towards the centre of the syncline, ultimately discharging to the River Dinin, unless it is captured *en route* by boreholes; and
- Rainfall recharge occurs only in the unconfined portion.

A study by Daly et al. (1980) provides useful insight into structural controls on hydrogeology in the Castlecomer Plateau. The study includes three schematic representations of the structural controls and these are included below as Plates 7.5 to

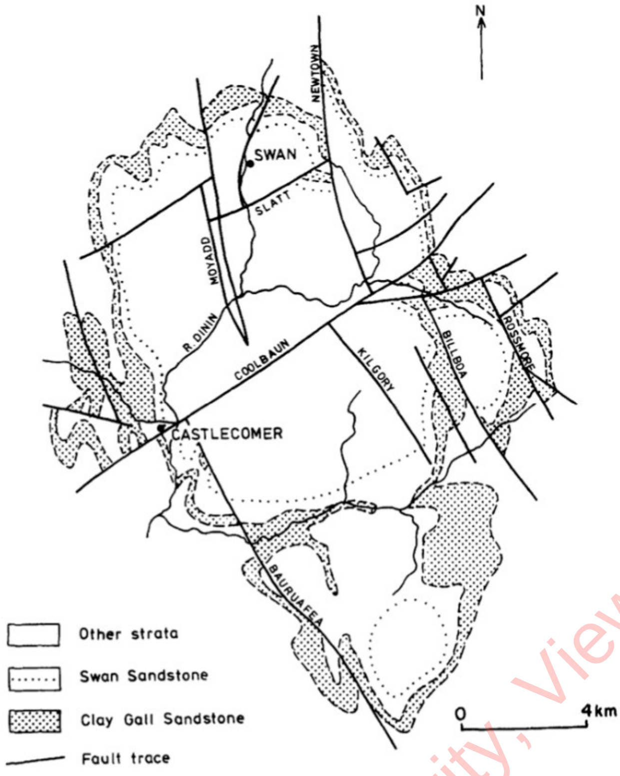
Plate 7.7. The following key points relating to this project have been selected from the study as follows:

- The two main sandstone aquifers in the Castlecomer Plateau, these being the Clay Gall Sandstones and the Swan Sandstones, are in variable hydraulic continuity due to major fault displacements. This faulting separates the plateau into three effectively independent groundwater blocks;
- The Clay Gall Sandstones are between 2–58 m in thickness;
- The sandstone aquifers are largely confined. A number of boreholes in the area are artesian, which can produce up to 160 m^3/d;
- In the centre of the plateau, the Clay Gall Sandstones are displaced to depths of 246 m below ground level;
- Primary, intergranular permeability is negligible;
- Transmissivities range up to 14 m^2/d. The artesian yields and transmissivities are an order of magnitude higher close to faults;
- Recharge to the sandstone aquifers only occurs in the higher outcrop areas around the rim of the plateau;
- When the aquifer abuts against a fault, flow can only continue when the aquifer is not entirely displaced or is contact with another aquifer across the fault; and
- The regional piezometric map (Plate 7.5) suggests groundwater flow direction through the Spink Quarry is from north to south. The structural fault 2 km to the south does not act as a flow barrier.



[Application Site is in the Upper Left, NW, Corner of the Image: west of Swan]

Plate 7.5 Distribution of Cross Fault Permeability and Piezometric Surface (Daly et al. 1980).



[Application Site is in the Upper Left, NW, Corner of the Image.]

Plate 7.6 Geology of the Castlecomer Plateau (Daly et al. 1980).

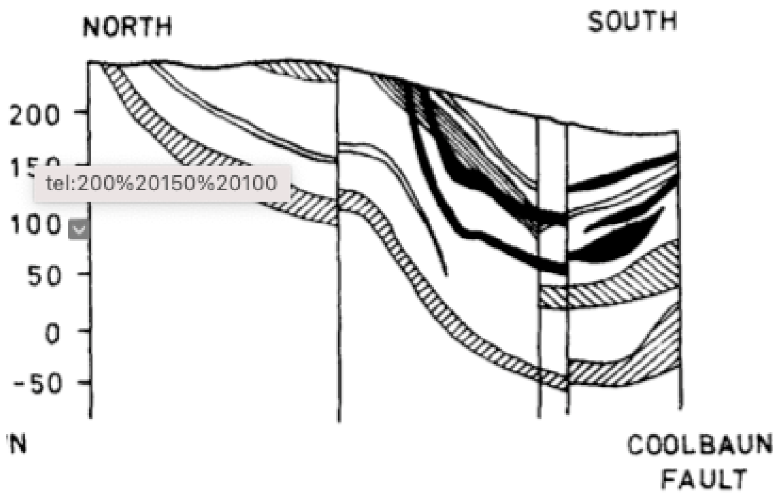


Plate 7.7 Section parallel to Newtown Fault—Clay Gall Sandstone shown Dipping from North to South (Daly et al. 1980)

7.4.2.4 Historical OSI Mapped Wells

Historical 6” and 25” Ordnance Survey of Ireland (OSI) maps were consulted as a reference point for identifying domestic wells, springs and other hydrological features of interest in the area. Springs and wells mapped in the area are shown on Figure 7.7, and described briefly below:

- A spring is shown just south of the site entrance and coincides with a visible flow of surface water, though not clearly an upwelling;
- A spring is shown just outside the site boundary, adjacent to the north-western corner of the site;
- Four springs are mapped opposite the quarry entrance, on the south facing slope of the hill which peaks 1.3 km to the north;
- Five springs are mapped on either side of local road L77921, which extends south from Larkin’s crossroads and runs across the western face of the hill just west of the quarry;
- Three springs are mapped 750–1,250 m east of the quarry on the slopes of an east trending valley; and
- A well is mapped 750 m east of the site, on the northern side of the R430. This is the only mapped well for the area.

All of the above listed features are mapped on the exposed Clay Gall Sandstones, with many of these mapped close to the contact between this formation and the confining lower permeability bedrock. They are all mapped within the Lm aquifer and coincide with abrupt breaks in slope.

7.4.2.5 GSI Well Database

The GSI well database contains records on only a small number of wells in the locality, these being:

- 5.4 m shallow dug well, 325 m west of site (accuracy 20 m);
- 6.1 m shallow dug well, 1 km north (accuracy 2 km);
- 18.9 m borehole, 1 km north (accuracy 2 km);
- 3.7 m shallow dug well, 1.4 km south (accuracy 20 m);
- 3.4 m shallow dug well, 2 km southeast (accuracy 20 m); and
- 78 m borehole, 2 km southeast (accuracy 100 m);

Other wells are mapped at a distance of approximately 2 km from the site, but with a location accuracy of only 2 km. These are predominantly shallow dug wells.

The overall conclusion from review of the available mapped well records is that the groundwater system, as a means of domestic water supply, is dominated by easily accessible spring discharges at the surface. That is the overall conclusion of desk mapping review. A door-to-door survey of local residences and farms was then completed to complete the assessments.

7.4.2.6 Third Party Wells

Local water supply is by private wells rather than Irish Water/Local Authority mains network or Group Water Scheme supply. While the Swan PWS is to the east of the site, it does not serve the area around the quarry. The outer source protection zone of the Swan PWS SPZ's mapped western boundary is 1.25 km east of the quarry's most eastern boundary (Figure 7.6). The quarry is therefore well outside the area mapped for protection of the Swan PWS. The Source Protection Zones (SPZs) are delineated with large factors of safety.

The Laois County Council online planning system provided location information regarding local domestic wells because Laois issues domestic residence planning permission with Conditions regarding the water supply well.

An Bord Pleanála Inspector's Report for case PL11.130640 (2011) discussed the issue of local wells as follows:

> *"<u>Groundwater and Surface Waters</u>*
>
> *Concern in respect of groundwater is expressed mainly in the submissions for local residents. Concerns are expressed in respect of the physical impact on the water table by reason of water extraction and other interference affecting the supply in existing local wells, also in respect of potential contamination of ground water by such as hydrocarbons. There appears to be no public water supply in the area so that local residents and farms are dependent on private wells for domestic and farming needs. Regarding the matter of groundwater supply, the submitted EIS*

(as amended in further information and clarification to the Planning Authority) highlights the limited water requirements of the quarry (stone will not be routinely washed) and points to the likely availability of water on-site from "perched water tables" in the rock formations proposed for exploitation in the proposed development. It is submitted that use of water from this source will ensure that the existing local wells – which draw from the main, deeper "contained aquifer" – will not be adversely affected. It is stated in the EIS that in the event that the local residents'/farms supply source is impacted due to the development, the applicants will drill and install a new deeper supply source. This matter is further addressed in planning conditions proposed by the Planning Authority.

The SRFB in its submission on the appeal refers briefly to the issue of "possible intersection of groundwater", and makes a recommendation of segregation of uncontaminated and contaminated waters on site for the purposes of efficiency and maximising retention times for any heavily contaminated water. However the reference of the SRFB to intersection of groundwater appears to be in respect of the perched water referred to in the EIS. While sympathising generally with residents' concerns over planning conditions, the SRFB does not state any fundamental concern regarding impact on the main water table deep below the site. Regarding the matter of potential contamination of water supply, it is submitted for applicants and in the EIS that the nature of the underlying geology and its associated hydrological regime are such that there are inherent safeguards for the main groundwater body in the area. The supply aquifer for wells in the vicinity is "contained" by reasons of depth and the impermeable nature of overlying strata. Illustrations are provided in the EIS and in appeal documentation.

It is also outlined in the EIS, and in submissions in the appeal, that measures would be in place to prevent contaminations of water. These would include physical containment of hydrocarbon spillages and availability of mop up spill kits and retention of sediments as appropriate in designed pond areas on site. No formal technical assessment of the groundwater impacts has been presented for or by the Planning Authority in the current appeal case. Certain questions relating to groundwater were raised by the Planning Authority in "further information", and certain answers obtained. Conditions relating to the matter of potential groundwater impacts are proposed by the Planning Authority in its Decision in the case. In response to a request by An Bord Pleanála (letter dated 24 March 2003) – requesting any specific observations of the Planning Authority in respect of groundwater issues raised by appellants – the Planning Authority refers specifically to proposed conditions nos. 27, 28, 29, 30 and 31, attached in order to avoid the risk of pollution. It is submitted for the Planning Authority that condition no. 31 enables the

Planning Authority to monitor the impact of the development on groundwater.

Notwithstanding the paucity of technical assessment on the matter of groundwater presented for the Planning Authority on the current appeal file, I must observe that the submitted appeals are largely unsubstantiated. I have read the EIS and studied carefully the appeal submissions for the applicant. The description of the underlying geology which provides in-built safeguards for the protection of the water table and groundwater supplies (and quality) appears quite credible. Accordingly, in respect of groundwater supply and quality, I consider effective monitoring to be the ultimate safeguard for the public interest in this case."

7.4.2.7 Public Water Supplies & Source Protection Areas

The Swan PWS source BH, and an associated observation BH, are mapped by the GSI at a distance of 2.6 km east of the site (GSI 2000). Historically, it is reported that 650 m^3/d is abstracted from an artesian borehole on the riverbank of the Clogh River at Swan Bridge, a short distance upstream of Swan village (Wright 2000). Fitzsimons & Wright (2000) report that the borehole abstracts from a unique bedrock, considered unusual due to it having a markedly different hydrochemical signature relative to other boreholes evaluated in County Laois. The outer source protection area (SPA) serving Swan PWS comes to within 1.25 km of the eastern site boundary, limited where it comes up against a north-south trending structural fault (see Figure 7.6). As previously stated, Hydro-G consulted with the GSI Groundwater Section querying the availability of updated information regarding the Swan PWS, and while the scheme was more recently reviewed, they have not changed the mapping (Taly Hunter Williams, pers. comm. 2021).

The next nearest SPAs are those serving Kyle & Orchard and Ballyroan, which come to within 5.5 km (north) and 7 km (northwest) of the site, respectively.

None of the PWS sources are within the potential radius of influence of the quarry site in terms of groundwater flow direction and each of the above schemes are within different topographical catchments. Therefore, no potential for interaction with the site is envisaged.

There are no National Federation of Group Water Scheme sources within 10 km of the site.

7.4.2.8 Groundwater Vulnerability

Groundwater vulnerability is a measure of the risk that a potential groundwater contamination event may have on the groundwater beneath. It is a measure of how vulnerable groundwater is to a potential contamination event and is a function of the nature of the overlying soil cover, the presence and nature of the subsoil, the nature of the strata, and the thickness of overburden above the water table.

The vulnerability categories, and methods for determination, are presented in Groundwater Protection Schemes (GSI 1999), and Table 7.2 reproduces the GSI's Groundwater Vulnerability Criteria. The guidelines state that *'as all groundwater is hydrologically connected to the land surface, it is the effectiveness of this connection that determines the relative vulnerability to contamination. Groundwater that readily and quickly receives water (and contaminants) from the land surface is considered to be more vulnerable than groundwater that receives water (and contaminants) more slowly and in lower quantities. The travel time, attenuation capacity and quantity of contaminants are a function of the following natural geological and hydrogeological attributes of any area:*

1. The subsoils that overlie the groundwater.
2. The type of recharge - whether point or diffuse.
3. The thickness of the unsaturated zone through which the contaminant moves.

Table 7.2 Groundwater Vulnerability Criteria (GSI 1999)

Subsoil Thickness	Hydrogeological Requirements				
	Diffuse Recharge			Point Recharge	Unsaturated Zone
	Subsoil Permeability & Type				
	High permeability (sand & gravel)	Moderate permeability (sandy subsoil)	Low permeability (clayey subsoil, clay, peat)	(Swallow holes, losing streams)	(sand & gravel aquifers *only*)
0–3 m	Extreme	Extreme	Extreme	Extreme (30 m radius)	Extreme
3–5 m	High	High	High	N/A	High
5–10 m	High	High	Moderate	N/A	High
> 10 m	High	Moderate	Low	N/A	High

Notes: (i) N/A = not applicable
(ii) Permeability classifications relate to the material characteristics as described by the subsoil description and classification method

Groundwater vulnerability for the entire site is mapped by the GSI as Extreme (X) and Extreme (E) due to the occurrence of rock at or near surface. Due to the nature of quarrying, which requires removal of overburden, the groundwater vulnerability rating at all quarry sites will be extreme. The groundwater vulnerability is presented as Figure 7.8.

The Castlecomer GWB report (GSI 2004) states that groundwater vulnerability is generally low except at the perimeter recharge area, where it is typically Extreme.

7.4.2.9 Groundwater WFD Status

The site lies within the Castlecomer GWB. Information presented by the EPA confirms that for the reporting period 2013–2018, the Castlecomer GWB (European Code IE_SE_G_034) is assigned:

- WFD Risk = Not at Risk; and
- Groundwater Status = Good.

7.4.3 HYDROLOGY

The hydrological component of the assessment requires an understanding of surface water drainage patterns in the area and clarification of the surface water catchments contributing flow to the various watercourses in the area.

7.4.3.1 Regional Hydrology

The site occupies an elevated position on the northern slopes of the Castlecomer Plateau. A raised topographical feature that connects the hills to the north and south runs broadly through the centre of the site and serves as a surface water catchment divide, separating headwaters of the River Clogh to the east and the Owveg River to the west. Watercourses on the EPA network database are included in Figure 7.1.

The Owveg River rises 5 km north of the site on the southern slopes of Fossy Mountain. The river drains a relatively narrow catchment as it flows southwards. On reaching Larkins Crossroads, just 600 m west of the site, where its catchment size is 7.6 km^2, the river flows westwards to Boleybeg, before reverting to its southward path. The Owveg outfalls to the River Nore at a distance of 22 km, approximately, downstream of the site near Ballyragget. Essentially, the Owveg River drains the northern, north-western and western toe slopes of the Castlecomer Plateau.

The River Clogh is formed from a series of first order streams that rise 4.5 km northeast of the site. A spring rising on the site is one small tributary contributing to the River Clogh. The main channel of the Clogh flows southwards, passing 2.5 km east of the quarry at Swan, at which point the upgradient area has a catchment of 23.7 km^2. The Clogh outfalls to the Dineen River 4 km south of Swan. The Dineen passes through Castlecomer and outfalls to the River Nore just north of Kilkenny, which is 12 km downstream of the Nore-Owveg confluence.

The River Nore outfalls to the River Barrow at New Ross, which ultimately outfalls to the sea at Waterford Harbour. The largest urban centre in the Nore catchment is Kilkenny—the other main urban centres in this catchment are Abbeyleix, Callan and Thomastown, all of which lie downstream, hydrologically, of the application site.

7.4.3.2 Local Hydrology

Low-lying ground in the area is characterised by a number of small open drains and channels, many of which appear to be spring fed. The EPA river network database shows two first order streams in close proximity to the site, these being:

1. Aughatubbrid Stream (labelled by the EPA as Clogh_010) – The natural headwaters of this stream are fed by a spring that rises in the eastern half of the quarry. The spring flows overground following the land gradient towards the roadside on the northern boundary of the site. Flow enters what appears to be two connected, excavated and unlined settlement ponds. Waters leaving this area enter a channel that runs eastwards along the southern side of the R430. The stream continues to flow eastwards and enters a first order stream (Knocklead) 1.8 km east of the site. This watercourse outfalls to the River Clogh just below Swan.
2. Garrintaggart Stream – natural headwaters leave the north-western corner of the site, flowing north then west, before outfalling to the Owveg River 600 m west of the site. This first order stream drains a catchment area of 7.6 km^2 to the outfall.

The catchments contributing to the streams described above are illustrated in Figure 7.9.

7.4.3.3 Surface Water WFD Status

The application site is situated in the Nore Catchment (Hydrometric Area 15). The GWB Ireland is now one RBD, such that there are no regional RBDs anymore (River Basin Management Plan for Ireland, 2018–2021; Department of Housing, Planning and Local Government).

Table 7.3 WFD Surface Water Data

Station	Owveg (Nore)_010	Clogh_010
Monitoring Station	Bridge West of Spink	Clogh Bridge
Ecological Status 2013-2018	Good	Good
WFD 3rd Cycle Risk Status	Not at Risk	At Risk
Reason for Risk Status	n/a	Moderate biological condition
Primary Pressure	n/a	Agriculture (point and diffuse)
Trend: ammonia	Upward	Upward
Trend: TON	Upward	Upward
Trend: orthophosphate	Upward	Upward

WFD data relating to surface waters east and west of the site are summarised in Table 7.3. The Status of each river is reported by the latest WFD cycle as ‘Good’. The Clogh however is assigned a risk status of ‘At Risk’, the primary pressure attributed to this risk status is ‘Agriculture & Pasture’, with sediment and grazing animals being investigated as impacting watercourses (Sub catchment assessment report for the Clogh "15_12 Dinin [North]_SC_010 Subcatchment Assessment WFD Cycle 2). The Owveg River is assigned a risk status of 'Not at Risk'. Quarrying activities are not listed as a risk factor in either catchment.

7.4.3.4 EPA Q-Ratings

The closest EPA monitoring station on the River Owveg (Nore) is 1.3 km to the west of the site, where the most recent biological rating was Q4 (2019), equivalent to Good. The closest EPA monitoring station on the River Clogh is 3.5 km to the southeast, where the most recent biological rating was Q4 (2005), equivalent to Good.

There is a reasonably consistent trend of biological water quality being Q4 (Good) on the Owveg over the past twenty years. Those Q4 Biological Ratings on the Owveg were maintained during the operation of the quarry under the previous owner's management. There would appear to be no Biological Monitoring evidence for impact on the western hydrological system.

Biological monitoring on the River Clogh ceased sixteen years ago—the results prior to 2005 varied between Q3-4 and Q4 (Good).

Table 7.4 Recent Biological Water Quality Monitoring Results

Watercourse	Owveg (Nore)_010	Clogh_010
Location	1.3 km west of site	3.2 km southeast
Station	Bridge west of Spink	Slatt Bridge
2019	4	
2016	4	
2013	4	
2010	4	
2007	3-4	
2005	4	4
2001	4	3-4
1998	3-4	4
1995		3-4
1991	4	4
1987	3-4	4

7.4.3.5 Designated Areas

Designated sites were also presented in Figure 7.1. Both the Clogh River and Owveg River contain intermittent channel sections that are mapped as being part of the River Barrow and River Nore SAC.

Habitats within the SAC that are listed in Annex I/II of the EU Habitats Directive include floating river vegetation, dry heath, hydrophilous tall herb communities and petrifying springs. Other listed habitats that occur throughout the site include wet grassland, marsh, reedswamp, improved grassland, arable land, quarries, coniferous plantations, deciduous woodland, scrub and ponds. The freshwater habitats support an array of important species, examples of which include freshwater pearl mussel (*Margaritifera margaritifera),* Nore freshwater pearl mussel (*Margaritifera durrovensis*), white-clawed crayfish, salmon, twaite shad and three lamprey species.

The Nore main channel is a designated salmon river and tributaries provide important spawning grounds. The GSI GWB Descriptor Sheet (2004) suggests that there are no terrestrial ecosystems associated within the Castlecomer GWB.

7.4.3.6 Hydrometric Stations & Low Flows

There are no active hydrometric gauges on the River Owveg. The nearest hydrometric gauge on the River Clogh is at Slatt, but this is inactive and no low flow data are available. The nearest active gauge relevant to the eastern catchment is on the River Dinin at Castlecomer.

In assessing the feasibility of potential discharge routes, the potential mixing points are considered to be:

1. Western = confluence of the Garrintaggart and Owveg; and
2. Eastern = confluence of the Aughatubbrid and Knocklead Stream.

According to the EPA HydroTOOL model, the 95%ile flows at the mixing points on the western and eastern routes are 0.010 and 0.009 m^3/s, respectively. An alternative method was used availing of the ratio of derived low flow rate estimated per unit catchment upstream of the relevant hydrometric gauge. The variation between the two methods was not significant and the average from the two approaches was taken.

Streamflows in the receiving waters were measured on multiple occasions by Envirologic using an Aqua Data Fluvial RC3 Electromagnetic Velocity Meter. Post-processing of data yielded the streamflow rates presented in Table 7.5. The initial dataset suggests that both catchments have a ‘flashy’ Hydro-Graph response, which means that they respond rapidly to rainfall.

Table 7.5 Streamflow Information and Rates

Item	Potential discharge point – Western Route	Ballyragget Hydrometric Station (15012)	Potential discharge point – Eastern Route	Potential discharge point – Eastern Route	Slatt Hydrometric Station (15013)	Castlecomer Hydrometric Station (15019)
River	Owveg	Nore	Knocklead	Clogh	Clogh	Dinin
Status	n/a	Active	n/a	n/a	Inactive	Active
Active Period	n/a	1988	n/a	n/a	1978-2008	1989-present
Location	Larkin's Cross	Ballyragget	Moyadd Bridge		Slatt Bridge	Castlecomer
Catchment area, km^2	7.61	1057	6.98	12.18	20.24	140.2
95%ile flow (EPA Hydronet), m^3/s		2.72				0.226
Specific 95%ile flow $m^3/s/km^2$ using ratio at hydrometric gauge		0.0026				0.001612
95%ile flow (inferred from catchment ratio), m^3/s	0.020		0.011	0.020		
95%ile flow (EPA Hydrotool), m^3/s	0.010		0.009	0.016		
Average 95%ile based Hydrotool and Hydrometric Gauge data	0.015		0.010	0.018		
Flowrate on 08/04/21, m^3/s	0.020			0.017		0.618
Flowrate on 05/05/21, m^3/s	0.023			0.019		0.445
Flowrate on 24/05/21, m^3/s	0.187			0.280		5.74

7.4.3.7 Flood Risk

7.4.3.7.1 Historical OSI Maps

Neither the historical 6" OSI maps, dated c. 1830–1840, or 25" OSI maps, dated c. 1888–1913 show any indicators of potential flooding within the site boundary.

The Aughatubbrid Stream is shown on the 6" maps as rising 250 m east of the site, whereas the 25" maps show the stream as rising within the site from a spring. There are no indicators of flooding, areas prone to waterlogging or marshy areas on the 6" or 25" maps either side of receiving watercourses east of the site.

The routing of the Garrintaggart Stream is shown on the 6" maps to be as per current status. There are no indicators of flooding, areas prone to waterlogging or marshy areas on the 6" or 25" maps either side of receiving watercourses west of the site.

7.4.3.7.2 OPW Flood Maps

Consultation of the OPW flood hazard mapping shows no indication that historical flooding events have occurred within 10 km of the site. The nearest downstream flood events occurred at Ballyragget and Castlecomer.

7.4.3.7.3 Benefitting Land Maps

Neither the Aughatubbrid nor the Garrintaggart Streams are maintained as part of arterial drainage networks. The only section of maintained channel in the area is a 1 km long reach extending upstream from Boleybeg Bridge. Lands either side of this portion of channel are designated benefitting lands. Benefitting land maps were prepared to identify areas that would benefit from land drainage schemes and typically indicate low-lying land near rivers and streams that might be prone to flooding. The emphasis of these schemes was the improvement of agricultural land. Works appear to be locally based and part of Boleybeg Drainage District.

7.4.3.7.4 Catchment Flood Risk Assessment and Management (CFRAM)

No areas within the Owveg or Clogh River catchments have been covered by the more detailed OPW CFRAM mapping system.

7.4.4 RAINFALL, RUNOFF & RECHARGE

A preliminary, general and unrefined surface water runoff calculation for the entire 20 ha area of the site is outlined below using Met Eireann rainfall and evapotranspiration values along with GSI recharge coefficients.

7.4.4.1 Rainfall

Monthly gridded rainfall data was sourced from Met Éireann (Walsh 2012) and is presented in Table 7.6.

Table 7.6 Long Term Mean Monthly Rainfall Data (mm) (Met Éireann)

J	F	M	A	M	J	J	A	S	O	N	D	Annual
107	78	85	76	76	78	77	97	86	122	109	106	1096

Average Annual Rainfall (AAR) over a 30-year period is 1,096 mm.

Average annual potential evapotranspiration rates in the Castlecomer GWB are given as 457 mm (GSI 2004). Actual evapotranspiration (AE) is estimated by multiplying PE by 0.95, to allow for the reduction in evapotranspiration during periods when a soil moisture deficit is present (Water Framework Directive 2004). Actual evapotranspiration is therefore 434 mm/yr (0.95 PE).

The Effective Rainfall (ER) for the site, using Met Eireann AAR data, is determined as follows:

$$ER = AAR – AE$$

$$= 1096 \text{ mm/yr} – 434 \text{ mm/yr}$$

$$ER = 662 \text{ mm/yr}$$

The GSI database estimates effective rainfall to be 625 mm/yr (https://dcenr.maps.arcgis.com/).

Given that the calculation using the Met Eireann Effective Rainfall value and the GSI mapped value are similar, the GSI mapping values shall be adopted in the rainfall-runoff calculation, as follows:

Overall site area runoff-recharge:

= area x ER

= 200,000 m^2 x 0.625 m/y

= 125,000 $m^{3/}$yr

= approximately equivalent to 342 m^3/d

Adopting the Effective Rainfall rate falling on the site as 0.625 m/yr, on average, and considering the entire site area of c. 19.6 ha, then the volume of water generated directly from rainfall landing on the site is calculated to be 125,000 m^3/yr or 342 m^3/d, on average. It has previously been described that the site straddles a catchment divide (Figure 7.1). This catchment boundary splits the site evenly in half, with 10 ha (10,000 m^2) naturally draining to the east and 10 ha naturally draining to the west. Accordingly, approximately 171 m^3/d rainfall-runoff would be generated, on average, in each half of the site.

7.4.4.2 Recharge

Using vulnerability classifications and hydrogeological settings, recharge coefficients can represent the ratio of precipitation that theoretically infiltrates vertically to the water table to that which moves as surface overland flow. Based upon the vulnerability classification of extreme, the GSI presents rainfall and recharge information and maps the site area as follows:

- GSI Effective Rainfall (mm/yr): 625;
- Quarry recharge coefficient: 85 % where bedrock is exposed (assume across entire site); and
- Off-site recharge coefficient on topographically upgradient lands (south): 22.5 % (till overlain by gley soil, extreme vulnerability).

7.4.4.3 Site Water Balance

A water balance derived from rainfall landing on the entire working area of the site and topographically upgradient lands is presented as Table 7.7.

Table 7.7 Rainfall Derived Water Balance

Parameter	Unit	Western Half of Site	Eastern Half of Site	Topographically upgradient lands (western half)	Topographically upgradient lands (eastern half)	Total
Area	m^2	100,000	100,000	27,000	63,000	290,000
Effective rainfall	m/yr	0.625	0.625	0.625	0.625	
Rainfall volume	m^3/yr	62,500	62,500	16,875	39,375	181,250
Rainfall volume	m^3/d	171	171	46	108	496
Recharge coefficient	%	85	85	22.5	22.5	
Recharge reaching bedrock head	m^3/yr	53,125	53,125	3,797	8,859	118,906
Surface runoff (recharge rejected at surface)	m^3/yr	9,375	9,375	13,078	30,516	62,344
Recharge cap	m/yr	No cap	0.1	No cap	0.1	
Recharge to bedrock aquifer	m^3/yr	53,125	10,000	3,797	6,300	73,222
Shallow subsurface flow (recharge rejected at bedrock head)	m^3/yr	0	43,125	0	2,559	45,684
Surface runoff plus shallow subsurface flow	m^3/yr	9,375	52,500	13,078	33,075	**108,028**
	m^3/d	26	144	36	91	**296**
	l/s	0.3	1.6	0.4	1.05	**3.4**
Destination		Sump	Discharge Pond @ Entrance	Sump	Discharge Pond @ Entrance	

Notes:

Within the quarry area itself, the aquifer classifications in Figure 7.6 show that the Clay Gall Sandstones exposed in the western half are locally important and moderately productive. Hence, no recharge cap has been applied by the GSI. These contrast with the low primary porosity / low permeability Coolbaun Formation, which is a poor aquifer and hence has had a recharge cap of 100 mm/yr imposed by the GSI.

Rainfall rejected either at ground surface or at bedrock head will move laterally as surface runoff or shallow subsurface flow. Most of the runoff generated in the north-western half of the quarry will collect in the sump pond on the quarry floor. Given the topographically enclosed nature of the sump, this water is then removed by pumping. Based upon values shown in Table 7.7, this is estimated to be in the order of 0.7 l/s. Based on visual observations and experience of the overflow from the sump, this rate is deemed realistic for the site situation.

Rainfall-runoff and shallow subsurface flows generated in the south-eastern half of the quarry will likely flow by gravity and collect in the excavated pond adjacent to the site entrance. This water will subsequently flow eastwards via a roadside ditch. This is as it always was, pre-site development. Based on visual observation, the flow in the roadside drain as it passes the eastern site boundary was estimated as 0.5 l/s. Springflow in the south-eastern half of the quarry was estimated from observation as being 1 l/s. This would suggest that the springflow is derived from rejected recharge in the south-eastern half of the site and topographically upgradient areas.

Based on the final determinations of information presented in Table 7.7, the combined total of runoff and shallow subsurface flow that needs to be managed by the site is 108,028 m^3/yr, equivalent to 296 m^3/d (3.4 l/s).

Annual recharge to the bedrock aquifer from rainfall landing on topographically upgradient lands and at the site itself is estimated to be 73,222 m^3 (201 m^3/d). The other component that is included in the quarry discharge is the groundwater removed from the bedrock aquifer in order to lower the water table and provide a dry working environment. This requires site-specific data describing hydraulic properties of the bedrock and will be analysed later in the chapter.

This preliminary water balance is a 'first run' desk-based exercise and it is acknowledged that the approach has certain limitations, such as:

- For simplicity, it has been assumed that all rainfall landing in the north-western half of the quarry will drain towards the sump. It is acknowledged that some runoff may be directed by gravity towards the north-western pond (Pond Tank No. 1);
- The recharge coefficients and recharge caps are derived from literature sources that may differ from actual values;
- Bedrock permeability in the Clay Gall Sandstones may be dominated by fracture flow. In this sense, it may be appropriate to invoke a recharge cap to represent lack of infiltration at bedrock head, and bedrock exposed on the previously active quarry floor;
- Some recharge may emerge on springs mapped on the periphery of raised ground outside the quarry; and
- The Castlecomer GWB report states that most of the Clay Gall Sandstones are confined.

Acknowledgement of these limitations facilitates the development of a more justifiable conceptual model and water management plan for the proposed development.

7.4.4.4 Regional Water Balance

To assess whether the proposed quarrying activities and potential discharge, as estimated from a local rainfall-recharge water balance, are likely to have an impact on regional water resources, an approximate regional water balance has been calculated and is presented as Table 7.8. Given that > 95 % of the site is underlain by the Castlecomer GWB and the inherent inaccuracies and uncertainties in the precision of the macro scale GIS mapping that delineates GWBs, it is perfectly reasonable to use only the Castlecomer GWB information to evaluate the potential for interaction with the regional regime.

Given that the Castlecomer GWB is reported to have an approximate area of 224 km^2 (GSI 2004) and that the GSI assigns a groundwater recharge value of 625 mm/yr, the volume of groundwater associated with this groundwater body is approximately 140,000,000 m^3/yr. This groundwater forms a baseflow component to the River Nore SAC.

Table 7.8 Regional Water Balance

Regional Water Balance Component	Value
GSI assigned area for Castlecomer GWB, km^2	224
Castlecomer GWB, m^2	224,000,000
GSI states majority of Castlecomer GWB is Lm, km^2	224
Total aquifer area, m^2	224,000,000
GSI Effective Rainfall, mm/yr	625
GSI groundwater recharge cap, mm/yr	No cap
Groundwater recharge, m/yr	0.625
Groundwater recharge to Castlecomer GWB, m^3/yr	140,000,000
Average daily groundwater recharge to Castlecomer GWB, m^3/d	383,561
Rainfall recharge to total Lm aquifer area, m^3/yr	140,000,000
Rainfall-runoff generated within the quarry and topographically upgradient lands, m^3/d	296 (see Table 7.7)
Rainfall-runoff generated within the quarry and topographically upgradient lands, m^3/yr	108,040
Proportion of quarry's discharge as a % of the total Lm aquifer area's annual recharge to groundwater from rainfall (%)	0.07

Table 7.8 shows that at a local scale, rainfall derived recharge at the site represents 0.07 % of the volume of groundwater discharging to the River Nore SAC system from the Castlecomer GWB. The water balance offers that the % of waters intercepted at the quarry is below the 5 % threshold value of the Water Framework Directive Working Group (GW5) and is therefore deemed to be of 'Low Potential Impact' and 'Not at Significant Risk' by WFD characterisation methods (GW5 2005). These water balance data provide the confidence to assert that there will be no adverse impact on the regional groundwater regime.

7.5 SITE INVESTIGATIONS

7.5.1 THIRD PARTY WELL SURVEY

Information on wells and springs in the area was gained during the desktop study using a combination of historical mapping, aerial photography and the information contained in the Laois County Council online planning system. The resolution of the GSI well location database is poor across the general area, and only one domestic well (shallow) is mapped within 1 km of the site. As stated, residences on all perimeter roads bounding the quarry are served by their own domestic wells. The survey revealed that there are 11 mapped wells within 500 m of the site's boundary.

A door-to-door survey of third-party wells in the area was initially carried out on 18th March 2021. This initial well survey was tentatively carried out during Level 5 Covid-19 restrictions and several residents urged caution and expressed a preference for a re-visit following the lifting of lockdown restrictions. A follow-up survey was carried out on 30th May 2021. Information collected during the survey is collated in Table 7.9. Third party well locations are presented in Figure 7.10.

7.5.2 QUARRY BEDROCK EXPOSURES

The *Spink Geological Assessment* report (SLR 2020), included as Appendix 6, describes the geology of the site in detail, and includes the following brief description of exposures:

- Exposures are described as showing the underlying Moyadd Coal Formation exposed at the toe of the face in the extreme northwest, with the overlying Coolbaun Formation exposed at the crest of the face in the south-eastern area. Almost all of the quarry is developed within the Clay Gall Sandstone with the entire sequence exposed on the weathered previously worked faces;
- The exposed quarry faces show a massive thick uniform sandstone at the base of the formation with a more variable interbedded sandstone and siltstone unit towards the top of the formation;and
- The bedding dip is typically towards the southeast and varies from < 5° to 10° with local steepening in the northwest due to the presence of a small fault.

The formation targeted for quarrying is the Clay Gall Sandstone with the material from the Coolbaun Formation suitable for low spec fills / cement production, etc. The black mudstones of the Moyadd Coal Formation are not targeted for extraction.

The Clay Gall Sandstone is exposed in the north-western half of the site, with one bench having previously been extracted. The south-eastern half of the site is partially worked, with the overlying Coolbaun Formation covering the Clay Gall sandstone in this area.

Table 7.9 Third Party Well Survey Results (Refer to Figure 7.10 for Property & Well Locations)

Property Ref. No.	Easting	Northing	Ground Elevation mOD	Top of Casing (toc), mOD	Groundwater Elevation, 18/03/21 mbtoc	Groundwater Elevation, 18/03/21 mOD	Notes
1	653,158	683,927	c. 210		c. 210		Declined participation on 18/03/21 pending further discussion/consultation with Lagan's representative. Homeowner absent during follow-up visit performed on 24/05/21 following consultation visit from Lagan's representative. Reportedly a 100 m deep artesian well, hence groundwater level can reasonably and justifiably be assumed as equal to ground level.
2	653,563	683,462	243.17	243.17	Inaccessible	Inaccessible	Declined participation on 18/03/21 pending further discussion/consultation with Lagan's representative. Previous supply to house and farm was from a shallow spring chamber in front garden. New well for water supply, which is c. 122 m deep, pump set at 116 m. Property visited again on 24/05/21 following consultation visit from Lagan's representative. New well surveyed in but heavy lifting machinery would be required to raise wellhead and Philmac fitting on rising main requires opening and closing to facilitate raising of wellhead. Resident stated preference for an end of summer groundwater level survey. Calculations in the study suggested that further visit was not necessary in terms of potential impact (i.e., none).
3	653,879	683,341	c. 245				Water source reportedly very high yielding and supplied several houses (to the east). Legal owner could not be located to gain permission to survey well.
4	654,043	683,297					Supplied by Property no. 3. Given uncertainty around ownership of (3) resident stated that it is likely they will need to drill new private well to now serve their own residence in any case.
5	654,086	682,954					Residents facilitated discharge route assessment on their lands in March 2021. Homeowner absent on March and May 2021 well survey visits.
6	652,882	682,687	c. 225				Homeowner absent on March and May 2021 well survey visits.
7	652,753	683,191	c. 200				House derelict so assumed supply remains to adjacent farm. Owner absent. Assumed connected to dwelling at (8).
8	652,798	683,303	c. 200				Owned by same resident at (1). Reported historical issues with iron ingress. Owner previously attempted to remediate by installing additional casing. There is a Spring immediately south of (8) shown on OSI maps still present, may be difficult to locate due to scrub. Refused permission to survey in March 2021. Property owner absent during May 2021 survey, tenant did not know where source was located.
9	652,935	683,492	c. 210				Homeowner absent on both well survey visits. Groundwater levels during 2008-2010 were 2.8–4.1 mbtoc (Byrne Environmental 2011).
10	652,827	683,587	192.76			191.54	Large diameter, shallow well chamber alongside road.
11	652,885	683,639					Shares supply with Property 10

7.5.3 QUARRY BEDROCK EXPOSURES

The *Spink Geological Assessment* report (SLR 2020), included as Appendix 6, describes the geology of the site in detail, and includes the following brief description of exposures:

- Exposures are described as showing the underlying Moyadd Coal Formation exposed at the toe of the face in the extreme northwest, with the overlying Coolbaun Formation exposed at the crest of the face in the south-eastern area. Almost all of the quarry is developed within the Clay Gall Sandstone with the entire sequence exposed on the weathered previously worked faces;
- The exposed quarry faces show a massive thick uniform sandstone at the base of the formation with a more variable interbedded sandstone and siltstone unit towards the top of the formation; and
- The bedding dip is typically towards the southeast and varies from < 5° to 10° with local steepening in the northwest due to the presence of a small fault.

The formation targeted for quarrying is the Clay Gall Sandstone with the material from the Coolbaun Formation suitable for low spec fills / cement production, etc. The black mudstones of the Moyadd Coal Formation are not targeted for extraction.

The Clay Gall Sandstone is exposed in the north-western half of the site, with one bench having previously been extracted. The south-eastern half of the site is partially worked, with the overlying Coolbaun Formation covering the Clay Gall sandstone in this area.

7.5.4 ROTARY CORE DRILLING

As part of the geological and resource evaluation for the proposal, four rotary cored boreholes were drilled, and the cores examined by SLR in February 2020. The geologists selected the core borehole locations centrally along the long axis of the site from northwest to southeast and perpendicular to strike. Cores were drilled to depths of 30–90 m, with locations illustrated in Figure 7.7. Borehole lithologies are summarised in Table 7.10.

The cores were examined by geologists and reported with conceptual sections relating to the proposed excavation profile across the site (SLR 2020), for the purposes of rock resource evaluation. The orientation of the site investigation transect comprising the core boreholes informed the geologist's logs and showed that the Clay Gall Sandstone dips from northwest to southeast, with the base of the formation deepening from 20 m in the north-western half to 72 m approaching the south-eastern boundary. The Clay Gall Sandstones are covered by the overlying Coolbaun Formation, with this cover depth increasing to 26 m approaching the eastern boundary.

Table 7.10 Summary Details of Rotary Cored Boreholes

ID	SP01	SP02	SP03	SP04
Location	NW corner, old processing area	Eastern end of quarry floor, west of sump	Central, unquarried area south of entrance	South-eastern, unquarried area
Eastern	653,172	653,275	653,412	653,591
Northing	683,287	683,196	683,063	682,949
Depth, m	30	40	60	90
Ground Elevation, m OD	225	225	240	247
Base Elevation, m OD	195	185	180	157
Coolbaun Formation Interval			0–12 m	0–26 m
Clay Gall Sandstone Interval	0–20 m	0–31 m	12–56 m	26–72 m
Moyadd Coal Interval	20–30 m	31–40 m	56–60 m	72–90 m

Geologists tend not to record water strikes in boreholes. It is rarely possible for them to identify where water is ingressing because they use water in the drilling rigs to lubricate, cool and remove any evidence of water in the geology during the water assisted cutting of the cores from the rock before being lifted to surface.

SP01 and SP04 were installed as 50 mm groundwater level monitoring points and groundwater level loggers were deployed in December 2020 to record trends in groundwater levels over time. SP02 and SP03 were decommissioned.

7.5.5 LARGE DIAMETER WELL DRILLING

Three large diameter 'Production Wells' were drilled between 18th – 22nd February 2021 for the purposes of a hydraulic evaluation. This evaluation was designed so as to establish true groundwater gradients, facilitate the application of a conventional pump tests and evaluate potential for impact on local domestic wells. The hydrogeological information gathered from the conventional well drilling and testing was used to calculate likely future water management volumes arising at the site. The large diameter boreholes were drilled to a target depth of 5 m, approximately, below the proposed deepest part of the site's final floor level, which is proposed to be 200 m OD and 190 m OD in the north-western and south-eastern zones, respectively, following the dip of the Clay Gall Sandstone formation.

Design and drilling supervision was undertaken by Dr. Pamela Bartley of Hydro-G. Drilling was conducted by Briody Well Drilling Ltd.

In general, construction involved opening with a 210 mm diameter drill bit and inserting 200 mm diameter OD steel casing to seal off surface water ingress. Drilling progressed below the steel casing using a 210 mm bit in an open hole. Each well was developed by airlifting for 3-4 hours during which well yields were estimated. The remainder of the borehole was left unlined because the rock is competent. The borehole logs and additional notes from drilling are presented in Appendix 7.1. Summary details and lithologies encountered are presented in Table 7.11, along with estimated yields encountered during drilling.

As expected for bedrock in Ireland, groundwater was primarily encountered in discrete zones. With the exception of ingress across a 5 m zone in PW1, all of the water strikes occurred along the interfaces between the different bedrock formations. It is clear that the largest water strikes were encountered at the interface where the Clay Gall Sandstones rest on the Moyadd Coal Formation.

In PW1, an initial, relatively minor water strike (10 m^3/d) occurred close to surface and corresponds with the interface between the base of the Coolbaun Formation and the top of the Clay Gall Sandstone. A similarly small ingress of 10 m^3/d was met at 15 m, with this gradually increasing to 25 m^3/d by 20 m bgl. Changes in geology were not observed here and it may be indicative of general weathering. A more substantial water-bearing fracture (75 m^3/d) was logged at 43 m, which marks the transition zone between Clay Gall Sandstone and Moyadd Coal Formation.

Table 7.11 Summary Details of Hydraulic Test Wells

ID	PW1	PW2	PW3
Location	Entrance	Processing Area	Weighbridge
Easting	653,411	653,096	653,269
Northing	683,148	683,299	683,338
Depth, m	61.5	51	56
Coolbaun Formation Interval	0–3 m		
Clay Gall Sandstone Interval	3–45 m	0–19 m	0–18 m
Moyadd Coal Interval	45–61.5 m	19–51 m	18–56 m
Water Strikes	10 m^3/d @ 2 m (232 m OD) 10 m^3/d @ 15–20 m (219–214 m OD) 75 m^3/d @ 43 m (191 m OD)	25 m^3/d @ 6 m (217 m OD) 75 m^3/d @ 10–17 m (213–206 m OD) 900 m^3/d @ 17 m (206 m OD)	10 m^3/d @ 17 m (211 m OD)
Total yield estimate from airlifting	100 m^3/d	1,000 m^3/d	10 m^3/d

In PW2, the initial inflow at 6 m below ground (25 m^3/d) corresponds to the base of made ground—this may be linked to the previous operator's construction of settlement ponds in this area. The ingress of an additional 75 m^3/d emanates from a 3 m thick layer of soft, creamy sands. A 3 m band of sandstone separated the sands from a 1 m deep zone that returned a significant volume of water (estimated during development to be ~900 m³/d) at 17–18 m below ground. The base of the significant water-bearing zone was the top of the underlying Moyadd Coal formation, which returned no additional water.

The small yield encountered in PW3 (10 m³/d) occurred at the interface between the base of the Clay Gall Formation and the top of the Moyadd Coal formation. No water ingress was noted from the underlying composite mudstone bedrock.

As stated, the borehole logs and additional notes from drilling are presented in Appendix 7.1.

7.5.6 GROUNDWATER LEVELS

The well heads at the site's boreholes were surveyed in on 24th May 2021. Manual dips to groundwater level was completed on occasional site visits. Depths to water and elevations are presented in Table 7.12. Dataloggers recorded water level constantly and those records are presented later.

Table 7.12 Groundwater Levels

ID	Depth m	Top of Steel Casing, mOD	Depth to Groundwater 22/03/21 mbtoc	Groundwater Elevation 22/03/21 mOD	Depth to Groundwater 24/03/21 mbtoc	Groundwater Elevation, 24/03/21 mOD	Depth to Groundwater 24/05/21 mbtoc	Groundwater Elevation, 24/05/21 mOD
SP01	30	222.94	0.49	222.45	0.52	222.42	0.64	222.30
SP04	90	246.40	18.38	228.02	17.56	228.84	15.30	231.10
PW1	61.5	234.90	11.31	223.59	11.77	223.13	11.15	223.75
PW2	51	224.06 & cut to 223.67	2.19	221.87	2.20	221.86	1.80	221.87
PW3	56	228.70	6.26	222.44	6.33	222.37	6.41	222.29
Sump	na	na	na	223.20	Not measured	Not measured	na	222.76
Spring	Na	na	na	242.98	Not measured	Not measured	na	242.98

7.5.6.1 Groundwater Flow Direction

The above groundwater levels infer that groundwater flow direction within the site is in a west-southwest direction towards PW2. The locally important Clay Gall Sandstone aquifer is unconfined within the north-western half of the site. The Clay Gall Sandstone extends southwards and becomes more confined as a result. The regional groundwater flow direction is at a different macro scale to that of the quarry site itself (Figure 7.11) and is known to be from NE to SW. The site's groundwater levels confirm that the topographical surface water catchment divides are not reflective of any distinct groundwater catchments.

7.5.6.2 Hydraulic Gradients

The following hydraulic gradients are calculated within the site. There is no significant difference in levels or gradients across the two monitoring events.

- March 2021

  (NE-SW) PW3-PW2 = 222.44–221.87 / 184 = 0.003 m/m

  (SE-NW) PW1-PW2 = 223.59–221.87 / 350 = 0.005 m/m

  (SE-NW) PW1-PW3 = 223.59–222.44 / 240 = 0.005 m/m

- May 2021

  (NE-SW) PW3-PW2 = 222.29–221.87 / 184 = 0.002 m/m

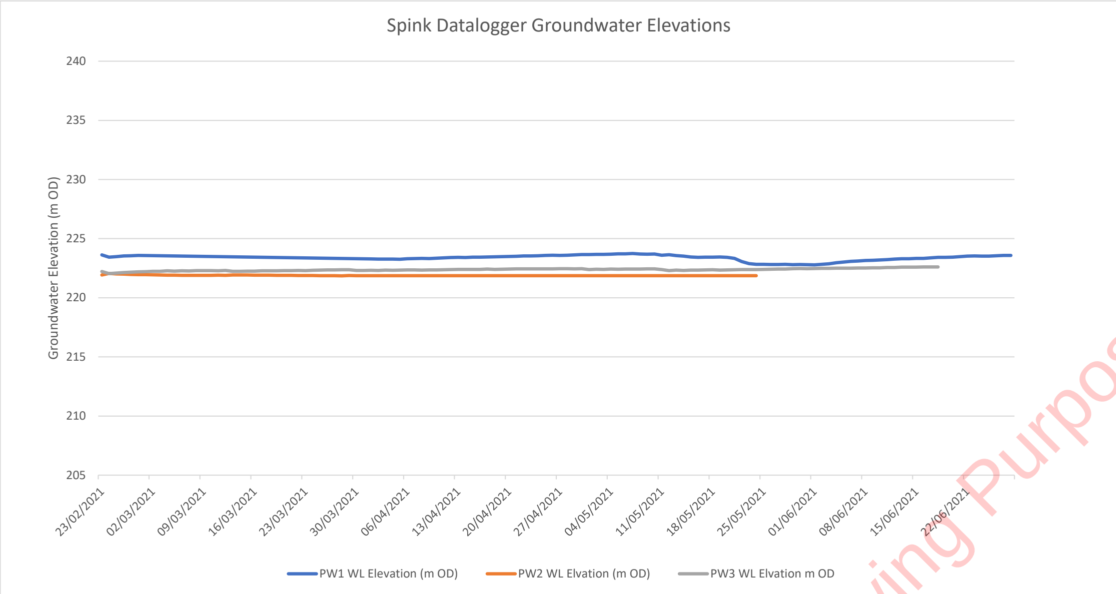
  (SE-NW) PW1-PW2 = 223.75–221.87 / 350 = 0.005 m/m

  (SE-NW) PW1-PW3 = 223.75–222.29 / 240 = 0.006 m/m

The calculated groundwater gradients range of 0.003 to 0.005 m/m in March 2021 and a range of 0.002 to 0.006 mm in May 2021 are equivalent to 2 to 6 mm change in water level over 1 m distance. These are considered imperceptible in hydrogeological scale assessments for the micro scales such as apply to quarry sites.

7.5.6.3 Groundwater Level Variation

Water level dataloggers were installed for the purposes of continuously recording winter and summer groundwater levels between December 2020 and May 2021. The compensated water level data suggests a relatively stable water level response with slight dropping in groundwater levels with the progression of the year, as is expected in a normal hydrogeological recession. The graph for datalogger water level response is presented in Graph 7.1.



Graph 7.1 Datalogger Water level Response

7.5.7 AQUIFER TESTING

Aquifer testing was performed with the aims of:

1. establishing the hydraulic properties of each of the geological formations in terms of transmissivity, specific capacity, hydraulic conductivity and storage coefficient; and
2. informing the conceptual understanding of the groundwater regime at the site.

The three 8" diameter Production Wells were evaluated using a series of pumping tests following installation. These tests consisted of:

1. Multi-stage step test. Step tests involve pumping the well for three to five discrete pumping rates for periods of equal duration. The duration of each step is generally between 60 and 180 minutes, depending on the drawdown/discharge characteristics of the well. The usual hydrogeological testing assumptions and conditions underlying the analysis of the step test are:
   - The aquifer from which groundwater is pumped has a seemingly infinite extent;
   - The hydraulic permeability of the aquifer is equal in all directions, the aquifer is of a certain thickness and homogeneous in rock composition over the area influenced by the step-pumping test;
   - Prior to pumping, the water level is (nearly) horizontal;
   - The aquifer is pumped step-wise at increased discharge rates;
2. Constant rate pumping test. The constant discharge test was used to determine hydraulic properties of the well, and to investigate the potential for drawdown in

nearby wells. Transmissivity is the rate water is transmitted through an aquifer in terms of a unit width and a unit hydraulic gradient. It equals the aquifer's hydraulic conductivity (permeability) times the aquifer thickness. The higher the transmissivity, the more prolific the aquifer is considered. The purpose of the constant discharge test was also to establish the stability of the hydrochemistry of the groundwater; and

3. Recovery test. Monitoring and analysis of groundwater levels following completion of test pumping. This phase facilitates the application of formulae to further characterise the groundwater body.

Groundwater levels were recorded in each production well, both intermittently using a manual dipmeter and continuously with the use of submerged pressure transducers (dataloggers). Stilling tubes were installed temporarily to facilitate a groundwater level dipmeter. Pumps, control valves and pumping rates were calibrated on the day preceding each step test. Flowrates were measured in real time using a magmeter and checked manually on an intermittent basis.

The Clay Gall Sandstone is exposed at surface at PW2 and PW3 and was logged at 3 m in PW1. With this in mind, it is treated as an unconfined aquifer in the analysis below. However, given that the primary inflows occur via secondary porosity, i.e., at the base of the formation, and at a number of discrete fractures, the aquifer is regarded as being heterogenous. The underlying Moyadd Coal formation is treated as an aquitard. Each of the wells fully penetrated the Clay Gall Sandstone.

7.5.7.1 PW1 Aquifer Testing

A Grundfos submersible pump (model MS402) was installed in PW1 at 53 mbgl. The pump is rated to lift 7 m^3/h (168 m^3/d) at a head of 36 m. Saturated thickness at start of the test was 50.2 m.

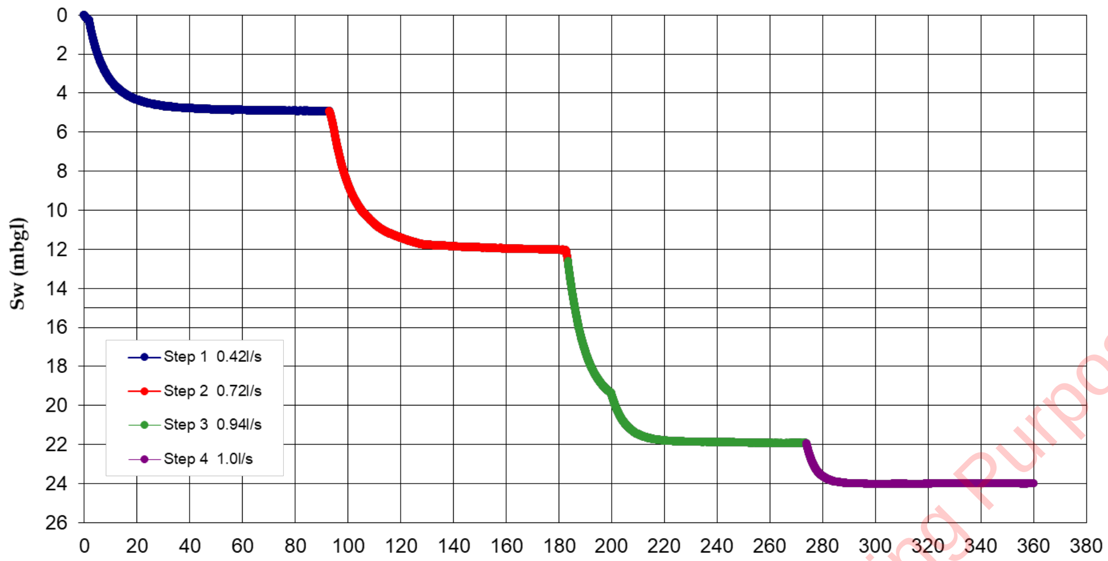
7.5.7.1.1 PW1 Step Test

A four-stage step test was carried out on the 23rd of March 2021—the steps had a discharge range from 0.4 l/s to 1 l/s. A step duration of 90 minutes was selected.

The results of the PW1 step test are presented in Table 7.13. Steady-state conditions appear to have been achieved towards the end of each step. The starting groundwater level was 11.77 m below datum (top of stilling tube). At the end of the test, the ground water level was at 36.29 m below the datum, equivalent to a drawdown of 24 m. The drawdown curve for each step is shown in Graph 7.2.

Specific yield describes the volume of water that an unconfined aquifer releases from storage per unit surface area of aquifer per metre of drawdown. Specific capacity (Sc) of the well is defined as the short-term sustainable yield or discharge from the well per unit depth of drawdown. Specific capacity can be used to provide the design pumping rate or maximum yield from a well, represented by:

$$Sc = Q / \Delta h$$



Graph 7.2 PW1 Drawdown Response during Step Test

Table 7.13 PW1 Step Test Results Summary

Step No.	Step time, mins	Discharge, l/s	Discharge, Q (m^3/d)	Observed Drawdown, m	Specific yield, s/Q	Specific capacity, (m3/d/m)	Predicted Drawdown, m
1	90	0.42	36.58	4.94	0.135	7.40	4.74
2	90	0.72	62.40	12.04	0.193	5.18	12.85
3	90	0.94	81.60	21.94	0.269	3.72	21.43
4	90	1.0	86.40	24.01	0.278	3.60	23.92

The equation used in the step test analysis for predicting drawdown for different pumping rates is Jacob's general equation (Cooper & Jacob 1946):

$$s_w = BQ + CQ^2$$

where:

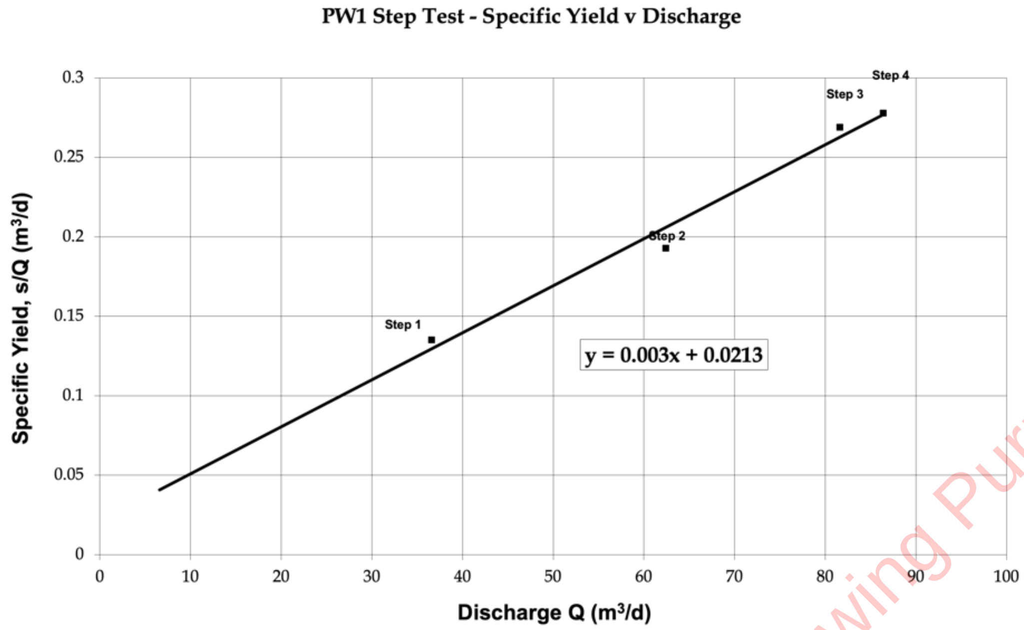
S_w = predicted drawdown of the water level in the well (m)

B = linear aquifer + well loss coefficient (d/m^2)

C = non-linear well-loss coefficient (d/m^4)

Q = discharge (m^3/d)

The specific yield was plotted against discharge and a best fit straight line was drawn through the data points (see Graph 7.3). The intersection of the line with the y-axis (B) and the slope of the line (C) are coefficients that relate to the hydraulic characteristics of the well and aquifer (Hantush-Biershenk's method).



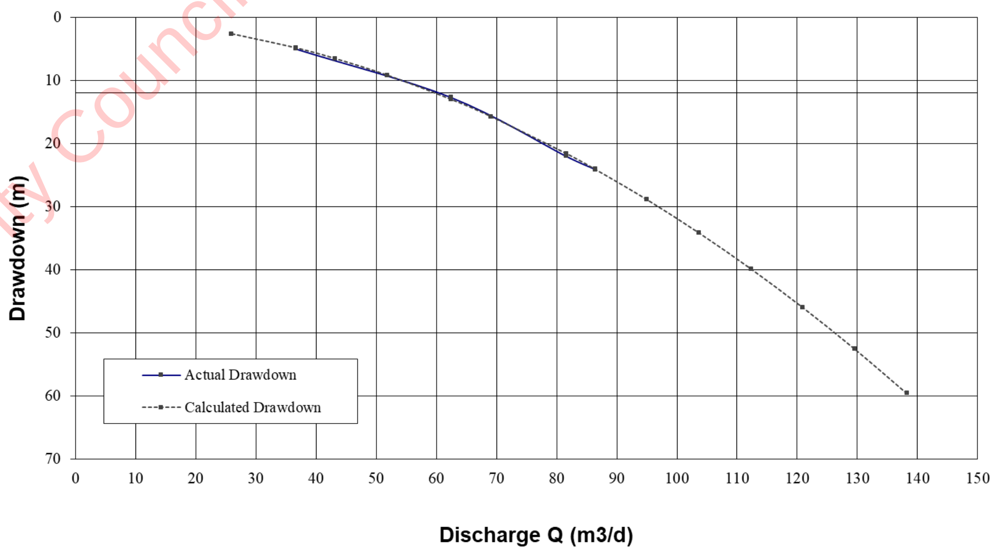
Graph 7.3 PW1 Specific Yield Plotted against Discharge

From the graph, B = 2.13 x 10^{-2} (d/m^2) and C = 3 x 10^{-3} (d^2/m^5).

For drawdown in borehole PW1, Jacob's general equation then becomes:

$$S_w = (2.13 \times 10^{-2})\,Q + (3 \times 10^{-3})\,Q^2$$

Using this equation, the predicted drawdown in the well was calculated and plotted against the discharge along with the measured drawdown (Graph 7.4). The drawdown-discharge curve measured during the step-pumping test is shown in the same graph. The two curves are similar, which shows that the calculated drawdown equation is an adequate model for the actual measured drawdown in the well.



Graph 7.4 PW1 Predicted and Actual Drawdown Plotted against Discharge

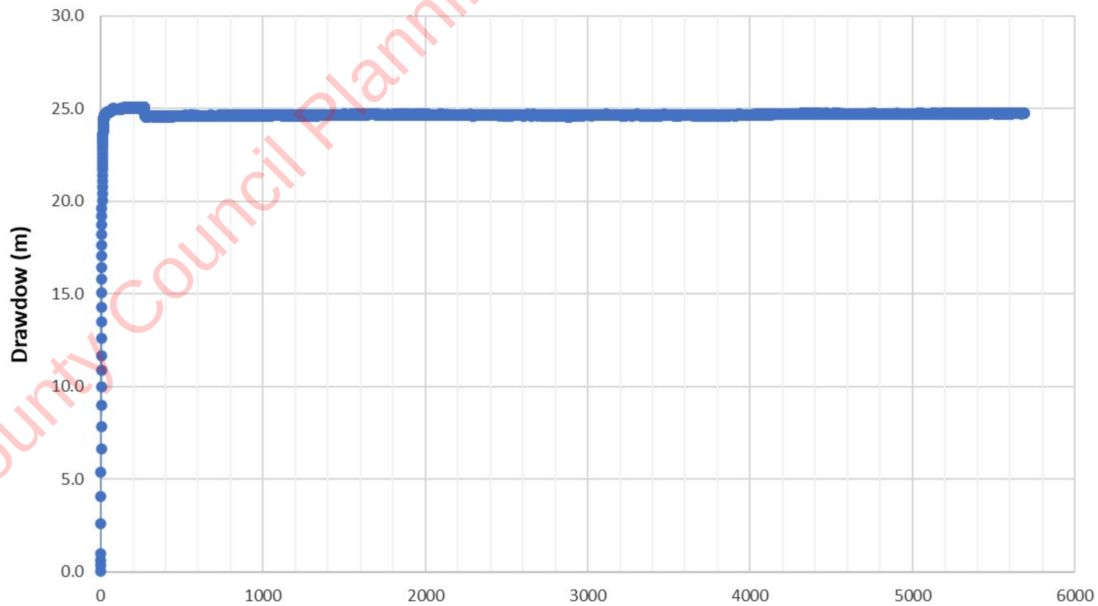
The maximum discharge of the pump (1.0 l/s) during the step test resulted in a dynamic water level of 35.57 mbdl.

Results of the testing suggest a reasonable estimation of yield for PW1 is 1 l/s (86.4 m³/d). This reasonably concurs with the drilling development phase estimated yield of 100 m³/d (Borehole Logs, Appendix 7.1).

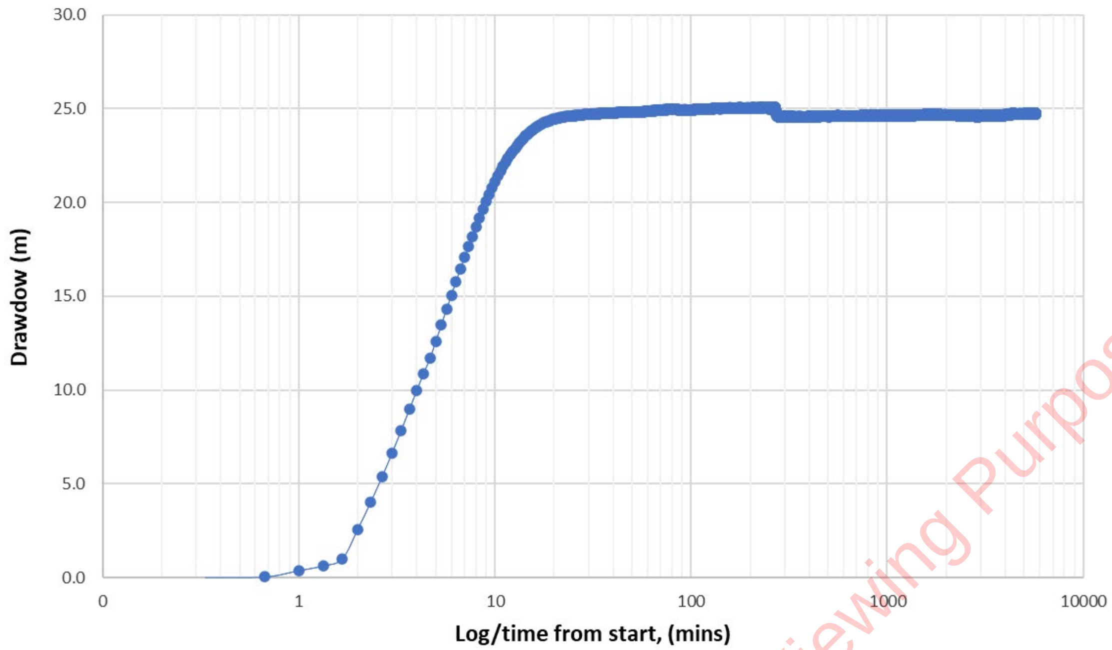
7.5.7.1.2 PW1 Constant Discharge Pumping Test

Upon completion of the step tests, water levels in PW1 were allowed to recover overnight. A constant discharge pumping test commenced on 24th of March 2021, at an average discharge of 0.96 l/s (83.6 m³/d). Test duration was 96 hours and total drawdown at the end of the test was 24.7 m (28/3/21 09:32). This compared favourably with the final stage of the step test.

Groundwater levels during the PW1 constant discharge test are shown in Graph 7.5. A review of the drawdown data reveals that the early-stage drawdown (i.e., initial 10 minutes) was approximately 20.7 m. Intermediate-time data (between 10–100 mins) shows a period when the rate of drawdown appears to slow substantially with overall drawdown for this time period being approximately 3.8 m. The log time-drawdown curve (Graph 7.6) demonstrates the distinct segments more clearly—a steep early-time segment representing an instantaneous release of water from storage followed by a flat intermediate segment reflecting the dewatering that accompanies the falling water table. For the remainder of the test, drawdown shows little variation, remaining in the range between 24.5 and 25 m below top of casing, whereby flow in the aquifer is essentially horizontal.



Graph 7.5 PW1 Constant Discharge Test Drawdown over Time



Graph 7.6 PW1 Constant Discharge Test Drawdown over Log Time

For PW1, the pumping water level stabilises relatively quickly. Initially, it was thought that this might be due to groundwater being in connectivity, and equalising, with the sump. However, the steady-state water level was 199 m OD, which is c. 24 m below the sump water level. PW1's Pump Test abstraction rate of 83.6 m^3/d was designed to maintain water level below the proposed depth of excavation in the vicinity of PW1, which is 199 m OD. Therefore, the drilling estimate was accurate and the groundwater yield in this area of the site is 100 m^3/d, approximately.

Transmissivity is the rate at which water is transmitted through an aquifer under a unit width and a unit hydraulic gradient. It equals the aquifer's hydraulic conductivity (permeability) times the aquifer thickness. The higher the transmissivity, the more prolific the aquifer is considered. The Cooper-Jacob pumping test solution for confined and unconfined aquifers was used to derive an estimation of transmissivity (T) for the aquifer. To facilitate the calculation, drawdown is plotted against time on a logarithmic scale, as per Graph 7.6.

Transmissivity was calculated using the Cooper Jacob's Method (Cooper & Jacob 1946):

$$T = (2.30\ Q) / (4\ \pi\ \Delta s)$$

where: Q = discharge, m^3/d = 83.64

Δs = drawdown over one log cycle (m) = 20.7 (1–10 mins)

= 3.8 (10–100 mins)

= 0 (100–1000 mins)

As a conservative estimate, the average drawdown between 1–10 minutes will be used:

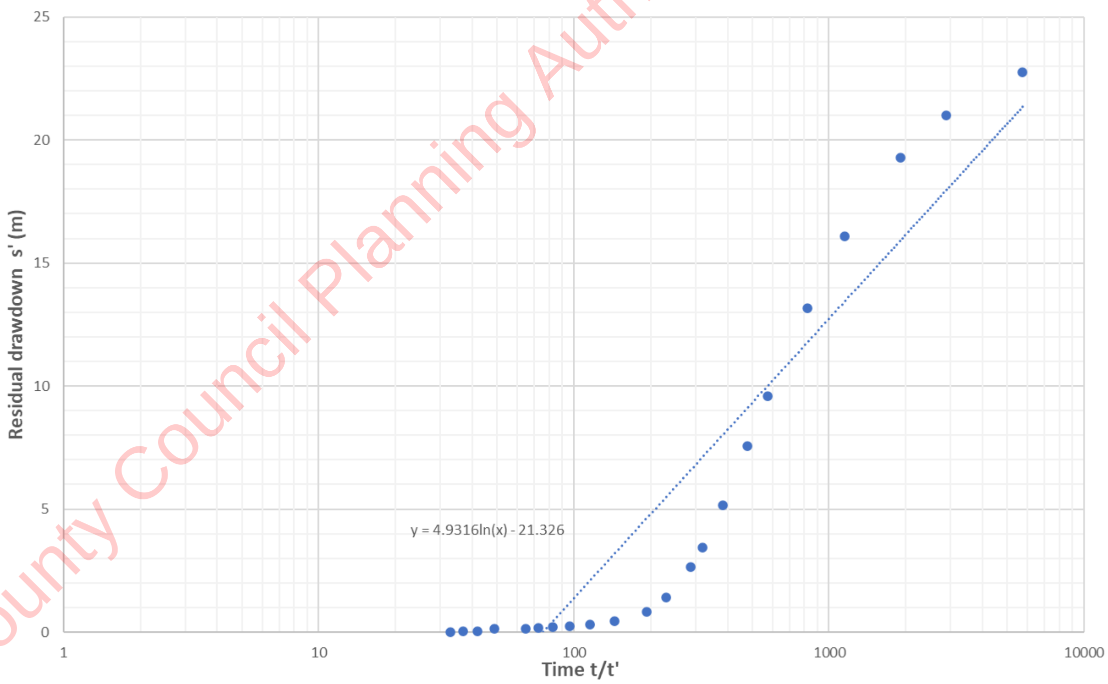
$$T = 2.3 \times 83.6 / 4 \times \pi (3.8)$$

$$T = 3.99 \ m^2/d$$

This value for PW1's T = 3.99 m^2/d is a low transmissivity and suggests that water is not easily transmitted through the aquifer.

7.5.7.1.3 Recovery Test

A recovery test was performed at the end of the constant rate test, where the response of residual drawdown is recorded until groundwater level in the well recovers back to normal pre-test levels (Graph 7.7). The Cooper Jacob's Method was used to estimate aquifer properties, this procedure involves fitting a straight line on a residual drawdown plot of s' (residual drawdown) versus log t/t' (ratio of time since pumping began to time since pumping stopped). This method is commonly used to estimate transmissivity (T) of an aquifer (Cooper & Jacob 1946 - Straight Line Solution) and yielded a transmissivity of 1.4 m^2/day. Considering the degrees of precision and wide range of T's possible, the T = 3.99 m^2/d and T = 1.4 m^2/d are not that different. T's can be in the 100's.



Graph 7.7 PW1 Drawdown Recovery following Cessation of Constant Discharge Pumping Test

Permeability is calculated by dividing the transmissivity by the saturated thickness of the aquifer. The saturated portion of the borehole is unlined and fully exposed to the aquifer.

Hydraulic conductivity, K = 1.4 m^2/day/50.2 m = 0.027 m/d (**3.1 x 10^{-7} m/s**)

Table 7.14 PW1 Aquifer Test Results Summary

Test	Cooper Jacob Transmissivity, m^2/d	K, m/d	K, m/s
Step 1	7.25	0.144	1.7 x 10^{-6}
Constant Discharge	3.99	0.079	9.2 x 10^{-7}
Recovery	1.35	0.027	3.1 x 10^{-7}
Average	4	0.1	9.7 x 10^{-7}

(Note: An average Hydraulic Conductivity of 10^{-7} m/s is more closely similar to CLAY than water-bearing bedrock).

7.5.7.2 PW2 Aquifer Testing

A Grundfos submersible pump (model SPE 60-5) was installed in PW2 at 14 mbgl. The pump is rated to lift 60 m^3/h (1,440 m^3/d) at a head of 45 m. There were several reasons for not installing the pump deeper into the borehole:

1. The target well producing section was at 17 mbgl. The water-bearing zone had a heavy sand load which presented a threat to the test pump if it was placed below the high yielding fracture.
2. The connectivity of the groundwater in the high yielding zone of PW2 with the local area's wells or springs was not known at this point.
3. Aquifer thickness is 19 m.

The hydrogeologists assessed that multiple constraints regarding safe management of 3 day constant rate test discharge of 1000 m^3/d, the uncertainty of the capacity of the local surface water network and potential impact on ecological receptors, required that testing at this location was by Step Tests only.

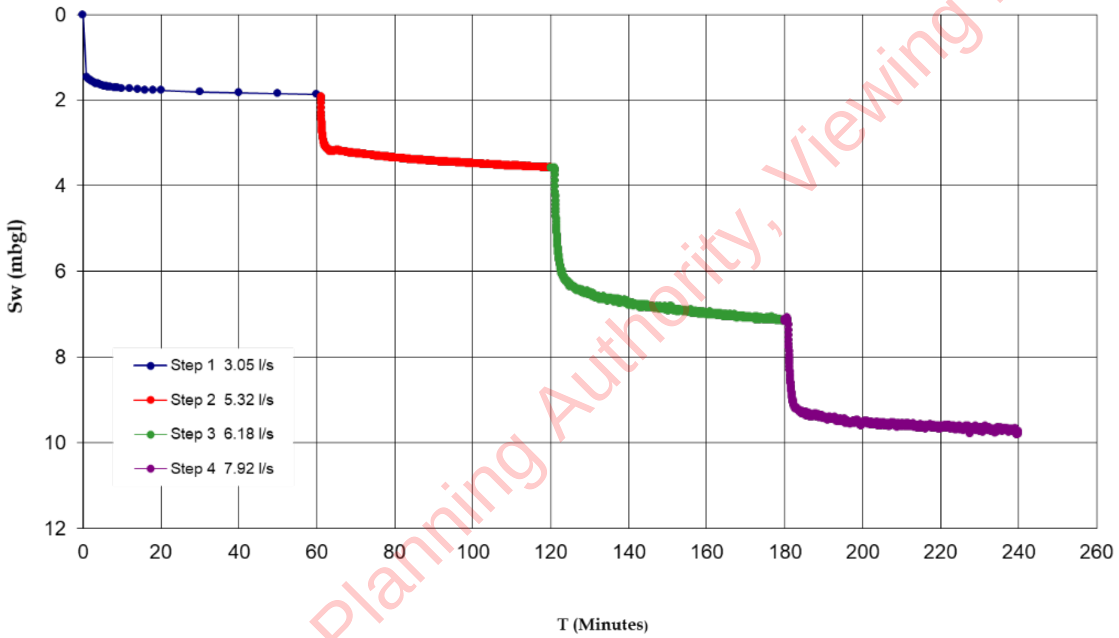
7.5.7.2.1 PW2 Step Test

A four-stage step test was carried out on the 1st April 2021—the step's discharge ranged from 3 l/s to 8 l/s. A step duration of 60 minutes was selected.

The results of the PW2 step test are presented in Table 7.15. The starting groundwater level was 2.20 m below the datum (top of stilling tube). At the end of the test, the groundwater level was 11.60 m below the casing level. The drawdown curve for each step is shown in Graph 7.8.

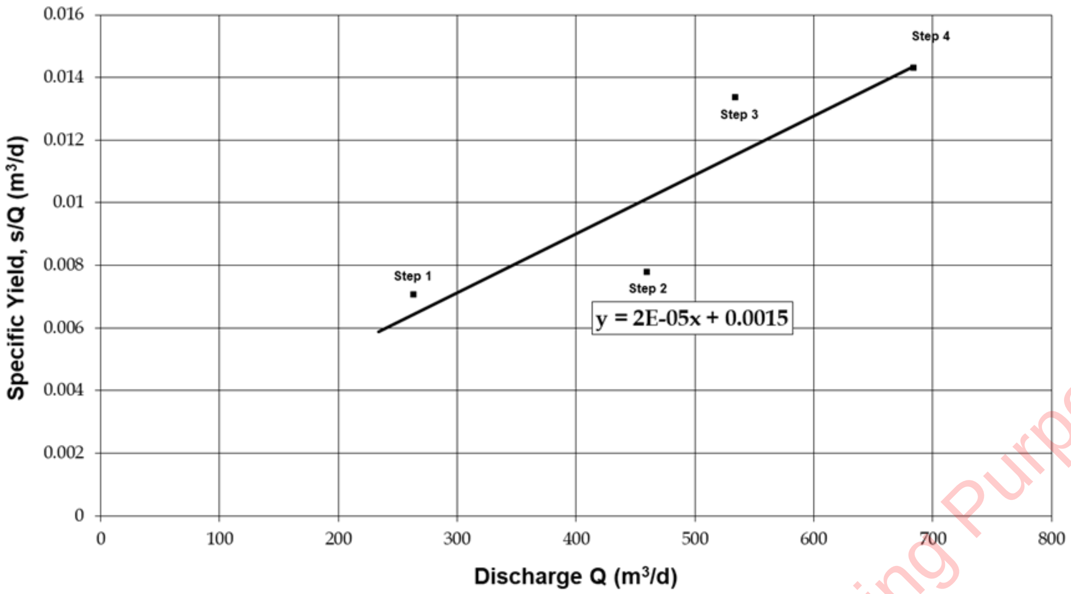
Table 7.15 PW2 Step Test Results Summary

Step No.	Step time, mins	Discharge, l/s	Discharge, m^3/d	Observed drawdown, m	Specific yield, s/Q	Specific capacity, $(m^3/d/m)$	Drawdown, m
1	60	3.05	264	1.86	0.071	142	1.70
2	60	5.32	460	3.57	0.0078	129	4.66
3	60	6.18	534	7.13	0.0134	75	6.16
4	60	7.92	684	9.79	0.0143	70	9.83



Graph 7.8 PW2 Drawdown Response during Step Test

The specific yield was plotted against discharge and a best fit straight line was drawn through the data points. The intersection of the line with the y-axis (B) and the slope of the line (C) are coefficients that relate to the hydraulic characteristics of the well and aquifer (Hantush-Biershenk's method). This is shown in Graph 7.9.

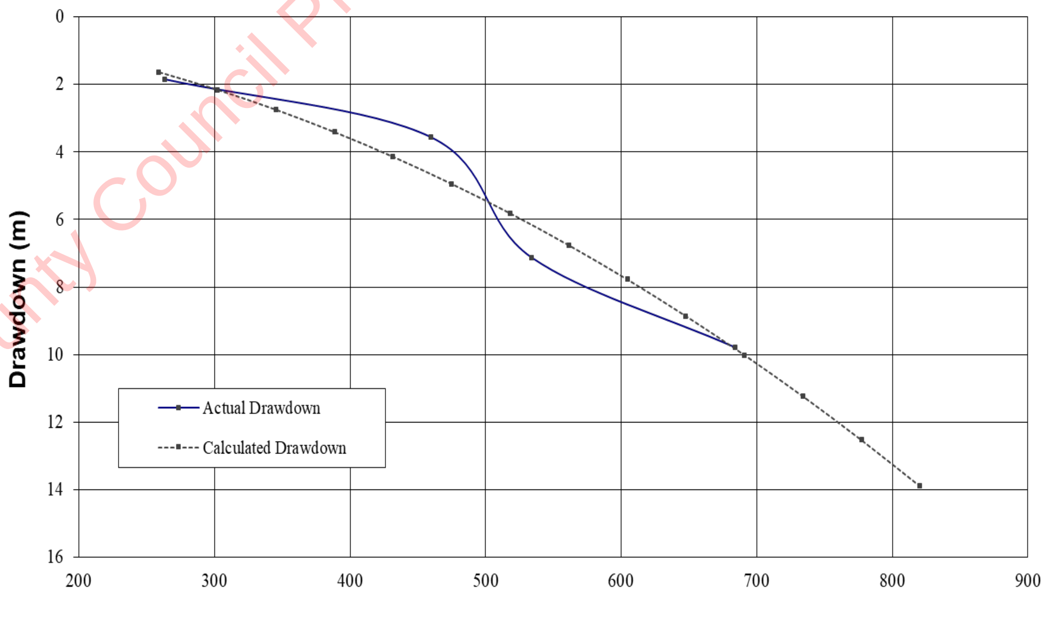


Graph 7.9 PW2 Specific Yield Plotted against Discharge

From the graph, B = 1.48 x 10^{-3} (d/m^2) and C = 1.88 x 10^{-5} (d^2/m^5). For drawdown in borehole PW2, Jacob's general equation is as follows:

$$S_w = (1.48 \times 10^{-3})\,Q + (1.88 \times 10^{-5})\,Q^2$$

The predicted drawdown in the well was calculated using this equation and plotted against the discharge along with the measured drawdown (Graph 7.10). The drawdown-discharge curve measured during the step-test is shown in the same graph. The two curves are similar, which shows that the calculated drawdown equation is an adequate model for the actual measured drawdown in the well.



Graph 7.10 PW2 Predicted and Actual Drawdown Plotted against Discharge

The maximum discharge of the pump (8 l/s) during the step test resulted in a dynamic water level of 9.79 bgl. To prevent pump cavitation, the groundwater level was prevented from coming within 3 m of the pump.

A constant rate discharge test was not performed for reasons regarding discharge constraints for the yield of PW2 and given the proximity of groundwater level to the pump. A recovery test analysis was not performed as steady-state conditions were not fully achieved at the cessation of pumping.

The transition from Clay Gall Sandstones to Moyadd Coal Formation occurs at 17 m. Aquifer testing of the latter underlying formation has shown that bedrock permeability is low in this formation. Therefore, the hydraulic properties returned in the testing of PW2 relate to the water-bearing zone only. It follows that extrapolating Graph 7.10 to predict discharge required to maintain drawdown at the target floor level in this part of the quarry may significantly overestimate dewatering requirements.

Table 7.16 PW2 Aquifer Test Results Summary

Test	Cooper Jacob Transmissivity, m^2/d	K, m/d	K, m/s
Step 1	185	11.1	1.2×10^{-4}
Step 2	143	8.5	9.8×10^{-5}
Step 3	73.5	4.4	5.1×10^{-5}
Step 4	123	7.3	8.5×10^{-5}
Average	131	7.8	9×10^{-5}

The result of calculations presented in Table 7.16 suggest that the hydraulic conductivity value of 7 m/d is in the range for Sand presented by Misstear et al. (2006) and Brassington (1998).

For the purposes of observation well monitoring, a datalogger was installed in SP01 during the PW2 constant discharge test. SP01 is only 80 m, approximately, from the Test Well. No effect at all was observed in SP01 in the four hours of testing on PW2. This further suggests a local feature at PW2 that does not extend into the proposed void.

In summary, the water-bearing zone at PW2 is at 17 m bgl and the tests completed suggest that an abstraction rate of 684 m^3/d from PW2 would be required. Therefore, there is no excavation planned in this part of the site. This part of the site is dedicated to water management and accommodates the existing ponds. It is proposed to main an 80 m buffer zone to Production Well PW2.

7.5.7.3 PW3 Aquifer Testing

A Grundfos submersible pump (model MS402) was installed in PW3 at 48 mbgl. The pump is rated to lift 7 m^3/h (168 m^3/d) at a head of 36 m.

7.5.7.3.1 PW3 Step Test

On the 29th of March 2021, Envirologic personnel visited the site and performed a calibration of the pump. During the calibration stage, it became clear that well yield was too low to support an accurate step-test.

The planned step-pumping test was to be performed at four discrete discharge rates from 0.4 l/s to 1 l/s. The duration of each step was chosen to be 90 minutes. The starting groundwater level was 6.33 m below the datum (top of the steel casing). The inlet of the pump was set at 42 m below datum. The pumping test commenced at a pumping rate of approximately 3.4 m^3/hr. Initial water level observations at the well head indicated a rapid drawdown of water level to approximately 31 m below top of casing (mbtoc) within the first 45 mins of the test. To prevent the pump from running dry it was decided to abandon the step test increments and continue pumping the well at the set discharge rate of 38.7 m^3/d. Thus, undertaking a constant discharge test on the well. Given the site insights gained from tests on PW1 and PW3 it was deemed appropriate to proceed straight to constant discharge rate test.

7.5.7.3.2 PW3 Constant Discharge Pumping Test

A constant discharge pumping test was commenced on 30th of March 2021 at an average discharge of 0.45 l/s (38.7 m^3/d). Total drawdown at the end of the test was 33.2 m. Saturated aquifer thickness at commencement of test was 11.7 m. Similar to PW1, the groundwater level stabilised relatively quickly in this instance at an elevation of 189 mOD, which is 11 m below the proposed quarry floor elevation in this general area of the site.

To enable calculation of transmissivity, drawdown was plotted against time on a logarithmic scale, as shown in Graph 7.11.

Transmissivity using the Cooper Jacob's Method (Cooper & Jacob 1946) is given by:

$$T = (2.30\ Q) / (4\ \pi\ \Delta s)$$

where: Q = discharge (m^3/d) = 38.7

Δs = drawdown over one log cycle (m) = 14.22 m (1–10 mins)

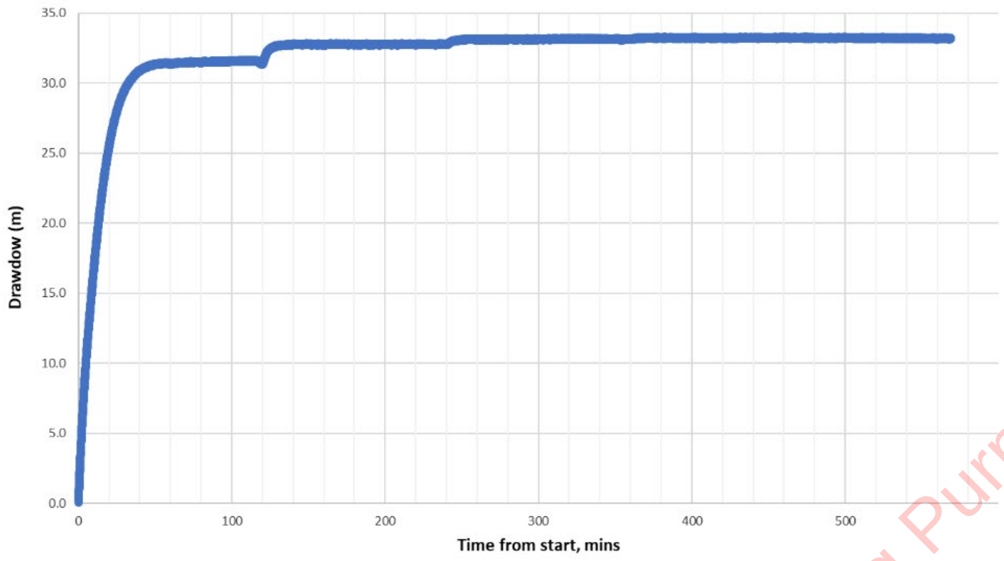
= 15.07 m (10–100 mins)

Mean = 14.65 m

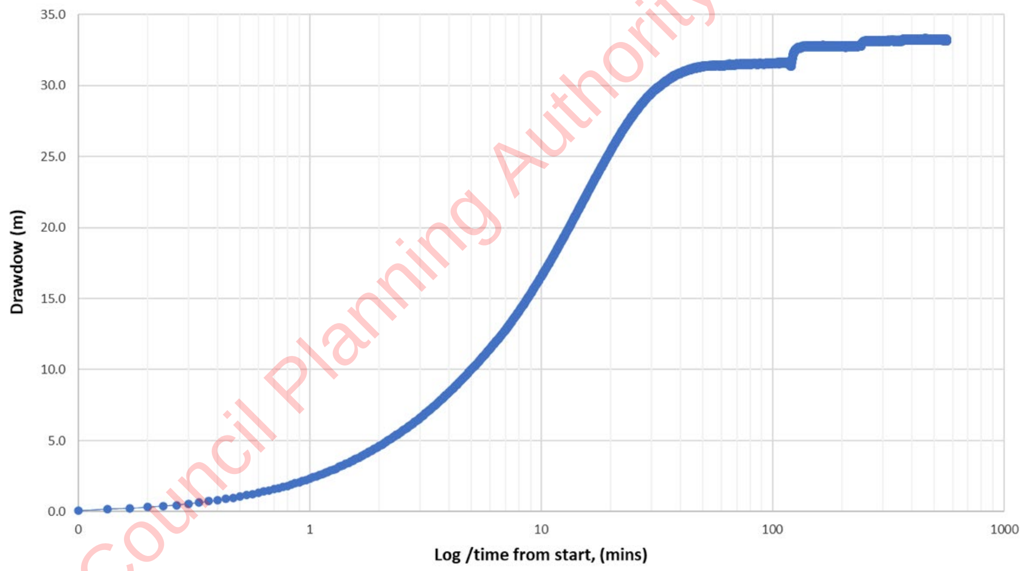
$$T = 2.3 \times 38.7 / 4 \times \pi\ (14.65)$$

$$T = 89.01 / 184 = 0.48\ m^2/d$$

$$K = 0.48375 / 11.7 = 0.04\ m/d = 4.8 \times 10^{-7}\ m/s$$



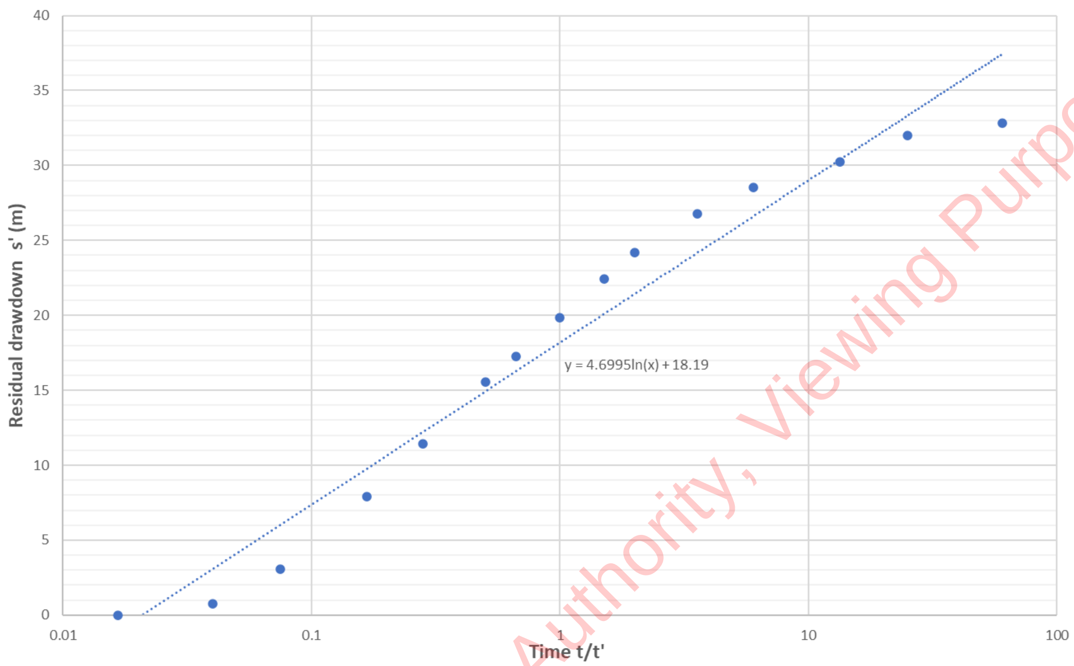
Graph 7.11 PW3 Constant Discharge Test Drawdown v's Time



Graph 7.12 PW3 Constant Discharge Test Drawdown v's Log Time

The hydraulic conductivity K value of 0.04 m/d is equivalent to 4 x 10^{-2} m/d, which is low and suggests no real permeability in the rocks in the PW3 area.

A recovery test was performed at the end of the constant rate test, where the response of residual drawdown is recorded until groundwater level in the well recovers back to normal pre-test levels. The Cooper Jacob's Method was used to estimate aquifer properties. This procedure involves fitting a straight line on a residual drawdown plot of s' (residual drawdown) versus log t/t' (ratio of time since pumping began to time since pumping stopped). This method is commonly used to estimate transmissivity (T) of the aquifer (Cooper & Jacob 1946; Straight line Solution). Refer to Graph 7.13. Average drawdown over a log cycle was 10.9 m (0.1–1 mins = 11 m; 1–10 mins = 10.8 m), which yielded a transmissivity of 0.65 m^2/d. Hydraulic conductivity was calculated as 0.055 m^2/d, equivalent to 6.4×10^{-7} m/s. Again, this is more closely similar to the hydraulic conductivity of CLAY than a water-bearing rock.



Graph 7.13 PW3 Drawdown Recovery following Cessation of Constant Discharge Pumping Test

7.5.7.4 Aquifer Testing Summary

The results from the aquifer characteristics testing are summarised in Table 7.17. Values have been rounded for ease of reference.

Table 7.17 Summary of Clay Gall Sandstone aquifer properties

BH ID	Safe Yield, m^3/d	Specific Capacity , $m^3/m/d$	T, m^2/d	D, m	K, m/d	K, m/s
PW1	100	5	4	50	0.1	1×10^{-6}
PW2	700	100	131	19	8	1×10^{-4}
PW3	40	1	0.6	12	0.05	6×10^{-7}

The Castlecomer GWB report (GSI 2004) states that well testing by Misstear et al. (1980) returned transmissivities in the order of 10 m^2/d (range 1 m^2/d – 500 m^2/d) and permeabilities in the order of 0.1 m/day (range 0.01 m/d – 50 m/d). The values obtained at Spink site are within the previously reported ranges but are at the lower end of each parameter's range.

Hydraulic properties of the Clay Gall Sandstones at PW1 and PW3 were at the lower end of the range and confirm that the primary porosity is low, with yield being entirely dependent upon fracturing and structural faulting. An example of structural faulting was demonstrated at PW2 with aquifer properties at the higher end of the range as suggested by Misstear et al. (1980).

The results would also appear to confirm that the Moyadd Coal Formation is an aquitard. Not enough of the Coolbaun Formation was encountered to test its hydraulic nature. However, it is assumed to be a low permeability unit and may also act as an aquitard, which would have the effect of confining groundwater in the Clay Gall Sandstones where such a sequence occurs.

7.5.8 GEOPHYSICS

The aquifer Production Well Phase (PW) drilling and hydraulic response tests revealed that the significant water-bearing zone encountered in PW2 during drilling is completely different to the hydrogeological characteristics found at PW1 and PW3. There is a couple of orders of magnitude more permeability in PW2 compared to the other two locations. Similarly, no geological strata indicating high yielding hydrogeological characteristics were encountered in any of the four site investigation core boreholes (SLR 2020). Given that no evidence exists to support a conclusion of high groundwater flows anywhere else in the quarry, the PW2 experience suggests that the feature is somewhat limited in lateral extent. While no extraction is proposed in this north-western portion of the quarry because it houses an extensive array of settlement ponds, the hydrogeologists decided that a resolution for the site could not be concluded without more evidence that the water-bearing feature is limited to the north-western corner.

The primary risk associated with any sand-filled cavity feature, such as that at PW2, is that it could release groundwater flows that must be accounted for in the management of the site. With respect to the correct assessment of flood risk to off-site receptors and potential impact on local residential potable supply sources, further evaluation at PW2 was deemed by the hydrogeologists as necessary for complete site characterisation.

Two approaches were discussed with a view to acquiring an additional understanding of the lateral extent, dip angle and orientation, thickness and depth profile of the sand feature. The two approaches considered were, as follows:

1. blast rig drilling of a high number of small diameter boreholes over a small area in the vicinity of PW2 to track the void; or
2. geophysics.

Geophysics was selected as the preferred option because it was determined that the geophysical approach would enable evaluation of the likely connectivity across the void to the sump. A geophysical survey was carried out by Apex Geophysics on the 30th April and the 4th May 2021. Upon analysis of the first two days of field results, Apex and the hydrogeologists determined a need for further clarification and Apex returned on the

28th May 2021. The geophysical investigation utilised 2D Electrical Resistivity Tomography (ERT). Nine ERT profiles were surveyed with an emphasis placed on the void between PW2 and the sump. The geophysical survey is included as Appendix 7.3.

The site's geology, as reported by (SLR 2020), indicates that almost all of the quarry is developed within the Clay Gall Sandstone Formation with beds typically dipping towards the southeast, and varying from < 5° to 10° with local steepening in the northwest due to the presence of a small fault.

The geophysical ERT survey returned findings showing the thickening of the Clay Gall Formation sandstones from north to south beneath the quarry floor and that the beds dip at an apparent angle of approximately 10° to the southwest. An increase in thickness of the sandstone/siltstone to the southeast was also noted. The interpreted geology from the ERT profiles show good agreement with the adjacent boreholes and wells, which have been drawn on the sections in Appendix 7.3.

The hydrogeologists do not consider the Rotary Core and Geophysics findings to be in conflict. The core boreholes were drilled in a straight line through the site almost NW-SE trending and therefore they did not have the opportunity to explore any dip in the N-S direction.

The geophysics focussed on PW2, the area around it and the subsurface of the quarry void as one moves from PW2 to the sump that is centrally located in the site. With respect to Apex's 2021 report for the site (Appendix 7.3), PW2 is located along profile R4 and at the western end of profile R2. The high yielding sand feature encountered at PW2 occurs near the base of the dipping sandstone beds of the Clay Gall Formation. The inferred groundwater flow direction is also towards this area. The ERT data indicates that the high-yielding zone in PW2 may correspond with part of a localised feature. This is also evidenced in the exposed face above the settlement ponds adjacent to PW2.

Profile R6, which runs in a northeast-southwest orientation at the centre of the quarry void indicates a vertical contact between sandstone/siltstone to the northeast and possible mudstone to the southwest. The steeply vertical nature of the contact suggests that it is faulted. The possibility of a northwest-southeast fault (See Drawing AGP21065_02) is supported by the variable response of ERT profile R3, which has lower resistivity values than expected from the dipping sandstone/siltstone layer in R2, R4 and R5 to the north.

A conceptual model for the site is presented by Dr. Yvonne O'Connell of Apex Geophysics (2021) and Hydro-G, as follows:

- There is a permeable water-bearing bed of weak sandstone at the base of the sandstone unit, dipping to the southwest and slightly to the east, and terminated at the south-western side of the quarry by a northwest-southeast vertical fault, which places the sandstone/siltstone against lower permeability mudstone;
- Such a model would have an increased head of groundwater as one moves to the southwest. This may account for the water-bearing feature encountered near the base of the sandstone/siltstone in PW2 compared to the low or absent yield in PW3

further up dip to the northeast and the low yield in PW1, also up dip to the northeast, relative to the central long axis zone of the quarry;

- From ERT Profile R2 and the geologist's log for corehole 20-SP-02, the base of the sandstone at the south-eastern end of the current quarry void is at around 195 m OD and the main water-bearing layer should therefore be below the proposed floor level of 206/200 m OD at this point. On this basis it appears that PW2 and the sump are not connected;
- The ERT profiles R4 and R5 confirm the thickening of the Clay Gall Formation sandstones from north to south beneath the quarry void's floor (note: area north of R4 appears to be affected by concrete/ foundations and is not included in the interpretation). The ERT indicates that the beds dip at an apparent angle of approximately 10° to the southwest (See Drawings AGP21065_R4 & AGP21065_R5) and are underlain by Moyadd Formation mudstones. R2 runs parallel to strike across the quarry floor in agreement with this interpretation (Drawing AGP21065_R2) and also shows an increase in thickness of the sandstone/siltstone to the southeast. R7 and R8 in the southwest of the quarry floor also show thick sandstone/siltstone. The interpreted geology from the ERT profiles shows good agreement with the adjacent boreholes and wells that have been drawn on the sections. PW2 is located along profile R4 and at the western end of profile R2. The high-yielding sand feature occurs near the base of the dipping sandstone beds of the Clay Gall Formation. R9 was recorded east of the quarry sump at elevations from 234 to 244 mOD. This profile indicates mudstones and siltstone/sandstone over sandstone in the northern half of the profile;
- The Apex (2021) report concludes that the potential sources of groundwater inflow on PW2 can be rationalised as follows:
    - The ERT data shows no indication that the high yielding sand feature in PW2 is part of a localised fault or weathered zone and therefore could be associated with a water-bearing layer of weak sandstone at the base of the Clay Gall Sandstone unit;
    - Profiles R6 and R7 were recorded in the south-eastern end of the exposed rock floor of the site and indicate a vertical contact between the sandstone/siltstone to the northeast and lower resistivity, possible siltstone with sandstone to the south. The steeply vertical nature the contact suggests that it is faulted. Similar vertical changes in rock resistivity are visible on ERT profile R3 which has lower than expected resistivity values than expected from the dipping sandstone/siltstone layer on R2, R4, R5 and R7 to the northeast. R8 is oblique to the interpreted fault and as such the sandstone/siltstone resistivities are slightly lower than observed north of the fault;
    - A fault was observed in the quarry face directly north of the silt ponds and 30 m west of the PW2 well. This fault does not appear to trend east-west towards PW2 as it is not observed on profiles R4 and R5. It may be north-

south trending which would be in line with possible faulting observed as vertical changes in rock resistivity on profile R3; and

- The following model is concluded: **A permeable water bearing bed of weak sandstone at the base of the sandstone/siltstone unit and dipping to the southwest and slightly to the east and terminated at to the south of the quarry by an east-west vertical fault which places the sandstone/siltstone against lower permeability siltstone with sandstone. Such a model would have an increased head of groundwater as one moves to the southwest and may account for the water bearing feature encountered near the base of the sandstone/siltstone in PW2, compared to the low or absent flow on PW3 further up dip to the northeast.**

7.5.9 DEWATERING ESTIMATIONS

Groundwater seepage into an open quarry void initiates a hydraulic response in the surrounding bedrock that is similar in a number of respects to radial flow towards a pumping well. Where the surrounding bedrock has low hydraulic conductivity, inflow rates and water management can be handled using sumps on the quarry floor.

There are no records of site water management, pumping regime or discharge rates during previous operations. Predicted dewatering rates are therefore estimated for the site using recommended formulae and site-specific data collected from intrusive investigation. The site's future dewatering demands and consequent water management needs will be determined using the characteristics encountered at the four core holes and further tested at the two production wells PW1 and PW3. It is judged that this is an appropriate strategy because geophysics and aquifer testing suggest that PW2's characteristics are unique to that corner of the site and there will be no extraction in that zone, given that it will be the water management area.

The principles for estimating groundwater flows are typically based on radial inflows, so the first step is to convert the quarry to its circular equivalent having the same area. The quarry site in the ownership of Lagan are broadly rectangular, with an approximate length of 800 m and a width of 250 m giving an area of c. 19.6 ha (190,600 m^2). The radius of a circle having an equivalent area of 200,000 m^2 is 252 m. For the purposes of comparison, the current sump has a radius of 60 m.

The methodology to determine the potential radial effect and the possible quantity of water requiring management at the site in the future is now presented in calculation steps, as follows:

1. Determine the Radius of Influence (Section 7.5.9.1);
2. Determine the potential volume of Groundwater Inflows to the Sump (Section 7.5.9.2);
3. Alternatively evaluate volumes that might occur by applying the concept of Recharge from the Upgradient Aquifer (Section 7.5.9.3); and
4. Conclude on the Total Dewatering Volumes that might arise in the future (Section 7.5.9.4).

7.5.9.1 Radius of Influence

The radius of influence can be estimated using Sichardt's Empirical equation as follows:

$$R_0 = C(H - h_w)\sqrt{K}$$

Where R_0 = radius of influence (excluding radius of theoretical well = final sump = 252 m radius)

C = constant = 3000

$H - h_w$ = current drawdown to sump

= 228 m OD (SP04) – 223 m OD (sump WL)

= 5 m

$H - h_w$ = proposed final drawdown to sump

= 223 m OD (SP04) – 190 m OD (average final floor wl)

= 33 m

K = bedrock permeability

= 1 x 10^{-6} m/s

= 0.1 m/d

R_0 = 99 m from edge of sump

R_0 = 349 m from centre of sump

The potential radius of influence upon completion of works is illustrated in Figure 7.12. There are no active groundwater receptors that may be at risk of impact from groundwater drawdown within that 350 m of the centre of the sump. The radius of influence comes close to the borehole at Property No. 2. Based on the information obtained during the well search, the borehole at Property No. 2 must be abstracting groundwater from a deeper bedrock formation because it was drilled deep and the pump is set deep. Information supplied to the project is that it is drilled to approximately 100–120 m below surface, and is not deemed to be at risk of impact due to the proposed dewatering elevation of 190 mOD, which is at least 40 m above the borehole water strike at Property No. 2. The fact that groundwater flow has been demonstrated to be controlled by the boundary contact layers between differing formations, the potential for impact is very low for this difference in elevation and the dip angles of the geological bedding planes found at the site.

7.5.9.2 Groundwater Inflows to Sump

When the floor of an open quarry is excavated below the water table, groundwater can enter the quarry through seepage faces in the walls of the void and/or as upward flow through the excavated floor base. There are commonly two components to the inflow: diffuse inflow widely distributed through the general rock mass and focused flow where permeable fractures intersect the exposed quarry faces. Using these principles, the analytical solution put forward by Marinelli & Niccoli (2000) is derived from the Dupuit-

Forcheimer approximation to estimate radial groundwater inflows to open pit quarries. Their solution incorporates a time-dependent factor.

$$Q(t) = (4 \pi K b s_w) / (2.3 \log (2.25 K b t / r_p^2 S))$$

where:

K = hydraulic conductivity of Clay Gall sandstones (0.1 m/d)

b = thickness of the fractured bedrock horizon (50 m)
S_w = design drawdown at the pit face (223 m OD – 190 m OD) = 33 m
r_p is the radius of the open pit (252 m)

S = specific storage (1 x 10^{-5} m^{-1}), textbook value

T = time since 'instantaneous' placement of the open pit

Dewatering Rate Q = 340 m^3/d after one month

Dewatering Rate Q = 264 m^3/d after six months

[**Note:** The design drawdown level to 190 m OD in the equation component 'S_W', above, is the average required dewatering level based on commencing in the western portion of the site and that consequent worked void area that will be available as a holding zone when the eastern portion is being worked. There is no point calculating the dewatering drawdown to 177 m OD across the entire site because most of the site's floor will be between 190 m OD and 225 m OD.]

7.5.9.3 Recharge from the Upgradient Aquifer

One could argue that radial approach may not be entirely appropriate to the uniqueness of Irish hydrogeological features and that it can overestimate inflows from lands downgradient of the site in terms of groundwater flow and underestimate inflows from lands hydraulically upgradient. Therefore, Envirologic applied an alternative approach which is typically used to delineate zones of contribution (ZOCs) to public water supply wells. This approach estimates the rate or volume of water to be removed from the quarry by assuming it will be equivalent to the rate of groundwater flow through the site that will be intercepted by excavation below static groundwater level.

The well survey shows that the groundwater flow direction is south-southwest, in line with the dip angle of the contact between the Clay Gall Sandstones and Moyadd Coal Formation. Hence, most groundwater inflow to the quarry is likely to arise from recharge to the Lm aquifer in the area north of the site. This 'zone of contribution' is presented in Figure 7.12. The map highlights the different recharge coefficients within this area. The areas applicable to each recharge coefficient are shown in Table 7.18. As the consideration of information returned in the assessment progresses it is becoming apparent that the recharge areas do not correspond with the topographical surface water catchment divides.

Recharge coefficients in the Lm area to the north are either 22.5 %, 60 % or 85 % depending on presence and depth of subsoil. As presented in Table 7.18, this approach yields a total recharge to the upgradient Lm area (in terms of groundwater flow) in the order of 950 m^3/d.

Table 7.18 Recharge to Clay Gall Sandstones upgradient of the site in terms of groundwater flow

Recharge coefficient	Area, m^2	Effective Rainfall, mm	Aquifer	Recharge cap, mm/yr	Recharge, mm/yr	Recharge, m^3/yr	Recharge, m^3/d
85 %	510,270	671	Lm	0	571	291,364	798
60 %	88,250	671	Lm	0	403	35,565	97
22.5 %	153,160	671	Lm	0	145	22,208	61
					Total Recharge	349,137	956

7.5.9.4 Future Dewatering Volumes

The amount of rainfall-runoff-recharge direct to the site is 296 m^3/d (refer to Table 7.7). It can be assumed that this is a volume that will require management. Envirologic has then presented two distinct methods for estimating groundwater inflows to the site as extraction nears completion. These have been simplified as follows:

1. **If the operator intersects the contact between the Clay Gall Sandstones and the Moyadd Coal Formation** then the amount of water to be managed is expected to be equal to the amount of recharge to the upgradient Lm aquifer. Based on the assumption that the majority of groundwater drains to the base of the aquifer unit whereupon it hits the Moyadd Coal aquitard and travels laterally along the contact, and that all of this rainfall-recharge flowing through the contact makes its way to the quarry sump, the potential volume of water to be managed on the average day becomes:

   Potential amount of water to be managed

   =

   Table 7.18's Recharge to Lm aquifer in area upgradient of the site in terms of groundwater flow = 956 m^3/d (349,137 m^3/yr)

   +

   Recharge to bedrock aquifer within site = 201 m^3/d (73,222 m^3/yr)

   +

   Surface runoff and recharge rejected at bedrock head within site = 296 m^3/d (108,028 m^3/yr)

   =

   1,453 m^3/d

2. **If the operator stays above the contact between the Clay Gall Sandstones and the Moyadd Coal Formation** then the amount of water to be managed is more accurately derived using the hydraulic properties of the bedrock aquifer. The hydraulic conductivity value used represents groundwater released from storage in

the drawdown zone around the proposed working quarry void and hence does not take account the contact encountered at PW2 at the base of the Clay Gall Sandstones because that area will not be worked.

Potential amount of water to be managed

=

Groundwater inflow based on drawdown and bedrock hydraulic conductivity = 264 m^3/d (96,673 m^3/yr)

+

Recharge to bedrock aquifer at site = 201 m^3/d (73,222 m^3/yr)

+

Surface runoff and recharge rejected at bedrock head = 296 m^3/d (108,028 m^3/yr)

=

761 m^3/d

These values are intended to be representative of maximum discharge rates that are only likely to be realised close to completion of rock extraction operations. Interim discharge rates will respond to the phasing scheme. Phased development commencing in the north-western half of the site will result in a large area available for sump, water holdback, settlement and discharge in a controlled fashion suitable to the particular characteristics of the known flashy surface water system outside the site.

The values calculated for future possible dewatering volumes will now be employed to evaluate the ability of the receiving waters to assimilate them from a hydraulic and hydrochemical perspective.

7.5.10 HYDRAULIC CAPACITY OF RECEIVING WATERS

Sustainable quarry operation requires that the local natural surface water drainage network has adequate capacity to receive and safely transmit the potential discharge rates outlined above.

This chapter has already described how the site straddles a mapped surface water catchment boundary that separates lands that drain naturally to the Owveg River to the west and the Clogh River to the east. Lands between the site and these watercourses are drained by a network of agricultural field drains and first order streams. The drainage routes connecting the site to both of these rivers was assessed for their potential suitability to safely receive and transmit natural catchment flows plus additional quarry discharge. In addition, the hydrological evaluations included an assessment as to whether quarry discharge could increase the risk of flooding in downstream receptors and adjoining lands.

7.5.10.1 Catchment Flows

The first step in hydraulic capacity assessment is to calculate streamflows that arise during extreme return period events (Q_{100}). Calculations are first presented for flood flows in the Garrintaggart Stream (to L7792 culvert), and these calculations are then repeated for the Aughatubbrid Stream. There are a number of distinct sub-catchments downstream of the site and these are outlined in Table 7.19. The flood flows in each sub-catchment are calculated below and these rates will be input into a hydraulic model to predict flood levels at various locations along the drainage network.

Table 7.19 Sub-catchments Applicable to Hydraulic Model

Reference	Description	Natural Upgradient Catchment Area, km^2
Western Discharge Route		
North-western discharge point	Western half of site	0.127
Garrintaggart Stream	At L7792 culvert	0.656
Garrintaggart Stream	At R430 culvert	0.883
Garrintaggart Stream	At outfall to Owveg River	0.980
Eastern Discharge Route		
North-eastern discharge point	At laneway adjacent to eastern site boundary	0.163
Aughatubbrid Stream	At rear of 'Property 5'	0.45
Aughatubbrid Stream	At laneway 1 km east of site	1.22
Aughatubbrid Stream	At confluence with Knocklead Stream	2.44
Knocklead Stream	At outfall to Clogh River	6.98

In order to assess the impact posed by potential dewatering at the site, two separate flood risk scenarios have been considered:

1. Pre-development - The streams were modelled in their existing form using natural catchment flood flows, this model includes all of the existing in-situ downstream engineered culverts and road bridges.
2. Post-development - The streams were modelled using the cross sections as per (i) plus the inclusion of an additional flow input to the model. This additional flow is intended to represent future proposed dewatering activities during development of the quarry and will be used to assess the remaining hydraulic capacity of the stream during a Q_{100} flood event.

7.5.10.1.1 OPW Advice

In selecting appropriate formulae, reference has been made to an advisory response from OPW Hydrology Section and Work Package 4.2:

- *'For catchments between 5 km² and 25 km² the preferred equation is the 'FSU small catchments' equation. When using the small catchment equation we generally advocate not using a pivotal site adjustment seeing as there is a very small pool of other small catchments from which to source a pivotal site.*
- *For catchments less than 25 km² we would always say that at least three methods should be explored and that the choice of the flow to be used is up to the practitioner.*
- *The WP4.2 report is intended to provide a further methodology for small catchment flood estimation. As far as we are concerned, it is the preferred method.*
- *For catchments less than 5 km² there is no FSU method applicable. For such 'small' catchments we would suggest that maybe the rational method or modified rational method could be used.'*

7.5.10.1.2 OPW FSU - 7 Variable Equation

The ungauged method can be used to determine flood flows at the site using catchment characteristics, which are then corrected using a correlation against descriptors for gauged catchments. The median annual maximum flood magnitude, QMED, as outlined in the Flood Studies Update (Nicholson & Bree 2013) is now preferred over the Qbar parameter described in the FSR (1975). The median is less sensitive to large extreme floods and to flood measurement error in general. The estimation method for ungauged locations is based on a regression analysis relating observed QMED to physical catchment descriptors (PCDs) at gauged locations in Ireland, given by the following equation:

$$QMED_{rural} = 1.237\text{x}10^{-5} \,.\, AREA^{0.937} \,.\, BFI_{soil}^{-0.922} \,.\, SAAR^{1.306} \,.\, FARL^{2.217} \,.\, DRAIND^{0.341} \,.\, S^{0.185} \,.\, (1 + ARTDRAIN2)^{0.408}$$

The PCDs applicable to the subject site are shown in Table 7.20.

A principal of the FSU is the concept of a pivotal site, which is defined as the gauging station that is considered most relevant to a particular flood estimation problem at the subject site and is used to adjust the QMED rural estimate. There is no suitable pivotal site for this small catchment.

The return-period flood flow (Q_T) is determined by an index flood method, whereby a growth factor as determined from an EV1 distribution plot is applied. In this case:

$$Q_T = QMED \times 2.69$$

$$Q_{100} = 0.178 \text{ m}^3\text{/s} \times 2.69$$

$$Q_{100} = 0.48 \text{ m}^3\text{/s}$$

Finally, a climate change growth factor of 20 % is applied:

$$Q_{100} = 0.48 \times 1.2$$

$$Q_{100} = 0.58 \ m^3/s$$

Table 7.20 Physical Catchment Descriptors Applicable to Western Stream where it Crosses L7792

PCD	Description	Units	Value
AREA	Catchment area	km^2	0.656
SAAR	Average annual rainfall	mm	868
BFIsoil	Baseflow index derived from soils data		0.5405
FARL	Flood attenuation from reservoirs and lakes		1
DRAIND	Ratio of river network to catchment area	km/km^2	0.99
S_{1085}	Slope of the main stream between the 10 and 85 percentiles	m/km^2	21.9
ARTDRAIN2	Proportion of river network included in drainage schemes		0
URBEXT			0
QMED		m^3/s	0.178

7.5.10.1.3 OPW FSU - Small Catchments Equation

The updated Flood Studies Update (Nicholson & Bree 2013) presents a revised formula more suited to catchments less than 25 km^2

$$QMED_{rural} = 2.0951 \times 10^{-5} \ . \ AREA^{0.9245} \ . \ BFI_{soil}{}^{-0.9030} \ . \ SAAR^{1.2695} \ . \ FARL^{2.3163} \ . \ S^{0.2513}$$

This yields a $QMED_{rural}$ value of 0.061 m^3/s.

As per the OPW Guidelines, a pivotal site adjustment factor is not being applied to the outcome of the small catchments equation.

The return-period flood flow (Q_T) is again determined by an index flood method, whereby a growth factor as determined from an EV1 distribution plot is applied. In this case:

$$Q_T = QMED \times 2.69$$

$$Q_{100} = 0.061 \ m^3/s \times 2.69$$

$$Q_{100} = 0.165 \ m^3/s$$

Finally, a climate change growth factor of 20 % is applied:

$$Q_{100} = 0.165 \times 1.2$$

$$Q_{100} = 0.198 \ m^3/s$$

7.5.10.1.4 OPW FSU - 3 Variable Method

The FSU 3-variable equation was developed as part of the FSU. It was developed as a 'short cut' equation for the estimation of flow in ungauged catchments.

$$QMED = 0.000302.AREA^{0.829} . SAAR^{0.898} . BFI^{1.539}$$

$$QMED = 0.036\ m^3/s$$

Application of the relevant growth factors as per above and 20 % climate change adjustment factor results in:

$$Q_{100} = 0.116\ m^3/s$$

7.5.10.1.5 Flood Studies Report, FSR (NERC 1974)

This is the original FSR method, with the regression coefficient for Ireland. Estimates from this equation should be treated with extreme caution. It is recommended that these equations should be used only for preliminary flood estimates.

$$QBAR = 0.0172.AREA^{0.94} . STMFRQ^{0.27} . S1085^{0.16} . SOIL^{1.23} . RSMD^{1.03} . (1 + LAKE)^{-0.85}$$

Table 7.21 Calculations of Q_{100} – FSR Ungauged Catchments

Area, km^2	STMFRQ, jn/km^2	S1085, m/km	SOIL	RSMD	LAKE	Q_{BAR} m^3/s	Q_{BAR} x 1.96 gf m^3/s	Q_{100} x 1.47 sfe m^3/s	Q_{100} x x cc (1.2), m^3/s
0.66	1.52	21.9	0.35	33.1	0.0	0.21	0.42	0.62	0.74

Growth factors of 1.96 and 2.6 were applied to determine Q_{100} and Q_{1000}, respectively.

7.5.10.1.6 Institute of Hydrology Report 124 (1994)

Report No. 124 derives an equation to estimate flood flows for small rural catchments (less than 25 km²). The equation has a standard factorial error (SFE) of 1.65.

$$Qbar_{rural} = 0.00108\ (AREA^{0.89} x\ SAAR^{1.17}\ x\ SOIL^{2.17})$$

Table 7.22 Calculations of Q_{100} – IH124

Area, km^2	SAAR	SOIL	Q_{BAR} m^3/s	Q_{BAR} x 1.96 gf m^3/s	Q_{100} x 1.65 sfe m^3/s	Q_{100} x x cc (1.2), m^3/s
0.66	868	0.35	0.21	0.41	0.67	0.81

This method was developed for small catchments (< 25 km²) in the UK. It's derivation did not include any Irish catchments. The equation tends to overestimate QBAR for the smallest of the UK catchments used.

Without implementing the SFE, the Q_{100} rate plus 20 % climate change factor was reduced to 0.49 m^3/s. This value is comparable to results derived from other formulae.

7.5.10.1.7 Modified IH 124 (Cawley & Cunnane 2003)

$$Qbar_{rural} = 0.000036\ (AREA^{0.94} \times SAAR^{1.58} \times SOIL^{1.87})$$

Table 7.23 Calculations of Q_{100} – Modified IH124

Area, km^2	SAAR	SOIL	Q_{BAR} m^3/s	Q_{BAR} x 1.96 gf m^3/s	Q_{100} x 1.65 sfe m^3/s	Q_{100} x x cc (1.2), m^3/s
0.66	868	0.35	0.149	0.29	0.48	0.58

Without implementing the SFE, the Q_{100} rate plus 20 % climate change factor was reduced to 0.35 m^3/s. Again, the unadjusted value is reasonably consistent with the FSU and FSR results above.

7.5.10.1.8 TRRL & ADAS

Agricultural Development and Advisory Service (ADAS) , which is a precursor to

Transport and Road Research Laboratory (TRRL), is only applicable for catchments smaller than 0.4 km^2. This methodology shall not, therefore, be applied.

7.5.10.1.9 Summary of Flood Flow Calculations

Results from the OPW recommended methods are summarised below in Table 7.24. The results from the standard OPW FSU equations and Modified IH124 are in line with the average taken across the four other approaches and deemed the most appropriate for use in flood simulations.

The OPW FSU formulae were derived using Irish catchments and full datasets from Irish hydrometric gauging stations. The FSU also incorporates catchment descriptors derived from Irish digital elevation models. In line with OPW recommendations, an adjustment factor was not applied to the small catchments outcome. The OPW recommend that the Modified Rational Method is used for catchments smaller than 5 km^2. This equation yields the flood flow rates in line with the averages and values derived from this method were selected. IH124 is excluded as it was derived using non-Irish catchments.

Table 7.24 Summary of Calculated Flood Flows

(Inc. 20 % Climate Change Factor), m³/s unless Stated

Approach	Garrintaggart L7792	Garrintaggart R430	Aughatubbrid Confluence with northern channel (CSG)	Aughatubbrid laneway 1,200 m east
Catchment area, km^2	0.66	0.88	0.16	1.22
FSU Standard	0.58	0.76	0.15	1.03
FSU small catchments	0.198	0.26	0.054	1.34
FSU – 3 variable	0.116	0.15	0.036	0.19
FSR 6 – including SFE	0.74	0.90	0.29	1.12
IH124 – including SFE	0.81	1.05	0.23	1.41
Modified IH124 – including SFE	0.58	0.76	0.15	1.04
Minimum	0.12	0.15	0.04	0.19
Maximum	0.81	1.05	0.29	1.41
Average	0.50	0.65	0.15	1.02

7.5.10.2 Western Route Hydraulic Model

A hydraulic model was compiled using *Flood Modeller Pro* software, which was then used to simulate water levels at different points along the stream. Separate inflows were introduced at appropriate locations.

Overall, the western route model consists of 26 cross sections that were surveyed by Envirologic using the Trimble RTK VRS technique. Cross section locations are shown in Figure 7.13 and extended downgradient of the proposed discharge point by 970 m, reaching the Owveg River. Manning's coefficient of 0.03 was applied to open river channel bed sections and a value of 0.045 was applied to riverbanks. The following is a list of the critical structures on the Garrintaggart Stream. There are six additional field crossings not listed below that have been included in the model.

1. CSA Culvert below R430 at north-western corner of quarry
   - Gully surface = 214.1 m OD
   - Upgradient invert = 212.55 m OD
   - Downgradient invert = 211.36
   - Culvert diameter unconfirmed as inaccessible though the chamber supporting the gully structure has a height of 0.99 m and width of 0.45 m. The culvert outlet could not be safely revealed on the downgradient side of the R430.
   - Length = 8.57 m
   - Gradient = 0.139 m/m

- Q_{100} = 17 l/s
- Using Bentley Flowmaster minimum required pipe diameter is 0.15 m, though this depends on consistent gradient of 0.139 m/m along entire pipe run. Confirmation of the current pipe diameter and gradient requires a CCTV survey. A minimum pipe diameter of 450 mm is recommended to accommodate road runoff.

2. CSH Culvert below L7792
   - Concrete box culvert
   - Invert = 196.10 m OD
   - Height = 0.69 m
   - Soffit = 196.80
   - Width = 0.55 m
   - Gradient = 0.034 m/m
3. CSM Culvert below R430
   - Concrete pipe culvert
   - Invert = 181.60 m OD
   - Diameter = 1.35 m
   - Soffit = 182.95
   - Gradient = 0.07 m/m

All other surveyed sections were unimpeded open channels. Surface water levels as observed on 16th March 2021 are presented below in Table 7.25. Inflows for the validation procedure were measured at three locations using an electromagnetic streamflow velocity meter as follows:

- Channel north of discharge = CSD = 4.2 l/s
- Field crossing = CSE = 7.7 l/s
- L7792 crossing = CSH = 13.1 l/s
- Open channel = CSJ = 13.6 l/s

The water levels predicted using the measured flows were generally within 100 mm of the actual surveyed water levels. The exception was at CSK/CSL with an error of 290 mm that is attributed to a lack of GPS signal due to canopy cover and required a manual cross section. For the purposes of this assessment, the model is considered to be valid and accurate.

The conveyance capacity of all surveyed cross sections along the stream were assessed for suitability to transmit Q_{100} flood flows, with an allowance included for climate change. The predicted surface water elevations are presented in Table 7.25.

Table 7.25 Western Stream: Summary of Calculated Flood Flows

(Inc. 20 % Climate Change Factor), m^3/s unless Stated

Section	Gradient, m/m	Validation, 16th March 2021				Inflow, m^3/s	Q_{100} flood flow	Inflow, m^3/s	Q_{100} flood flow + max. discharge ($0.017\ m^3/d$)
		Surface water level, m OD	Envirologic Model Input, m^3/s	Envirologic Model Output	Difference, m				
CSADn			0.01			0.02	209.31	0.037	209.38
CSBUp	0.0067	209.18		209.15	0.03		209.15		209.17
CSBDn	0.0067	208.27		208.23	0.04		208.23		208.25
CSC	0.097		0.02			0.58	206.87	0.58	206.87
CSD	0.057	205.25		205.19	0.06		205.39		205.39
CSEUp	0.08	199.87		199.84	0.03		200.04		200.05
CSEDn	0.031	199.56		199.56	0.00		199.92		199.92
CSF	0.014	196.99		196.98	0.01		197.24		197.24
CSG	0.043	196.42		196.23	0.19		196.94		196.96
CSHUp	0.055	196.37		196.23	0.14		196.43		196.43
CSHDn	0.043	195.65		195.62	0.03		195.75		195.75
CSIUp	0.022	194.41		194.40	0.01		194.73		194.74
CSIDn									
CSJ	0.022	191.78	0.02	191.79	-0.01	0.18	192.20	0.18	192.20
CSKUp	0.0385	188.37		188.40	-0.03		188.56		188.56
CSKDn		188.31		188.02	0.29		188.26		188.27
CSLUp	0.037	183.52		183.80	-0.28		183.92		183.92
CSLDn	0.043	182.60		182.38	0.22		182.49		182.49
CSMUp	0.043	181.70		181.67	-0.03		181.82		181.82
CSMDn	0.037	178.95		178.93	0.02		179.23		179.23
CSN	0.036	178.95		178.88	0.07		179.10		179.11
CSO	0.036	172.11		172.11	0		177.00		177.00

The longitudinal section in Appendix 7.4 shows some friction losses cause elevated water at most of the culvert inlets but that during flood events the water levels do not rise above the soffit of critical structures CSH, under the L7792 (196.80), and CSM, under the R430 (182.95). A headspace of 370 mm remains in the L7792 culvert during flood flows.

The results show that the discharge can be adequately accommodated by the receiving water and shall cause only a negligible increase in stream water levels during an extreme storm event, including allowance for climate change.

Hence, upgrade works are not deemed necessary on the western route to facilitate the predicted discharge during a storm event. A CCTV survey of culvert CSA, beneath the R430, will be necessary in the future to ensure the required diameter, gradient and condition of this structure. Improvements or reconditioning are possible, if required.

7.5.10.3 Eastern Route Hydraulic Model

The eastern route model consists of 23 cross sections that were surveyed using Trimble RTK VRS technique. Cross section locations are shown in Figure 7.14 and extended 1,200 m downgradient of the entrance pond, reaching a private laneway that provides access to a dwelling and farmyard. The following is a list of the critical structures surveyed on the Aughatubbrid Stream.

1. CSC Culvert below laneway at north-eastern corner of quarry
    - Upgradient invert = 227.59 m OD
    - Downgradient invert = 227.47 m OD
    - Culvert has fully collapsed. Water continues to flow through the rubble of the collapsed structure.
    - Length = 6.75 m
    - Gradient = 0.018 m/m
    - Q_{100} = 17 l/s
    - Using Bentley Flowmaster minimum required pipe diameter is 0.30 m, though this depends on consistent gradient of 0.018 m/m along entire pipe run. Confirmation of the current pipe diameter and gradient requires a CCTV survey. In the future, a minimum pipe diameter of 500 mm is recommended. This is feasible should planning be granted.
2. CSF Culvert below field entrance crossing
    - Concrete pipe culvert
    - Upgradient Invert = 224.07 m OD
    - Downgradient Invert = 223.91 m
    - Diameter = 0.30 m
    - Soffit = 224.37 m OD
    - Length = 4.0 m
    - Gradient = 0.04 m/m
3. CSN Culvert below laneway
    - Upgradient = 2 x 600 mm concrete pipes; IL = 202.71 m OD
    - Upgradient soffit = 203.31 m OD
    - Downgradient = 2 x concrete box culverts (height = 950 mm; width = 550 mm). The upgradient pipes appear to have been added on to the original box sections.
    - Soffit = 182.95
    - Gradient = 0.03 m/m

All other surveyed sections were unimpeded open channels. Surface water levels as observed on 18th March 2021 are presented below in Table 7.26. Inflows for the validation procedure were measured at three locations using an electromagnetic streamflow velocity meter as follows:

- Channel downgradient of entrance pond = CSA = 0.5 l/s
- Channel crossing north-south below R430 near eastern dwelling = joins at CSG/CSH = 10 l/s
- Inflow from southern side of channel between CSJ and CSK = 2 l/s

The water levels predicted using the measured flows were generally within 100 mm of the actual surveyed water levels. The exception was at CSH with an error of 180 mm that is attributed to the inflow from a channel that drains the northern side of the R430. For the purposes of this assessment the model is considered to be valid and accurate.

The conveyance capacity of all surveyed cross sections along the stream were assessed for suitability to transmit Q_{100} flood flows, with an allowance included for climate change. The predicted surface water elevations are presented in Table 7.26. The simulation was run with a 400 mm pipe at CSC.

With reference to the survey point notations on Figure 7.14, the current infrastructure along the eastern route **is not capable** of safely transmitting flood flows.

The following minimum upgrades are necessary:

1. Section area 'CSC' needs to be upgraded to a 400 mm pipe.
2. Section area 'CSN' needs to be upgraded. This corroborates reports from the resident using this lane who stated that the twin-pipe culvert at Section area 'CSN' surcharges during heavy rainfall.

Table 7.26 Eastern Stream: Summary of calculated flood flows

(inc. 20 % climate change factor), m^3/s unless stated

Section	Gradient, m/m		Validation, 16th March 2021			Inflow, m^3/s	Q_{100} flood flow level, m OD	Inflow, m^3/s	Q_{100} flood flow + max. discharge (0.017 m^3/d)
		Surface water level, m OD	Envirologic Model Input, m^3/s	Envirologic Model Output	Difference, m				
CSA	0.009	229.15	0.01	229.12	0.03	0.03	229.13	0.047	229.15
CSB	0.016	228.60		228.47	0.13		228.49		228.51
CSCUp	0.017	227.68		227.68	0		227.75		227.79
CSD	0.027	227.53		227.50	0.03		227.56		227.57
CSE	0.023	225.86		225.78	0.08		225.80		225.81
CSFUp	0.020	224.09		224.10	-0.01		224.18		224.18
CSFDn	0.020			223.97			224.04		224.05
CSG	0.007	222.39	0.02			0.15		0.15	
CSH	0.017	222.11		221.93	0.18		222.10		222.11
CSI	0.037	220.81		220.84	-0.03		220.96		220.97
CSJ	0.062	216.87		216.90	-0.03		216.99		216.99
CSK	0.026	213.73		213.63	0.1		213.75		213.75
CSL	0.030	210.76		210.72	0.04	0.85	210.95	0.85	210.95
CSM	0.035	207.31		207.24	0.07		207.43		207.43
CSNUp	0.011	202.89		202.81	0.08		203.09		203.09
CSNDn	0.011			201.47			201.75		201.75
CSO	0.011	201.47		201.47	0		201.5		201.50

7.5.10.4 Stream Hydraulic Capacity Summary

The primary purpose of the assessment was to determine the capacity of the streams to receive flows from future proposed dewatering activities during quarry development.

Generally, the inclusion of an additional input to represent maximum predicted quarry discharge did not result in a perceptible increase in water levels during a flood event. The input from the quarry discharge is small relative to the stormflows and becomes smaller as the catchment size increases progressing downstream.

Based on the model simulations the western route is more suitable for safely transmitting predicted quarry discharge.

With reference to the survey point notations on Figure 7.13 and Figure 7.14, the following measures should also be implemented to improve hydraulic functionality in the general area of the site:

- Upgrade section area ‘CSC’ on eastern route.
- Any future discharge of groundwater to the eastern route will require upgrading of Section area ‘CSN’.
- Continue to permit greenfield runoff and spring flow from eastern area to the current natural outfall to the eastern channel as per present, until such a time in the future phases’ excavation commences in this area.
- CCTV survey of Section area ‘CSA’ on western route.

7.5.11 HYDROCHEMISTRY

7.5.11.1 Groundwater Quality

Groundwater quality sampling commenced in December 2021 (winter) and was followed up by further sampling in March, April and May 2021. The March/April 2021 groundwater samples were retrieved towards the end of the constant test on each of the production wells. The pump test samples were tested for a comprehensive suite of hydrochemical parameters. Given that no contaminants were detected, subsequent analyses focussed on those parameters likely to change with recharge. In addition to borehole samples, the floor sump was sampled.

Field recordings for physiochemical parameters, temperature, dissolved oxygen, pH, conductivity and oxidation-reduction potential (ORP) had stabilised at the time of water sampling. The latter sampling events focused on fulfilling the requirements of a discharge licence application, namely samples representative of the likely discharge and receiving waters.

Samples were delivered to ALS on day of sampling for analysis of microbiological parameters and biochemical oxygen demand (BOD). Remaining samples were filled into the appropriate sample containers that contained the appropriate fixation substance per parameter, stored in cooler boxes and dispatched by courier on sampling day for analysis of remaining hydrochemical parameters by Element Laboratories, Deeside, UK. It is becoming standard practice amongst hydrogeologists to send samples to the UK labs because the degrees of precision is more resolute.

Groundwater quality results are presented in Table 7.27. Certificates of Analysis are presented in Appendix 7.5.

Results presented in Table 7.27 as follows:

- Electrical Conductivity, pH, Alkalinity and Total Hardness are as expected for the Sandstone bedrock hydrogeology.

- No hydrocarbons were detected in any samples. Results suggest < Limit of Detection of the laboratory analyser. This suggests no historical impacts reside at the site.

- Nitrate concentrations are below the expected national baseline, nitrites are low and ammonia levels are an order of magnitude lower than the Groundwater Regulation's Threshold Trigger Values. It is therefore concluded that there is no historic residue from explosives used for blasting, no impact from the local area's private on-site wastewater treatment systems and no agricultural impact from the wider area. Total Phosphorus and Ortho-phosphate concentrations are below the limit of detection of the analyser and hence suggest excellent groundwater quality. Overall, it is concluded that all nutrient concentrations are all very low and within the Groundwater Regulation Threshold Values.
- Faecal and non-faecal coliforms were detected in the sump but this is typical of open water areas, which can be impacted by birds. Groundwater sampled at PW1 adjacent to the sump contained no counts of bacteria.
- With respect to metals, all the Groundwater Regulation's specified metals are within Regulatory values. For example, Aluminium, Cadmium and Zinc concentrations in the groundwater are low, which is good because those parameters have potential to threaten the ecology of waters receiving the discharge of quarry waters. At this site there is no potential for harm.

Based on the results in Table 7.27, groundwater quality at the site complies with the European Communities Environmental Objectives (Groundwater) Regulations 2010 (as amended 2011, 2012, 2016) and its discharge of these waters should not have a detrimental impact on receiving waters. Hydrochemical assimilation capacity simulations, presented later, will test this.

The analyses for hydrochemical parameters completed at the site is greater than specified in the Groundwater Regulations because the results for the groundwater and outfall sump will be used in conjunction with the receiving surface water's characteristic to evaluate hydrochemical assimilation capacity.

Table 7.27 Summary Groundwater Quality Results

[Refer to Appendix 7.5 for Laboratory Certificates of Analysis for all parameters and all sampling events]

Parameter	Units	PW1	PW2	PW3	Sump	Outfall Pond	Outfall Pond	Outfall Pond	Groundwater Regulation Threshold Values (2010, as amended 2016) *
Date		26/03/21	08/04/21	08/04/21	08/04/21	08/04/21	05/05/21	24/05/21	
Electrical Conductivity	µS/cm	372	220	279	293	224	210	190	800 - 1875
pH		7.1	7.7	8.8	7.4	7.5	7.8	7.9	Not specified
Field DO	mg/l	4.4	12.1	12.4	2.4	11.4	11.0	10.9	Not specified
Aluminium	µg/l	13.7	22.3	72.5	33.6	21.9	79.4	21.4	150
Cadmium	µg/l	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	3.75
Iron	µg/l	16	85	**216**	21	51	76	9.9	Not specified
Manganese	µg/l	**425**	41.6	17.0	4.6	**143**	44.9	2.1	Not specified
Mercury	µg/l	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0.75
Zinc	µg/l	2.3	5.5	4.1	3.9	4.2	1.6	< 1.5	75
Calcium	mg/l	47	42	41	25	46	53.8	27	Not specified
Magnesium	mg/l	18.6	10.9	11.2	9.6	13.0	17.6	10.5	50
Potassium	mg/l	< 1	1.6	0.6	1.8	1.9	2.4	2.1	Not specified
Sodium	mg/l	8.9	8.4	11.0	8.4	8.8	11.6	8.8	150
Sulphate	mg/l	12.7	45.3	7.07	27.5	58.3	60.4	28.4	187.5
Chloride	mg/l	16.7	12.9	15.5	13.8	13.4	13.9	13.3	187.5
Nitrate (NO_3)	mg/l	2.7	4.0	3.1	2.4	< 0.2	0.4	2.0	37.5
Nitrite (NO_2)	mg/l	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.375 ug/l
Ammonium as N	mg/l	0.025	0.016	0.016	0.016	0.025	0.016	0.008	0.065 to 0.175
Orthophosphate as P	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01		Not specified
Total P	mg/l	0.006	0.011	0.012	0.011	0.012	0.013	0.012	Not specified
Alkalinity ($CaCO_3$)	mg/l	186	110	102	86	121		84	Not specified
Total Hardness	mg/l	191	152	165	109	178	185	106	Not specified
TOC (Element)	mg/l	< 2	< 2	< 2	< 2	< 2	< 2	2	Not specified
TPH (C5-C35)	µg/l	< 10	< 10	< 10	< 10	< 10			7.5 ug/l TV ^
PAH Total	µg/l	< 0.195	< 0.195	< 0.195	< 0.195	< 0.195			0.075 ^
MTBE	µg/l	< 5	< 5	< 5	< 5	< 5			10
BTEX compounds	µg/l	< 5	< 5	< 5	< 5	< 5			
Suspended Solids^^	mg/l	< 10	< 10	< 10	< 10	< 10	< 10	< 10	Not specified
COD	mg/l	Not analysed / not a 'groundwater' parameter.				< 5	10	< 5	Not specified
BOD	mg/l	< 2				2	3	< 2	Not specified
Total coliforms	MPN/ 100 ml	0				86	122	13	Not specified
Faecal coliforms	MPN/ 100 ml	0				0	6	0	Not specified

* Threshold values relevant to an assessment of the general quality of groundwater in a groundwater body in terms of its ability to support human uses has been significantly impaired by pollution. Where this threshold was not stated, that relevant to an assessment of whether groundwater intended for human consumption in drinking water areas is impacted by pollutants and/or is showing a significant and sustained rise in pollutant levels was applied.

** Unknown pattern. Reported by CLS. 'unknown pattern' means that it is not a known hydrocarbon, the laboratory state that it may be natural from peat. Subsequent analysis will differentiate hydrocarbon species.

^ The Irish EPA acknowledge that no laboratory can achieve the TPH and PAH TVs. It is generally accepted that a <LOD result shall suffice to demonstrate no hydrocarbon content in the waters.

^^ Suspended Solids' Limit of Detection in the UK Laboratory is relatively high. It is most likely that results are a fraction of the <10 mg/l reported.

7.5.11.2 Surface Water Quality

Surface water quality monitoring results, representing receiving waters to the east and west, are tabulated in Table 7.28. Certificates of Analyses are attached in Appendix 7.5.

The two sampling points are considered to be the primary mixing points applicable to the potential eastern and western discharge routes.

An additional sample was retrieved at a point labelled SW2. This is from a drain that runs along the northern side of the R430, east of the quarry, just before it enters the Aughtubbrid Stream. The location of the surface water monitoring points are shown on Figure 7.1.

As per the groundwater at the site, the nutrient concentrations in the surface waters are very low and suggest that neither diffuse agriculture nor on-site wastewater treatment systems are significant pressures in either catchment.

While both faecal and non-faecal coliforms are elevated in samples of surface water in both catchments, this is typical of all surface waters in Ireland.

Several parameters returned relatively higher concentrations in the eastern catchment when compared to the western catchment. These included conductivity, aluminium, cadmium and zinc. The fact that the similarly elevated concentrations were determined at both SW2 monitoring point and at the Clogh River monitoring point suggests that these results represent naturally different hydrochemical signature to the east, relative to the west. The concentrations are not problematic.

Surface water monitoring results (Table 7.28) demonstrate that the surface waters in both directions comply with High Status Environmental Quality Objectives of the Surface Water Regulations (2009 as amended 2012, 2015 and 2019) for the specified and significant parameters of BOD, Ammonia-N, ortho-P and Cadmium. This is as it should be in the headwaters of the River Nore. It is usual that surface waters close to quarries can be of higher quality than those surface waters in proximity to agri-forestry and livestock grazing systems.

In addition, the surface waters in both directions have low concentrations for nitrates, nitrite, suspended solids and other indicator parameters, which although not specified in the Surface Water Regulations, do aid in the assessment of generally good water quality in the headwaters of the River Nore.

Table 7.28 Surface Water Quality
[Surface Water Regulation Specified Parameters and compliance highlighted]

Parameter	Units	Owveg	Clogh	SW2	Owveg	Clogh	Owveg	Clogh	Surface Water Regs (2009, as amended 2012, 2015, 2019)
Date		**08/04/21**	**08/04/21**	**08/04/21**	**05/05/21**	**05/05/21**	**24/05/21**	**24/05/21**	
Temperature	C	7.8	7.8	8.1	7.9	7.8	8.4	11.7	
Electrical Conductivity	µS/cm	220	299	293	200	270	215	234	
Field pH	pH units	**6.3**	**7.4**	**7.4**	**6.7**	**6.8**	**6.9**	**6.2**	**4.5 – 9.0**
DO	mg/l	12.1	3.9	2.4			11.0	10.7	95 to 120 % saturation
Aluminium	µg/l	41.9	181.0	100.2	53	584.7	560	1466	
Cadmium	**µg/l**	**< 0.03**	**0.06**	**< 0.03**	**< 0.03**	**0.08**	**0.05**	**0.11**	**1.5**
Iron	µg/l	97.3	282.10	158.0	108.7	626.1	571.3	1265	
Manganese	µg/l	7.1	18.0	18.4	7.5	16.4	17.1	2.1	
Mercury	µg/l	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	
Zinc	µg/l	3.8	5.4	4.1	1.8	4.6	< 1.5	< 1.5	
Calcium	mg/l	45.5	36.4	28.6	54.8	31.3	32.9	27.0	
Magnesium	mg/l	4.3	5.2	5.9	6.3	5.1	2.8	10.5	
Potassium	mg/l	1.4	1.3	2.3	2.7	2.2	2.2	2.1	
Sodium	mg/l	7.3	8.1	13.3	11.6	8.4	3.6	5.6	
Sulphate	mg/l	8.6	28.9	7.6	8.3	23.3	6.6	11.3	
Chloride	mg/l	12.2	11.4	20.9	17.8	13.4	9.2	9.8	
Nitrate (as NO_3)	mg/l	0.9	1.5	7.0	2.3	2.3	1.7	1.6	
Nitrate (as N)	mg/l	0.203	0.34	1.58	0.52	0.52	0.383	0.361	
Nitrite (as NO_2)	mg/l	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	
Nitrite (as N)	mg/l	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	
Ammoniacal Nitrogen as NH4	mg/l	0.03	0.03	0.03	0.03	0.03	0.04	0.03	
Ammoniacal Nitrogen as N	**mg/l**	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**	**0.033**	**0.025**	**0.4 to 0.9 mg/l High Status**
Orthophosphate as P	**mg/l**	**0.016**	**< 0.01**	**0.013**	**0.016**	**< 0.01**	**0.023**	**0.013**	**0.025 to 0.0445 mg/l MRP-P High Status**
Total P	mg/l	0.031	0.018	0.027	0.037	0.032	0.093	0.085	
Alkalinity ($CaCO_3$)	mg/l	149	87	89	152	85	95	43	
Total Hardness	mg/l	149	108	93	151	99	95	50	
TOC	mg/l	5	5	5	9	5	16	22	
Suspended Solids^^	mg/l	< 10	< 10	< 10	< 10	< 10	< 10	< 10	Not specified in Surface Water Regulations but Salmonid Regulations = 25 mg/l and Pearl Mussel Regs specify no change.
COD	mg/l	< 5	< 5		18	25	37	50	
BOD	**mg/l**	**< 1**	**< 1**		**< 1**	**< 1**	**< 2**	**2**	**High Status 1.3 to 2.2 mg/l BOD**
Total coliforms	MPN/ 100 ml	68	488		1120	1046	> 2420	> 2420	
Faecal coliforms	MPN/ 100 ml	42	488		727	461	2420	770	

^^ Suspended Solids' Limit of Detection in the UK Laboratory is relatively high. It is most likely that results are a fraction of the <10 mg/l reported.

7.5.12 CONCEPTUAL SITE MODEL

A preliminary conceptual site model (CSM) was developed using all information collected. The purpose of the CSM is to incorporate results from the different strands of testing and to present a coherent understanding of the hydrological and hydrogeological regimes in an around the site as they are understood to date. It is important to note that there is no information regarding previous quarrying activities and water management at the site.

The site is positioned on the northern periphery of the Castlecomer Plateau and this is most clearly represented in Figure 7.6.

There are three geological formations underlying the site, as well as overlying glacial till, where the sequence in the area is:

1. Till, a thin covering that is present on the raised, south-eastern half of the site;
2. Coolbaun Formation – hard shales, poor aquifer. Present only to a limited depth on the south-eastern half of the site.
3. Clay Gall Sandstones – fractured sandstones, moderate aquifer. Fully exposed in the north-western half of the site to a depth of 20 m, dipping to around 50 m in the central area.
4. Moyadd Coal Formation – mudstones, poor aquifer.

The configuration of the geological formations is most clearly presented in the SLR (2020) Geological Report for the site (Appendix 6). For the purposes of ease of reference, geological cross sections from SLR (2020) are reproduced here as Plates 7.8 to 7.10. The geological cross sections are important in the CSM because the point of contact or the base of the sandstones dictates the hydrogeology. Borehole Logs (Appendix 7.1) present the water strikes with the points of contact between formations.

In terms of Hydrogeology, the Coolbaun and Moyadd Coal bedrock formations generally have low matrix permeability, are low-yielding and can be characterised as aquitards. Exposed faces around the sump show the Clay Gall Sandstones to be quite broken in structure with no discrete inflows. Groundwater in the Clay Gall Sandstones is said to be confined where this formation is sandwiched between the Coolbaun and Moyadd Coals. This was reinforced by a local well survey which revealed that potable supply to domestic properties is a mixture of shallow ‘spring’ wells and deep, artesian boreholes. The springs tend to coincide with outcropping along the base of the Clay Gall Sandstones.

Internally, the quarry has three distinct areas: (i) the north-western area which has been excavated to one bench and which contains a processing area associated with the previous operator’s activity and water management areas; (ii) the partially worked south-eastern area; and (iii) the central area containing some stockpiles and the sump.

Proposed works involve extraction of bedrock by blasting and mechanical means as an open quarry void. The floor of the proposed excavation is 200–206 m OD in the north-western half of the site, deepening to 190 m OD in the south-eastern portion of the site, essentially following the Clay Gall Sandstone dip as described in SLR (2020).

In addition to the SLR (2020) reported dip on the base of the Sandstones to the south-east, an Apex geophysical assessment at the site (2021) suggests that the sandstone beds of the Clay Gall Sandstone Formation also dip from north to south-southwest at an apparent angle of approximately 5–10°, equivalent to 8–18 m per 100 m. A survey of on-site groundwater monitoring points shows groundwater flow direction follows this north to south-southwest dip orientation. Local area well survey confirmed that the groundwater flow direction is not in line with topographical controls. It seems that recharge into the Lm bedrock aquifer continues to infiltrate to the underlying aquitard and then flows southwards towards the quarry, travelling along the dipping beds of the Clay Gall Sandstones. Flow direction within the site is in a west-southwest direction towards PW2. The locally important Clay Gall Sandstone aquifer is unconfined within the north-western half of the site. The Clay Gall Sandstone extends southwards and becomes more confined as a result. The regional groundwater flow direction is at a different macro scale to that of the quarry site itself (Figure 7.11) and is known to be from NE to SW. The site's groundwater levels confirm that the topographical surface water catchment divides are not reflective of any distinct groundwater catchments.

Given that the regional groundwater flow is NE to SW, the site poses no threat to the Swan PWS source. The outer source protection zone of the Swan PWS SPZ's closest boundary to the quarry is 1.25 km east of the quarry's most eastern boundary (Figure 7.6). The quarry is therefore well outside the area mapped for protection of the Swan PWS. The SPZs are delineated with large factors of safety.

Production Wells of 8" diameter were drilled within the quarry in order to facilitate large diameter pumps, if required, and pumping tests were performed to quantify the aquifer characteristics. In each of the three large diameter boreholes, the largest water strikes were encountered at the base of the Clay Gall Sandstones at the contact with the underlying Moyadd Coal Formation. In PW1 and PW3, the yields at this interface were modest and would only be capable of supporting small abstractions on a local scale. Hydraulic conductivity of the Clay Gall Sandstones was in a narrow range between 0.05–0.1 m/d at these two boreholes. The results suggest that vertical recharge through the locally important sandstone aquifer is moderate until it is impeded upon reaching the Moyadd Coal aquitard at which point it is most likely that groundwater flow is dominated by lateral flow. A schematic Cross Section through the site, showing all boreholes and PW drilling observed water strikes, is presented in the cross Section for the site as Plate 7.11.

However, the site's hydrogeology is complicated by the high yield encountered close to the western boundary in PW2. A large water strike was encountered at the same interface between the Clay Gall Sandstones and the underlying Moyadd Coals. However, there was a substantial weathered sand zone at this point of contact. The hydraulic Conductivity at this point was high at K = 8 m/d. A yield of this scale might be considered capable of supporting a large number of wells, and or a public supply, when its volumetric yield is considered but it is the experience of Hydro-G that the turbidity of waters arising in such sand features usually rules the well out as a viable, economic, treatable Public Water Supply Source.

No excavations are planned at PW2, instead it is proposed that the settlement ponds will remain in-situ here, as per the previous operation. The water-bearing zone is also c. 16 m below the existing floor level in this area. This area of the site will not be worked.

The band of sand that was the source of the main water strike was not found in any of the other site investigation boreholes (four core holes and two other Production Wells) nor observed on any exposures. This includes SP01, 81 m to the east, and PW3, 185 m to the northeast. Well logs suggest that somewhere between PW1 and SP01/PW3 the high-yielding sands taper out into a smaller fracture zone which yields little water. Nevertheless, further geophysical work was commissioned in 2021, and reported by Apex (2021) to explore the extent of the high-yielding zone in PW2. The interpretation of the resultant geophysical survey concluded that the high-yielding zone encountered at PW2 occurs where the dipping bed comes up against a fault and that it is confined to the southwest corner of the site. It is therefore unlikely to be capable of providing a long-term yield of the original drilling test estimate of 900 m^3/d nor the sort pumping test's approximate suggestion of 700 m^3/d. The geophysics confirmed the limited extent of this feature at PW2.

Numerous calculation methods suggest that the potential volume of water to be managed on the average day at the site could range from 761 m^3/d to 1,453 m^3/d, dependent upon the intersection, or not, of the **contact between the Clay Gall Sandstones and the Moyadd Coal Formation.** The primary mitigation measure for the site is therefore to ensure all excavation stays above the contact between the Clay Gall Sandstones and the Moyadd Coal Formation. The quarry design takes this into account so as to maintain at least a 5 metre buffer above the contact between the Clay Gall Sandstone Formation and Moyadd Coal Formation. Drilling and geophysics showed no evidence of significant water-bearing fractures within the Clay Gall Sandstone bedrock formation itself. A buffer will be maintained around PW2 that will not be subject to blasting or excavation. Given the cavity was not detected at SP01 a buffer of 80 m to PW2 is considered reasonable.

Another groundwater evaluation method adopted the ZOC rationale, whereby the void was conceptualised as a water supplying a well and the area explored mathematically so as to determine the potential zone for recharge from the upgradient groundwater catchment. Given the understanding regarding groundwater flow direction and topographical controls for the area, groundwater recharge to the site using that methodology suggests a daily groundwater contribution of 956 m^3/d.

Although numerous evaluation methods suggest that dewatering volumes could range from 761 m^3/d, 956 m^3/d and to a maximum of 1453 m^3/d, the maximum value has been adopted in all simulations for hydraulic and hydrochemical feasibility in the receiving environment. The calculated values are intended to be representative of maximum discharge rates that are only likely to be realised close to completion. Interim discharge rates increase in a progressive manner according to the phasing scheme. Calculations suggest a Dewatering Rate Q = 340 m^3/d after one month and Q = 264 m^3/d after six months. Phased development commencing in the north-western half of the site will result in a large area available for sump retention, water holdback, settlement and discharge in a controlled fashion that is suitable to the characteristics of the known flashy surface water system outside the site.

The final radius of influence of future dewatering is estimated to be 350 m from the centre of the sump and this will not impact local wells because there are no wells in that radius.

Hydraulic modelling of the surface water system, based on cross sections and surveying, has demonstrated that the local area's surface water network can accommodate the envisaged dewatering amounts, in combination with flood flows and allowances for climate change. The western route is better.

With respect to surface water monitoring, the surface waters in both directions comply with High Status Environmental Quality Objectives of the Surface Water Regulations (2009 as amended 2012, 2015, 2019) for the specified and significant parameters of BOD, Ammonia-N, ortho-P and Cadmium. This is as it should be in the headwaters of the River Nore. Our conceptual understanding of catchment hydrology is that surface waters close to quarries can be of higher quality than those surface waters in proximity to agri-forestry and livestock grazing systems. This is supported by the WFD characterisation of the River Clogh, downstream of the site, being classified as 'At Risk' from agricultural sources.

With respect to groundwater quality, which will contribute some of the site's discharge volume in addition to rain falling on the site, the groundwater underlying the site contains no hydrocarbons, the groundwater is pure with a TOC <2 mg/l and all nutrients comply with the requirements of the Groundwater Regulation Threshold Values (2010 as amended 2016).

In addition, the surface waters in both directions have low concentrations for all nutrients including nitrates, nitrite, suspended solids and other indicator parameters, which although not specified in the Surface Water Regulations, do aid in the assessment of generally good water quality in the headwaters of the River Nore.

The understanding of the hydrogeological regime at the site and surrounding area now enables advancement to design the appropriate site water management scheme.

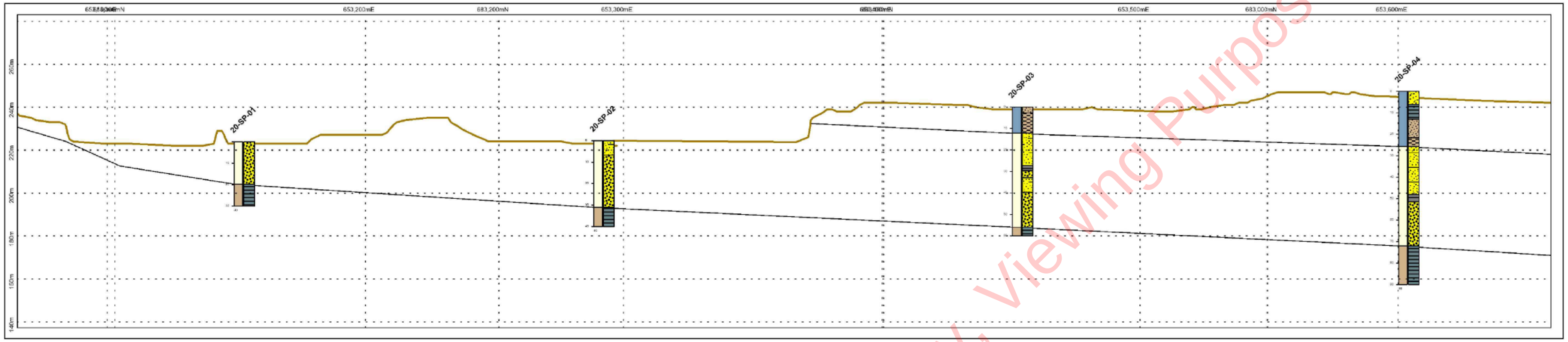
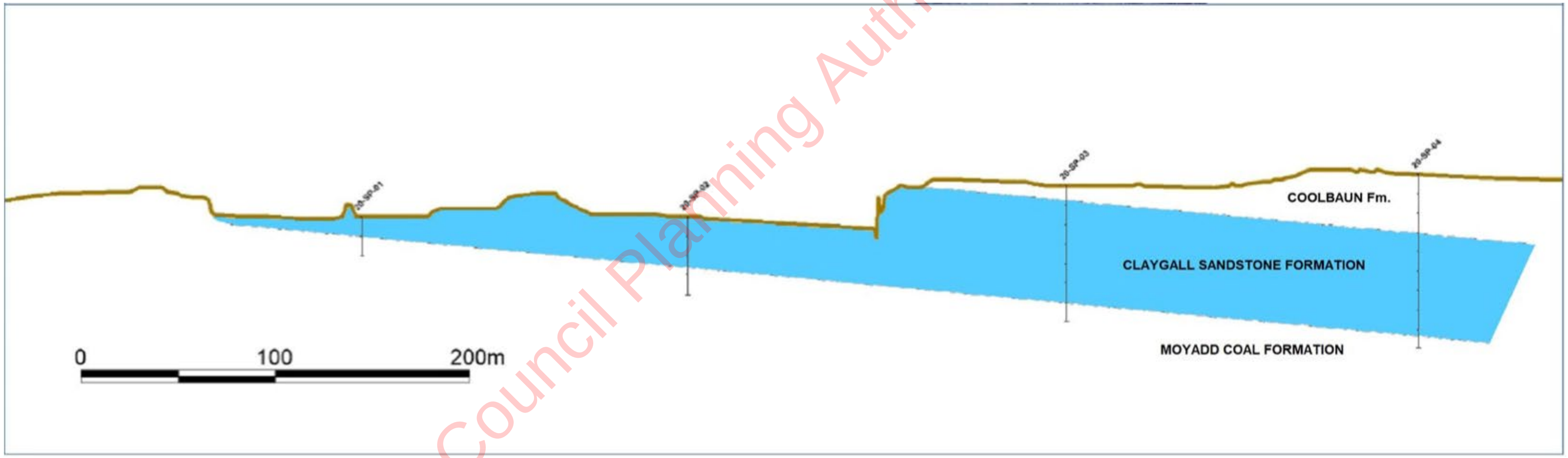


Plate 7.8 Schematic Cross Section through NW-SE Plane.



Target Formation Shown in Blue (Modified from SLR 2020)

Plate 7.9 Schematic Cross Section through NW-SE Plane (SLR 2020)

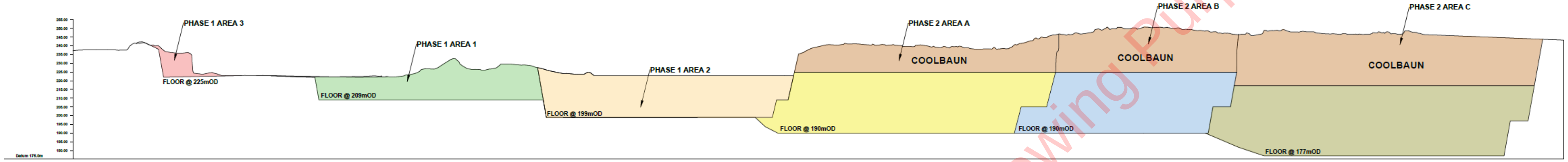


Plate 7.10 Simplified Cross Section Showing Phased Extraction

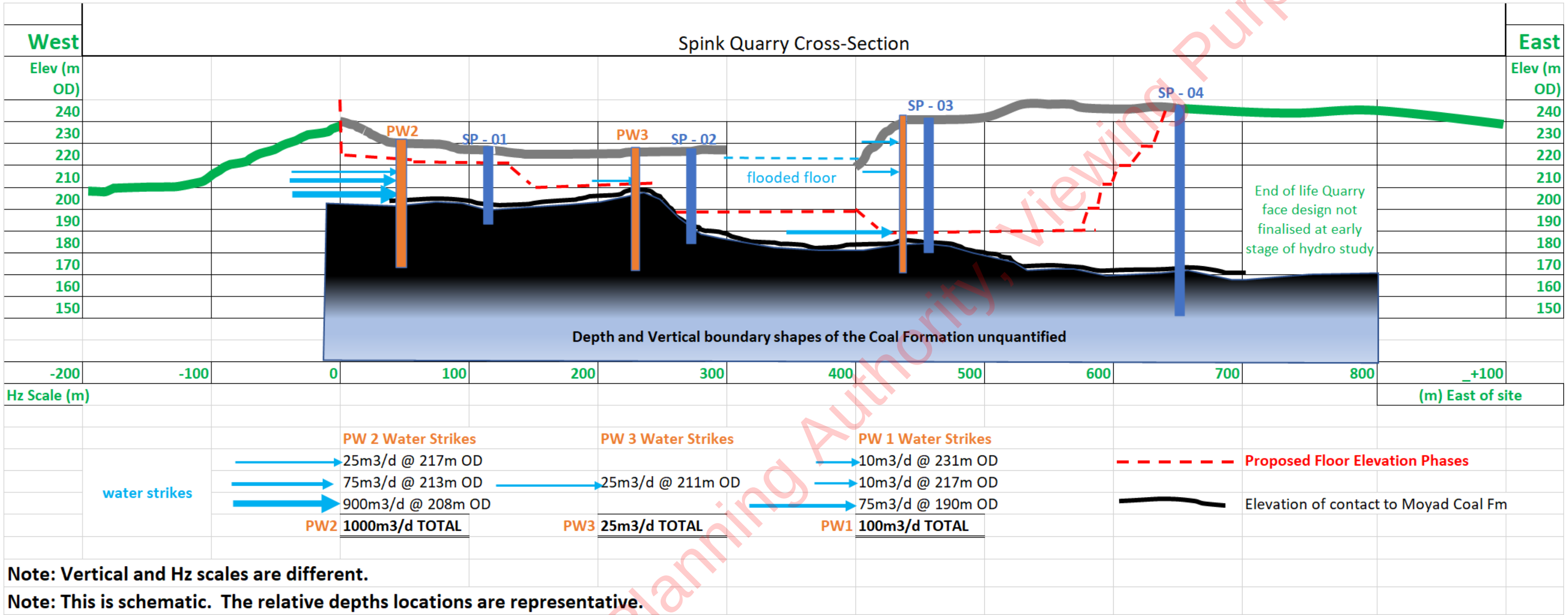


Plate 7.11 Hydrogeological Cross Section through the site

7.5.13 WATER MANAGEMENT PLAN

7.5.13.1 Proposed Development Scheme

It is proposed that the quarry will be worked in a series of benches (typically 10 to 20 metres) down to a final depth of 200 m AOD in the western quarry area and 190 m in the eastern quarry area (Refer to Figures 3.1 and 3.3). The development will see the extraction of both the Clay Gall Sandstone Formation and Coolbaun Formation, which overlies the Clay Gall sandstones to the east of the existing quarry sump.

Prior to site investigation works, Hydro-G and Envirologic discussed an alternative scheme with the applicant that would involve Leaving a 20 m wide natural bedrock barrier (causeway) would be maintained along the eastern edge of the existing sump, extending from the site entrance to the southern boundary. This approach would negate the requirement for constant pumping of the main sump in the medium term, thereby reducing the short to medium-term pumping demand. Dry working conditions would be achieved in the eastern area by pumping groundwater inflows collected in a new sump back into the existing main sump via a short channel. Any suspended sediment transported in this channel settles out in the main pond. Groundwater level in the main sump could be maintained by an overflow mechanism, which would direct waters to the settlement ponds, in line with the current overflow control. The discharge rate would not exceed the pumping rate from the new sump in the eastern area. Upon reaching target levels in the eastern area, dewatering would progress to include the main sump. That initial development phase concept has not been pursued for the following reasons:

- The Clay Gall Sandstone that would form the causeway may not be sufficiently impermeable to provide ample hydrogeological separation between the eastern and western areas;
- The thick layer of Coolbaun shale/sandstone requiring removal to excavate the high quality Clay Gall Sandstone;
- Added certainty provided by subsequent field investigation confirming that the high-yielding cavity at PW2 is limited in areal footprint;
- The groundwater catchment to the site does not match the topographically defined surface water catchments.

7.5.13.2 Extreme Rainfall Events

A brief assessment is required to ensure that the sump is capable of temporarily storing stormwater that drains to it during an intense rainfall event.

Stormwater volume draining to the sump is based on a contributing catchment area of c. 290,000 m^2.

Table 7.29 shows that the 1 in 100-year rainfall contribution to the sump over a 24-hour period is 21,460 m^3. The current sump has an approximate radius of 60 m, which suggests an effective storage of approximately 11,000 m^3 per meter depth. Therefore, a 2 m deep sump can accommodate the extreme event.

Table 7.29 Potential Rainfall-Runoff Inflows to the Quarry Sump during Extreme Rainfall Events

Considered Catchment m^2	Rate	1 in 1 year	1 in 10 year	1 in 50 year	1 in 100 year
290,000	**24-hour event**				
	mm	13	52	67	74
	m	0.013	0.052	0.067	0.074
	Rainfall-runoff to sump, m^3/d	**3,770**	**15,080**	**19,430**	**21,460**
	6-hour event				
	Mm	4.1	34	46	52
	M	0.004	0.034	0.046	0.052
	Rainfall-runoff to sump, m^3/d	**1,189**	**9,860**	**13,340**	**15,080**

7.5.13.3 Attenuation Storage Requirements

It has been shown that the bedrock to be quarried has a low-moderate permeability, so it can be reasonably assumed that during extreme storm events the contribution from groundwater seepages is low relative to the overall contribution from precipitation as runoff. It is therefore necessary to attenuate stormwater generated on site, such that it leaves the site at a rate less than or equal to greenfield runoff rates. This is an important feature of the quarry in that it provides very large attenuation capacity storage, which will provide significant protection from flooding to downgradient receptors. An allowance needs to be made to allow a certain amount of precipitation to leave the site at a controlled rate.

Pre-development greenfield runoff rate is given by:

$$QBAR_{rural} = 0.00108\ (AREA)^{0.89} \times (SAAR)^{1.17} \times (SOIL)^{2.17}$$

where $QBAR_{rural}$ = mean annual flood flow from a rural catchment (m^3/s)

AREA = exposed quarry floor upon completion (km^2) = 200,000 m^2 = 0.2 km^2

SAAR = standard annual average rainfall depth (mm) = 1,096 mm

SOIL = soil index, a composite index determined from soil survey maps that accompany the Flood Studies Update

= 0.3, representing SOIL 2, applicable to permeable soils over rocks

It is recommended that flood risk assessment based on the methodology in Volume 2 of the Greater Dublin Strategic Drainage Strategy (2005) is not applied to an area of less than 50 hectares. It suggests that the runoff from smaller areas is then linearly interpreted. A theoretical catchment area of 0.5 km^2 (50 ha) was used for initial calculations. The Q_{BAR} rate applicable to the theoretical catchment area of 0.5 km^2 is:

$$QBAR_{rural} = 0.00108\ (0.5)^{0.89} \times (1096)^{1.17} \times (0.5)^{2.17}$$

$$QBAR_{rural} = 0.154\ m^3/s\ (154\ l/s)$$

The linear interpolation of Q_{BAR} from a catchment of size 50 ha down to gross site area and net hardstanding is shown in Table 7.30. The limiting discharge rates for the 75 and 100 year return period storm events are presented in Table 7.30 using growth factors of 1.87 and 1.96, respectively, in accordance with relevant TII guidance (TII 2015). An SFE is not applied for attenuation calculations.

Table 7.30 Linear Interpolation of Q_{BAR} for On-Site Hardstanding

Item	Area, ha	Q_{BAR} (m^3/s)	Q_{75} (m^3/s)	Q_{100} (m^3/s)
Unit	1	0.0031	0.006	0.006
50 ha as calculated	50	0.154	0.288	0.302
Total catchment area	29	0.089	0.167	0.175
Hardstanding/Site area	20	0.062	0.115	0.121

The applicant does not intend to vary the discharge rate in response to the return period greenfield runoff rate. The discharge rate will instead be fixed. The maximum potential pumping rate from the sump to the ponds will be 61 m^3/h (1453 m^3/d; 17 l/s), i.e., less than the Q_{BAR} (62 l/s) and pre-development greenfield runoff rates during extreme rainfall events for the excavation area (121 l/s). This confirms that quarry discharge rates do not increase flood risk to downgradient receptors.

In its most restrictive approach, attenuation storage is calculated when outflow is limited to Q_{BAR}. The sump must be capable of storing the balance of the stormwater during intense rainfall events.

Table 7.31 presents the return period rainfall depths for a range of durations, as provided by OPW FSU online portal. Design rainfall rates were obtained from the OPW FSU facility. A 20 % increase in design rainfall depths was adopted to account for climate change.

In line with standard practice, discharge surface water should be limited to pre-quarrying discharge rate in order to mitigate against downstream flooding. The attenuation storage requirements when the outflow is restricted to Q_{BAR}, i.e., 62 l/s, are shown in Table 7.31.

Table 7.31 Design Rainfall Rates and Attenuation Storage using Outflow of 62 l/s

Duration, D, hrs	R, mm	R x 1.2, mm	I, m³	O, m³	I – O, m³
0.25	22.1	26.5	5,304	56	5,248
0.5	26.6	31.9	6,384	112	6,272
1	32.1	38.5	7,704	223	7,481
2	38.6	46.3	9,264	446	8,818
4	46.6	55.9	11,184	893	10,291
6	51.9	62.3	12,456	1,339	11,117
12	62.6	75.1	15,024	2,678	12,346
18	69.8	83.8	16,752	4,017	**12,734**
24	74.1	88.9	17,784	5,357	12,427
48	87.3	104.8	20,952	10,713	10,238
72	98.6	118.32	23,664	16,070	7,594
96	108.7	130.44	26,088	21,427	4,661
144	118.1	141.72	28,344	26,784	1,560

Table 7.31 shows that the stormwater generated during a 1 in 100-year event of 18 hours duration is I = 16,752 m³. Restricting the outflow to greenfield runoff rate, Q_{BAR}, results in a permissible outflow of O = 4,017 m³. The balance, i.e., (I-O) = 12,734 m³, must be withheld via attenuation, and released at greenfield runoff rate or less (62 l/s, equivalent to an instantaneous rate of 5,357 m³/d).

Limiting the discharge rate to a maximum of 1,453 m³/d (17 l/s) increases the extreme rainfall event storage requirement to 15,650 m³ over the same 18-hour duration. As quarrying progresses a sump with a minimum available volume of 15,650 m³ should be maintained, this could take the form of 75 m by 75 m and an unsaturated depth of 3 m, or equivalent.

7.5.13.4 Settlement Pond Design

Waters will be pumped from the sump to a settlement pond system. The existing settlement ponds have been recommissioned and are now ready to remove particulate matter from waters prior to discharge from site (Refer to Plate 7.3). Designs for the site are based on the recommendations in 'Environmental Management in the Extractive Industry' (EPA 2006) and '*CIRIA Report C532: Control of Water Pollution from Construction Sites and Quarries'* (CIRIA 2001). The formulae below will be used to determine the optimal dimensions of the settlement ponds such that any discharged quarry water is free of suspended solids above a threshold size.

Inflow to the settlement pond system will be pumped from the quarry sump. The potential inflow to the settlement pond is assumed to be 8.8 l/s (equivalent to an instantaneous rate of 762 m^3/d) but as a conservative measure ponds should be capable of treating the maximum potential calculated future discharge volume of 1,453 m^3/d.

The overflow rate through the settlement pond should be equal to the settling velocity of the smallest particle the pond is designed to remove. The pond is being designed to remove 0.015 mm particles of bedrock-derived sediment. This is the particle size for silt which is significantly smaller than the size of rock fragments.

7.5.13.5 Calculation of Settling Velocity for Particles (Stokes' Law)

The following equation is used to calculate the settlement velocity of particles:

$$V_s = g \cdot (\rho_s - \rho_w)\, d^2 / 18\mu_w$$

Where:

g = Acceleration due to gravity is 9.81 m/s^2

ρ_s = density of the bedrock particle (sandstone/mudstone) = 2.65 g/cm^3 or 2.65 x 10^3 kg/m^3

ρ_w = density of fluid = 1.00 g/cm^3 or 1 x 10^3 kg/m^3

μ_w = dynamic viscosity of water = 1.002 x 10^{-3} kg/ms @ 20˚C (or 1.519 x 10^{-3} @ 5˚C and 0.797 x 10^{-3} @ 30˚C)

d = particle diameter = 0.000015 m

The temperature of the fluid, in this case water, is dependent on the ambient temperature. In the following calculations, 5°C was used as a conservative temperature. A conservative particle density was taken as 2.65 g/cm^3.

Using Stokes' Law, the settling velocity of particles of 0.015 mm, assumed spherical, in water was calculated for the above-mentioned water temperature and particle density:

$$V_s = \frac{9.81 m/s^2}{18 \times 1.519 \times 10^{-3}} \times (2.65 \times 10^3 - 1.00 \times 10^3) \times (1.5 \times 10^{-5})^2$$

$$= 1.33 \times 10^{-4} \text{ m/s}$$

<u>Pond Surface Area</u>

Minimum pond area is given by:

$$A = Q / V_s$$

Where:

A = pond surface area, m^2

Q = inflow = 762 m^3/d = 0.0088 m^3/s

V_s = settling velocity of the selected particle size = 0.000133 m/s

$$A = 0.0088\ m^3/s \ /\ 0.000133\ m/s$$

$$A = 66\ m^2$$

Retention Time

Minimum Depth of the pond, D, is given by:

$$D = R \times V_s$$

Where R = retention time, s

Using a rule of thumb that 2 hours is an adequate retention time, the depth of the pond is:

$$D = 7{,}200\ s \times 0.000133\ m/s$$

$$\text{Minimum } D = 0.96\ m$$

Pond Dimensions

Informed by the above equations, the required minimum settlement pond dimensions are:

Length = 10 m

Width = 7 m

Depth = 1.0 m

As outlined above the existing ponds in the south-western corner have confirmed dimensions, as follows:

- Pond Tank No. A = 62 m x 12 m x 1.0 m = 744 m^3 (surface area = 744 m^2)
- Pond Tank No. B = 72 m x 12 m x 1.0 m = 864 m^3 (surface area = 864 m^2)

As previously stated, upon adequate retention time, clarified water will leave the south-western corner's settlement tank system by a high-level overflow and travel by gravity flow via a constructed channel to two final concrete structured settlement ponds located in the north-western corner, these being referred to as:

- Pond Tank No. 2 = 541 m^3
- Pond Tank No. 1 = 541 m^3

All these existing ponds are constructed from concrete and are impermeable (Plate 7.3).

Overflow Rate

Surface overflow rate is given by:

$$V_o = Q / A$$

$$V_o = 0.0088\ m^3/s \ /\ 1{,}608\ m^2$$

$$V_o = 0.0000055 \text{ m/s}$$

At this overflow rate, particles smaller than 0.000015 m diameter with a settling velocity of / 0.000133 m/s will settle out. This meets the requirements for appropriate management.

Actual Residence Time

Residence time is given by:

$$T_r = V / Q$$

Where:

V = pond volume = 1,608 m^3

$$T_r = 1{,}608 / 0.0088 \text{ m}^3\text{/s}$$

$$= 182{,}727 \text{ s}$$

$$= 51 \text{ hours}$$

The above exercise was repeated for the potential maximum outflow rate, 1,453 m^3/d (0.0168 m^3/s). The existing ponds satisfy the criteria to settle out bedrock particles, producing a surface overland flow rate of 1 x 10^{-5} m/s and a residence time of 27 hours.

The existing settlement pond systems are therefore deemed to be adequate. Additional clarification will be provided in the final ponds prior to discharge.

7.5.13.6 Discharge Route

Quarry water currently leaves the north-western half of the quarry by gravity *via* an open ditch that extends northwest from the final clarification pond through the roadside embankment. This ditch has become silted up over time, such that waters now flow along a very narrow channel on the southern side of the R430 before entering a gully. This gully is located 120 m northwest of the final pond outfall. In the course of pre-planning consultation with Laois County Council, they requested that adequate measures are enacted so as to ensure that stormwater or discharge leaving the quarry does not contribute to road runoff in the area. This can easily be completed following clear out of Laois County Council's under road culvert in that area. The current connection between the final outfall pond and the aforementioned gully chamber shall be upgraded by way of a maintained open channel and subsurface pipe connection to the gully manhole. The diameter of the connection pipe shall not be greater than the R430 culvert, the diameter of which shall be ascertained by CCTV survey.

7.5.14 HYDROCHEMICAL CAPACITY OF RECEIVING WATERS

Water sampling and flow monitoring results are now employed to assess the ability of both the eastern and western routes to safely assimilate the predicted discharge and thereby ensure compliance with the Surface Water Regulations 2009 (as amended 2015, 2019) and the objectives of the Water Framework Directive.

Mass balance and assimilative capacity calculations have been determined on order to assess whether the receiving waters are capable of safely assimilating the discharge. Taking a conservative approach, surface water assimilation capacity assessment is carried out by employing:

1. The 95%ile flow conditions for the receiving water.
2. The Maximum Scenario discharge from quarry = 1,453 m^3/d.

Given that the hydraulic capacity simulations suggest that the western route is better, it is the Owveg River that will now be considered in terms of its hydrochemical ability to receive the discharge. The Owveg River is designated by the EPA as being of Good status under the Water Framework Directive.

For the purposes of informing appropriate discharge licence limits assimilation capacity calculations are presented for the Surface Water, Salmonid and Pearl Mussel Regulation parameters of significance, as follows:

- BOD;
- Orthophosphate;
- Ammoniacal nitrogen;
- Suspended solids; and
- Nitrates.

While there is no suspended solids EQS specified in the Surface Water Regulations, the parameter simulation is included here because of the Salmonid and SAC Conservation Objectives for the Pearl Mussel habitat in the downgradient River Nore, which receives the Owveg River at a river length distance of 20 km, approximately. While the Salmonid Regulations suggest a limit of 25 mg/l for suspended solids, the Pearl Mussel Regulations require no change in Suspended Solids concentrations. The headwaters of Pearl Mussel catchments are important. However, there are substantial ponds, in excess of the site's requirements for the management of Suspended Solids concentrations in the discharge.

There is no guidance value for nitrates in the Surface Water Regulations (2009) and there is no drinking water abstraction downstream of the discharge point. For the purposes of mixing equations an EQS of 11.3 mg/l as NO_3-N is assigned for nitrates.

The current gravity flow natural stormwater outfall from the site forms the headwaters of the Garrintaggart Stream. Therefore, there is no upgradient surface water to perform mixing equations. Hence, any points on the Garrintaggart Stream already contain the existing quarry outfall in terms of flow and quality. As the primary receptor in terms of quality is deemed to be the Owveg River, contributing to a downgradient river system supporting Freshwater Pearl Mussels, the outfall of the Garrintaggart Stream to the Owveg River is determined to be the key mixing point for assimilation capacity simulation calculations.

The calculations adopt the most conservative scenario, whereby low flow conditions in the local river network coincide with maximum predicted quarry discharge. The scenario also assumes the Garrintaggart Stream is approaching no flow conditions during the simulations for worst case scenario evaluation.

7.5.14.1 Assimilation Capacity Simulations

The Department of the Environment (DoEHLG 2011) mixing equation is, as follows:

$$C_{sw} = [(C_{qd} \times Q_{qd}) + (C_{swu} \times Q_{sw})] / Q_{sw} + Q_{qd})$$

Whereby C_{sw} = predicted resultant downstream concentration in Owveg Stream

C_{qd} = concentration in discharge from quarry

Q_{qd} = Maximum Scenario discharge from quarry = 1,453 m^3/d = 0.0168 m^3/s =16.8 l/s

C_{swu} = background concentration in Owveg Stream upgradient of the mixing point

Q_{sw} = 95%ile flow at the simulation mixing point in Owveg River = 0.010 m^3/s = 10 l/s

The average 'outfall' concentrations for the quarry (Table 7.27) and the average surface water concentrations for the Owveg River (Table 7.28) were employed to evaluate the actual impact on the hydrochemical status of the receiving waters.

For the purposes of simplicity in the following text, the term 'Surface Water Regulations' in the discussion text is taken to refer to the Surface Water Regulations (2009 as amended 2012, 2015 and 2019).

7.5.14.1.1 BOD

$$C_{sw} = [(2 \times 16.8) + (1.33 \times 10)] / (26.8)$$

$$= 1.75 \text{ mg/l}$$

The quarry outfall's measured concentration for BOD was 2 mg/l, on average. The predicted BOD concentration in the Owveg River downstream of the site is 1.75 mg/l which complies with the Surface Water Regulation's EQS of 2.2 mg/l, applicable to a river water body of High Status under 95%ile conditions. As the BOD level in all stream samples were below the laboratory limit of detection, it is likely that actual post-mixing concentrations of BOD will be significantly less than that predicted.

7.5.14.1.2 Orthophosphate

The average orthophosphate concentration in quarry discharge was always below the 0.01 mg/l laboratory limit of detection. The mean concentration of orthophosphate in the receiving stream was 0.018 mg/l.

$$C_{sw} = [(0.01 \times 16.8) + (0.018 \times 10)] / (26.8)$$

$$= 0.013 \text{ mg/l } PO_4 \text{ as P}$$

The surface water mixing equations show that predicted orthophosphate concentration in the Owveg River downstream of the site is 0.013 mg/l, which complies with the Surface Water Regulation's EQS of 0.045 mg/l.

7.5.14.1.3 Ammoniacal Nitrogen

The average ammonia concentration observed in the quarry discharge was 0.013 mg/l. Average background stream concentrations were 0.028 mg/l.

$$C_{sw} = [(0.013 \times 16.8) + (0.028 \times 10)] / (26.8)$$

$$= 0.019 \text{ mg/l } NH_3 \text{ as N}$$

The surface water mixing equations show that predicted downstream concentration of ammonia is 0.019 mg/l as N. This represents an improvement on background quality and complies with the Surface Water Regulation's High Status EQS of 0.09 mg/l ammonia as N for 95%ile conditions.

7.5.14.1.4 Suspended Solids

$$C_{sw} = [(10 \times 16.8) + (10 \times 10)] / (26.8)$$

$$= 10 \text{ mg/l suspended solids}$$

The quarry's outfall ponds returned concentrations persistently below the Limit of Detection of the laboratory analyser, which is 10 mg/l SS. Therefore, the SS = <10 mg/l. However, the simulation will employ 10 mg/l SS as the worst-case simulation scenario. The surface water assimilation simulation equation suggests that the predicted downstream concentration of suspended solids will not change. All six samples analysed by Element Laboratories were below the laboratory limit of detection which was 10 mg/l. It is therefore likely that actual post-mixing concentrations of suspended solids will be less than 10 mg/l. The purpose of the assimilation evaluation for SS, given that there is no EQS for SS in the Surface Water Regulations, is for fish life and other ecological reasons. The Salmonid Regulations require a 25 mg/l SS quality objective and this is met. The Pearl Mussel Regulations require no change and this is also met.

Another example scenario simulation for SS could consider the <10 mg/l SS laboratory results for the discharge and receiving as possibly equivalent to 5 mg/l SS. Simulation adopting <10 mg/l SS = 5 mg/l SS suggests a resultant concentration as follows:

$$C_{sw} = [(5 \times 16.8) + (5 \times 10)] / (26.8)$$

$$= 5 \text{ mg/l suspended solids}$$

The overall take home point is that there will be no change in SS concentration.

7.5.14.1.5 Nitrates

$$C_{sw} = [(0.85 \times 16.8) + (0.15 \times 10)] / (26.8)$$

$$= 0.6 \text{ mg/l as } NO_3$$

The concentration of Nitrate in the discharge from the quarry averaged at 0.85 mg/l as NO_3. The concentration in the Owveg River averaged at 0.15 mg/l as NO_3. There is no EQS for nitrates in the Surface Water Regulations. The purpose for the assimilation capacity simulation for Nitrates is to demonstrate that the discharge of waters from the quarry does not cause an increase in the receiving water's nitrate nutrient concentration that could change its status. The resultant concentration in the receiving water is <1 mg/l NO_3. This is a very low NO_3 concentration.

7.5.14.1.6 Electrical Conductivity

$$C_{sw} = [(208 \times 16.8) + (212 \times 10)] / (26.8)$$

$$= 209 \text{ uS/cm Electrical Conductivity}$$

The Electrical Conductivity of the quarry's discharge averaged 208 uS/cm EC. The Owveg River's EC averaged 212 uS/cm. The resultant EC simulation result is 209 uS/cm. This change of 3 uS/cm is not significant when one considers natural variations observed in response to weather.

7.5.14.1.7 pH

$$C_{sw} = [(7.7\times 16.8) + (6.6 \times 10)] / (26.8)$$

$$= 7.3 \text{ pH}$$

The Owveg river at the point of measurement has a slightly acidic pH. The quarry's discharge normalises the river's pH and simulations suggest a change from 6.6 pH to 7.3 pH. The Surface Water Regulations suggest a range of 4.5 to 9 as the requisite for soft water, which this is. The resultant pH complies with the requirements of the Surface Water Regulations. The observed change, as a result of the discharge, is unlikely to affect downstream habitats and species because of the effect of the entire catchment. We are in the headwaters here. There is a large amount of assimilation capability downstream.

In overall conclusion, the mass balance calculations shows that all predicted concentrations of all parameters downstream of the discharge point comply with the High Status EQS's of the Surface Water Regulations (2009, as amended 2015, 2019) for those parameters specified in the Regulations. For other parameters, such as SS, Nitrates and Conductivity, the simulations suggest no change in the concentrations in the receiving waters as a result of the quarry's discharge.

7.5.14.2 Surface Water Assimilative Capacity & Headroom

The surface water assimilative capacity calculation is used to determine the ability of the receiving waters to assimilate discharge. It is proposed to pump the quarry's discharge to the west. The Owveg River and River Nore SAC are considered to be the primary receptors requiring risk assessment.

Given that the Owveg is classified as Good Status, this simulation considers the maximum permissible concentration for each parameter as equal to the Surface Water

Regulations (2009, as amended 2015, 2019) EQS's for Good Status for the 95%ile flow characteristic. Results of the assimilative capacity calculations are presented in Table 7.33.

Assimilative capacity (AC) = (C_{max} - C_{back}) x F_{95} x 86.4 kg/day

Where

C_{max} = maximum permissible concentration

= Surface Waters Regulations (2009) applicable to 95%ile flow conditions

C_{back} = mean upstream surface water concentration

F_{95} = 95%ile flow in Owveg River = 0.010 m^3/s

The percentage of the assimilative capacity or 'headroom' that will be used by the discharge can then be calculated using the effluent load information.

Percentage headroom utilised = (C_{new} - C_{back}) x 100 / Headroom

where C_{new} = predicted downstream concentration

C_{back} = mean upstream surface water concentration

Headroom = EQS - C_{back}

The results for Assimilation Capacity and Headroom are presented as 7.32. The simulations demonstrate that the quarry discharge will have the effect of reducing the downstream, predicted concentrations of ammonia and orthophosphate in the stream relative to the upstream concentrations. The results presented in Table 7.32 show there is capacity for an additional 0.11 and 0.057 mg/l of ammonia and orthophosphate, respectively. Results again confirm no change in Suspended Solids concentrations.

The upgradient concentration of BOD shows an available headroom of 1.3 mg/l. The current outfall from the quarry utilises 33 % of this headroom, which is marginally above the guideline allocation of 25 %. The predicted post-mixing BOD concentration is significantly less than the threshold value set out in the Surface Water Regulations (2009, as amended 2015, 2019). BOD in all stream samples was below LOD, whilst 50 % of discharge samples were below LOD.

With the exception of BOD, the mixing results show that when the maximum value from quarry discharge samples is applied the 25 % headroom is not exceeded. The ammonia, orthophosphate and suspended solids concentrations in the quarry outfall are such that they create additional headroom in the receiving surface watercourse. Therefore, not only are the Surface Water Regulations adhered to, the quarry shall assist the Objectives of the Water Framework Directive to improve water quality.

It should also be noted that it is most unlikely that the quarry will be discharging when the stream is under 95%ile flow conditions as both the river flows and quarry discharge share a direct correlation with precipitation rates in the preceding period.

Table 7.32 Summary of Stream Impact Assessment Calculations for both Mean & Max Discharge Concentrations

Parameter	Unit	BOD	BOD	Ammonia as N	Ammonia as N	Ortho P	Ortho P	SS	SS	Nitrates as N	Nitrates as N
Mass Balance											
Surface Water Regulation EQS @ 95%ile Flow	**mg/l**	**< 2.6**	**< 2.6**	**< 0.14**	**< 0.14**	**< 0.075**	**< 0.075**	**25**	**25**	**11.3**	**11.3**
Receiving waters, upstream	**mg/l**	**<1.33**	**<1.33**	**0.028**	**0.028**	**0.018**	**0.018**	**<10**	**<10**	**0.37**	**0.37**
Quarry Discharge	mg/l	<2 (mean)	<3 (max)	0.013 (mean)	0.016 (max)	<0.01 (mean)	<0.01 (max)	<10 (mean)	<10 (max)	0.85 (mean)	0.54 (max)
RESULTANT Receiving waters, downstream	**mg/l**	**1.75**	**2.38**	**0.019**	**0.020**	**<0.013**	**<0.013**	**<10**	**<10**	**0.6**	**0.78**
Assimilative Capacity											
Assimilative Capacity	kg/d	1.09	1.09	0.097	0.097	0.049	0.049	12.96	12.96	9.45	9.45
Quarry Discharge Load	kg/d	2.90	4.35	0.02	0.02	0.01	0.01	11.61	14.52	0.54	0.78
Headroom											
Headroom	mg/l	1.27	1.27	0.11	0.11	0.06	0.06	15	15	10.93	10.93
25 % allowed increase	mg/l	0.31	0.31	0.028	0.028	0.014	0.014	3.75	3.75	2.73	2.73
Actual increase	Mg/l	0.42	1.04	-0.009	-0.007	-0.005	-0.005	-1.25	0	0.002	0.107
% Headroom utilised	**%**	**33**	**82**	**-7.94**	**-6.50**	**-9.17**	**-9.17**	**-8.36**	**0**	**0.02**	**0.98**

7.5.14.3 Proposed Discharge Licence Limits

With reference to the calculations and resultant concentration simulation results presented in Sections 7.5.14.1 and 7.5.14.2, above, the sustainable Emission Limit Values for a Future Discharge Licence for the site are presented as Table 7.33.

Table 7.33 Proposed Discharge Licence Limits

Discharge Volume ELV	1453 m3/d									
Hydrochemical Parameter	Good Status EQS (mg/l)	Stream u/s (mg/l)	Quarry Discharge ELV (mg/l)	RESULTANT Concentration Stream d/s (mg/l)	AC	Quarry Discharge	Headroom	25% allowed increase	Actual increase to ensure only 25% Headroom	**% headroom utilised**
BOD	2.6	1.333	1.84	1.651	1.094	2.67	1.267	0.32	0.32	**25**
Ammonia	0.14	0.028	0.070	0.054	0.097	0.10	0.112	0.03	0.03	**24**
Ortho-P	0.075	0.018	0.041	0.033	0.049	0.06	0.057	0.01	0.01	**25**
SS	25	10	16	13.761	12.96	23.22	15.000	3.75	3.76	**25**
Nitrates as N	11.3	0.369	4.8	3.147	9.445	6.97	10.931	2.73	2.78	**25**
EC	not specified	212	250	236	parameter not specified					
pH	4.5 to 9	6.6	7.5	7.2	2.045	10.89	2.367	0.59	0.54	**23**

The mass balance and headroom calculations demonstrated that all predicted concentrations of all parameters downstream of the discharge point satisfy the Surface Water Regulations (2009, as amended 2012, 2015 and 2019). The information provided shows that there is sufficient basis for Lagan (Breedon Group), applying for permission to continue operations at the bedrock quarry at Spink, Co. Laois, to apply to Laois County Council for a licence to discharge to surface water as required under Section 4 of the Local Government (Water Pollution) Act, 1977. Ms. Ann Marie Callan of the Environment Section of Laois County Council advised that the Local Authority takes the position that a Discharge Licence cannot be issued for a site until planning is decided.

It is the intention of the applicant to present the Environment Section of Laois County Council with a 'Draft for Consultation' Discharge Assessment report when the Planning Application for the site is lodged. In this way, Environment can be informed in advance of Planning's enquiries with respect to the site. In this way, Planning Department has the benefit of the Environment Section's consideration of the feasibility and justification of the grant of a Section 4 Discharge Licence to discharge waters arising at the site to the local Owveg River via the Garrintaggart Stream.

If the local authority is in agreement that discharge of waters from this site is acceptable in principle, then the applicant can undertake any necessary additional works.

As part of proposed long-term compliance monitoring, it is now standard practice for the applicant to install an in-line flowmeter fitted with a datalogger to constantly measure discharge rates in real-time. A telemetry unit will allow the datalogger information to be observed remotely by the operator and their hydrogeologist. This will provide accurate data linked to daily flows and the seasonal pattern of flows.

7.5.15 PROCESS WATER

Relatively small amounts of water will be used for the purpose of process water, as follows:

- dust suppression, in the order of up to 2 m^3/d;
- mobile plant for washing of chips for surface road dressing. It is envisaged that the water requirement will be less than 2 m^3/d. This will be self-contained unit with recycling of process water;
- the existing wheelwash will be utilised. It is envisaged that top-up water demand will be less than 1 m^3/d.

Water for dust suppression, washing of chips and wheelwash can be sourced from the final outfall pond. Given the nature of site topography any excess water from the above processes shall drain by gravity back to the sump or be diverted to the inflow pipe of the settlement ponds.

7.5.15.1 Concrete Batching Plant

A concrete batching plant is proposed with water demand estimated to be 10–20 m^3/d. The plant is likely to produce up to 7 truckloads of concrete per day, with an estimated 1 m^3/d water exported per truck load. An additional 1–2 m^3/d will be used for washdown purposes. The batching plant will operate for 5.5 days per week. Washdown water from the batching plant shall be recycled through a dedicated closed water recycling system adjoining the batching plant. The site's Production Wells shall be retained for monitoring purposes and water supply.

7.5.15.2 Hydrocarbons

7.5.15.2.1 Fuel Storage

There will be no storage of fuel on site. Servicing of vehicles will take place off site. Lubricants and any other hydrocarbons will be stored on spill pallets.

All hydrocarbons will be handled and stored in accordance with the Environmental Management Guidelines - Environmental Management in the Extractive Industry (Non-Scheduled Minerals) (EPA 2006).

7.5.15.2.2 Refuelling

Refuelling of mobile plant will be carried out in the main by a licenced third party.

There exists an impermeable hardstanding pad in the former compound area. The hardstanding pad drains to a perimeter ACO-type drain. All hardstanding runoff passes to a hydrocarbon interceptor, which also has silt storage capacity. This interceptor will be cleaned out on a regular basis by a licenced third party contractor. The hardstanding is therefore appropriate for refuelling of mobile plant (e.g., loading shovel), haulage vehicle(s) and emergency repairs, where necessary.

Spill kits will be stored on site and site operatives will be trained in their appropriate usage.

A final protection measure will be provided by means of a hydrocarbon Interceptor on the inlet of the final element of the water management system, which is the 2-pond system in the north-western area of the site. Refer to Plate 7.3.

7.5.15.3 Welfare Facilities

7.5.15.3.1 Domestic Effluent

A septic tank and Bord na Mona Puraflo effluent treatment system were approved under P.A. Ref. 10/383. It is assumed that this system remains in-situ, but its condition is unconfirmed. This system is located to the rear of the former office/canteen and washroom area, close to the weighbridge.

Hydro-G has advised Lagan that no area with suitable subsoil currently exists at the site. No discharge can occur in the eastern portion of the site near the gate because of the spring rising and headwaters of the Clogh 010.

In cases where the site conditions are not suitable for percolation areas quarry operators use holding tanks which are maintained and routinely cleaned out by a licenced waste contractor. This solution can be implemented at this site in order to ensure no surface water or groundwater contamination.

7.5.15.3.2 Potable Water

With respect to an on-site supply, the site has three new production wells that can supply the site with potable water. Water quality results suggest that groundwater is of suitable quality for use at the site. Should successful planning be obtained, it is proposed to convert PW3 to a Production Well. Headworks shall be sealed with a concrete pad. An appropriate water treatment facility, including ultraviolet filter, shall be fitted to ensure water complies with the requirements of the Drinking Water Regulations (2014) prior to supply to staff at the site.

7.6 ASSESSMENT OF IMPACTS

7.6.1 CRITERIA FOR DETERMINATION OF IMPACTS

The significance of potential impacts on geological, hydrogeological and hydrological sensitive receptors was estimated by implementing an assessment as per the Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes (NRA 2008) and the Guidelines for the Preparation of Soils, Geology & Hydrogeology Chapters of Environmental Impact Statements (IGI 2013). These documents use groundwater and geological type attributes and measures to determine the magnitude of the impact on an attribute.

Table 7.34 illustrates the criteria for determining the importance of the geological and hydrogeological sensitive receptors at the site. Table 7.35 demonstrates the criteria for estimating the magnitude of the impact on an attribute. Table 7.36 presents the resulting estimation of significant potential impacts.

Table 7.34 Estimation of Importance of Sensitive Attributes

Importance	Criterion	Typical Examples
Extremely High	Attribute has a high quality or value on an international scale.	Groundwater supports river, wetland or surface water body ecosystem protected by EU legislation, e.g., SAC or SPA status.
Very High	Attribute has a high quality and rarity on regional or national scale.	River, wetland or surface water or groundwater body ecosystem protected by EU legislation. Aquifer providing a regionally important drinking water resource or supporting site protected under wildlife legislation.
High	Attribute has a high quality or value on local scale.	Aquifer providing locally important resource or supporting peat ecosystem – undesignated.
Medium	Attribute has a medium quality or value on local scale.	Aquifer providing water for agricultural or industrial use with limited connection to surface water. Eroding bog.
Low	Attribute has a low quality or value on local scale.	Non-aquifer. Cutover blanket bog.

Table 7.35 Estimation of the Magnitude of a Potential Impact of an Attribute

Magnitude	Criterion	Typical Example
Large Adverse	Results in loss of attribute and/or quality and integrity of attribute.	Loss of aquifer water supply by dewatering or major contamination event. Potential high risk of pollution to groundwater from routine run-off. Loss or change to non-SAC status, etc., SAC Annex 1 habitat loss.
Moderate Adverse	Results in impact on integrity of attribute, or loss of part of attribute.	Partial loss or change to aquifer characteristics. Potential medium risk of pollution to groundwater from routine run-off. Loss to a potential SAC Annex 1 habitat.
Small Adverse	Results in minor impact on integrity of attribute or loss of small part of attribute.	Potential low risk of pollution to groundwater from routine run-off. Risk of pollution from accidental spillages. Localised impact.
Negligible	Results in effect on attribute, but of insufficient magnitude to affect the use or integrity.	No measurable impact upon aquifer and no perceivable risk of pollution from accidental spillages. Slight impact. etc.

Table 7.36 Estimation of the Significance of Potential Impacts

Importance of Attribute	Magnitude of Potential Impact			
	Negligible	Small Adverse	Moderate Adverse	Large Adverse
Extremely High	Imperceptible	Significant	Profound	Profound
Very high	Imperceptible	Significant/ Moderate	Profound/Significant	Profound
High	Imperceptible	Moderate/ Slight	Significant/Moderate	Profound/ Significant
Medium	Imperceptible	Slight	Moderate	Significant
Low	Imperceptible	Imperceptible	Slight	Slight/Moderate

7.6.2 DESCRIPTION OF THE LIKELY IMPACTS

The procedure for determination of potential impacts on the receiving hydrogeological environment was to identify potential receptors within the site boundary and surrounding environment and use the information gathered during the field work and desk study to assess the degree to which these receptors will be impacted upon.

Half the application site lies within the existing quarry void, and when the full site is considered as a cumulative site, it is moderate in size. The site is therefore considered to be an attribute of high importance. In line with best practice, the individual impacts will be considered with respect to the application site, plus the cumulative impacts with respect to the application site and surrounding area.

A spring rises on the site, and this is a potential receptor.

Surface waters are potential receptors. While the EPA label the Clogh 010 as a river in the EPA surface water monitoring network, it is really groundwater emerging as a stream at ground level. The EPA Q Rating is 4 for the monitoring stations on the Clogh River and the Owveg 010, which are their closest stations to the site. The downstream River Nore SAC is a potential receptor.

Groundwater is a receptor.

The Planning and Development Regulations 2001-2021 require Impact Assessment under the headings of Do Nothing, Transboundary, Direct, Indirect, Cumulative, Residual & Worst Case. Impacts are also assessed in relation to construction, operational and decommissioning stages.

7.6.3 'DO NOTHING' IMPACTS

If the development did not proceed, the ground of the proposed development would remain a quarry floor within the existing quarry void excavated in the north-western half of the site and scrubland in the elevated south-eastern half of the site, which is the current site status. Thus, it would be expected that the application site would not undergo any changes in a 'do-nothing' scenario. Hydro-G and Envirologic have assessed that the site sits on the edge of the Castlecomer Plateau and that the interception and discharge from the site will not significantly change the groundwater dynamics component of the site. It is therefore assessed that to 'go deeper' is unlikely to change the 'do-nothing' scenario.

7.6.4 DIRECT IMPACTS

Hydro-G and Envirologic's assessment of potential impacts from the proposed development are summarised in Table 7.37, using the headings discussed under the criteria for determination of impacts. The main anticipated impact associated with the proposed quarry extension, in relation to Hydrogeology, relates to the potential contamination of groundwater from quarrying activities and the subsequent risk posed to surface water receptors. The proposed enhancement of the surface water management system is described earlier in this work.

Table 7.37 Potential Impacts

Activity	Attribute	Character of Potential Impact	Importance of Attribute	Magnitude of Potential Impact	Significance of Potential Impact
1. Fuel storage/usage on site	Groundwater Subsoils Local Rivers Clogh and Owveg (Nore)	. There will be no bulk fuels stored at the application site. Plant and equipment that operate at the quarry will be refuelled by competent fuel companies that dispense fuel directly into plant and equipment. Procedures will be in place for dispensing fuel with drip trays used during refuelling. Accidental spillage of contaminants during site operations may cause short to long term, moderate to significant impacts to soils, groundwater and the surface water environment, if not stored and used in an environmentally safe manner. Leakages from the hydrocarbon interceptor could occur if the interceptor is not correctly maintained.	Extremely High	Moderate Adverse	Profound
2. Excavation works and vehicle movement on site	Groundwater Bedrock Local Rivers Clogh and Owveg (Nore)	Excavation works will result in the same vulnerability of groundwater at the site as is now experienced by the same area of open bedrock. Procedures are in place for dealing with accidental spillages.	Extremely High	Moderate Adverse	Profound
3. Surface water Runoff & Discharge from the site	Groundwater Local Rivers Clogh and Owveg (Nore)	Quarry floor and internal road surface runoff or drainage systems have potential, if not correctly designed, to result in contamination of surface waters and groundwater. Accidental spillage could contaminate the aquifer by direct percolation or via the superficial water network. Changing the nature of surface water and groundwater dynamics in the catchment could affect downstream ecosystems. Downstream ecological receptors such as the Pearl Mussels, fish life and habitats could be affected.	Extremely High	Moderate Adverse	Profound
4. Increased dewatering	Castlecomer GWB	Lowering the quarry floor could lead to an increase of groundwater component in the sump, which will need to be dewatered. This will lead to an increase of water being discharged to the discharge zone. Lowering the quarry floor and an increased groundwater component associated with the void could lead to a resultant lowering of the water table outside the quarry, which might affect domestic wells.	Extremely High	Large Adverse	Profound
Blasting	Water Environment	Use of explosives at the site could add Nitrogen to the water environment.	Extremely High	Moderate Adverse	Profound

Assimilation capacity simulations for a potential **maximum** daily discharge volume of 1,453 m^3/d and ELVs are proposed for use in a discharge licence. The ELVs proposed are justifiable in the context of ensuring compliance with the Surface Water and Groundwater Regulations and are also justifiable in the context of water quality monitoring results at the quarry.

7.6.4.1 Direct Impact to Groundwater Levels in Third Party Wells

As was demonstrated previously in this work, there are no active groundwater receptors that may be at risk of impact from groundwater drawdown within the 346 m calculated radius of influence from the centre of the sump. The radius of influence comes close to the borehole at Property No. 2. Given the information obtained during the well search, the borehole at Property No. 2 must be abstracting groundwater from a deeper bedrock formation, because it was drilled deep and the pump is set deep. Information supplied to the project is that the borehole is drilled to 100–120 m, approximately below surface, equivalent to 120–140 m OD, and is not deemed to be at risk of impact due to the proposed dewatering elevation of 190 m OD, which is at least 40 m above the borehole water strike at Property 2. The fact that groundwater flow has been shown to be controlled by the boundary contact layers between the differing formations, indicates that the potential for impact is very low for this difference in elevation and the dipping slopes on the geological bedding planes found at the site.

7.6.4.2 Impacts of Blasting at the site

Mass balance calculations are presented to demonstrate the potential for the effects of blasting to impart nitrogen residues in the discharge waters, which has the potential to impact groundwater quality. The risk to groundwater and surface water is assessed by quantifying the resultant concentrations for the potential residual nitrogen compounds, Nitrate (NO_3), Ammonia (NH4) and Nitrite (NO_2).

Peak activity rates of the extraction activities, blasting frequency and the type of explosives proposed were supplied to Hydro-G. Lagan operate a network of sites throughout the country and their handling and explosives use and meets industry standards. The explosives used at Lagan sites are the usual Kemex emulsion, which is produced by Irish Industrial Explosives (IEE). The industry range suggests that 0.15 kg/tonne – 0.20 kg/tonne explosives across all quarries.

Kemex is a site mixed bulk emulsion explosives produced from an emulsion matrix. Emulsion matrix is essentially an aqueous solution of ammonium nitrate emulsified in oil. Kemex products may also contain ammonium nitrate prills, fuel oil, aluminium and/or gassing agents. The Technical Data Sheets (TDS's) and Material Safety Data Sheets (MSDS's) for explosives, primers and detonators to be used at the site were employed by Hydro-G in the calculation of potential residues and those data sheets are held on file at Hydro-G and by Lagan.

The literature suggests that small percentages of N compounds can remain as residual coatings on bedrock following blasting. This has the potential to be dissolved when it comes into contact with water, albeit the potential concentrations are low. The most frequently referenced study was published by Environment Canada in 1988 (Ferguson & Leask 1988). This study outlines a procedure for determining the residual N compounds for various mine site types. The stepwise procedure for predicting aqueous concentrations of N species used in the 1988 study is as follows:

1. Calculate the annual leached nitrogen loading (kg/yr) for the entire site based upon annual explosive mass usage and residual N fraction associated with explosive type;
2. Separate the leached nitrogen loading among quarry components (e.g., entering surface water, remaining on extracted rock, etc.);

3. Separate into loadings of N compounds (Nitrate, Nitrite and Ammonia), and;
4. Calculate the flow concentration.

The concentrations of N species in discharge water from the proposed extension at the application site quarry were calculated using this procedure. These data are presented in Table 7.34 below. The highest residual is for nitrate (99 %), and the upper limit of the range is used in all cases to determine the concentration of N species in pumped water. These are very conservative assumptions. The calculation also assumes that 100 % of residual N is dissolved in drainage waters and is subsequently pumped from the quarry by dewatering.

The results of the calculations presented in Table 7.38 clearly show that the residual N compounds would each have concentrations of less than 0.01 mg/l N. Specifically, the resultant concentrations in waters within the quarry, if impacted by explosives within the entire quarry site area, would be 0.0063 mg/l NO_3, 0.0015 mg/l NH_4 and 0.0004 mg/l NO_2.

For the purpose of context, the following is offered:

- The limit for nitrate in waters affected by agriculture is 50 mg/l NO_3 (Nitrate & Good Agricultural Practice Regulations), while it is also 50 mg/l NO_3 for the Freshwater Fish Directive (2006/44/EC). Therefore, the simulated resultant concentration of **0.0034 mg/l NO_3** for the quarry resulting from its use of explosives is massively lower than any regulatory Environmental Quality Objectives;
- The EQS for Ammonia in **High Status** Waters EQS (Surface Water Regulations 2009) is 0.04 mg/l NH_4 and the predicted resultant residual that might occur from blasting is 0.0008 mg/l. Therefore, an environmental impact is not envisaged because the resultant concentration calculated is at least an order of magnitude lower than the High Status EQSs of the Surface Water Regulations (2009);
- The calculated residual nitrite concentration is miniscule at 0.0002 mg/l NO_2;and
- Overall, the residual concentrations meet the requirements of the Threshold Values of the Groundwater Regulations (2010) and the targets set out in both the Freshwater Fish Directive and Salmonid Waters Regulations.

The risk of impact to local water quality arising from the use of explosives at the site is therefore non-existent, based on industry standard method of calculation. These calculations are based on PEAK abstraction rates.

Table 7.38 Concentrations of N Compounds from Explosives in Dewatering Discharge

EXPLOSIVE MASS BALANCE		
20	Total Site Area	ha
200,000	Total Area	m2
3,920,299	Volume of rock to be extracted	m3
3,332,254	Rock Volume accounting for 15% losses	m3
0.2	Explosive Mass Required	kg/m3
666,451	Explosives Mass Required	kg
20	Planned Duration of extraction	years
33,323	Explosives Mass Required per year	kg/yr
NITROGEN MASS BALANCE		
94%	% Explosive mass as Ammonium Nitrate	%
35%	% Ammonium Nitrate as N	%
10,963	Mass of N	kg/yr
0.06	Residual Fraction	
658	Residual N	kg/yr
Total N Species Generated by explosive's residues (areal annual loading rate)*	***32.89***	***Kg/ha/yr***
*facilitates comparison with agricultural inputs [total quarry area used]. Compare to 170 kg N/ha/yr Total Nitrogen loadings permitted in the Good Agricultural Practice Regulations (SI 605 of 2017)		
N COMPOUNDS**		
651	Residual NO_3 *(75-99% of Residual N value)*	**kg/yr**
158	Residual NH_4 *(0.5 - 24% of Residual N value)*	**kg/yr**
39	Residual NO_2 *(0-6% of Residual N value)*	**kg/yr**
****Highest % Residual Adopted as conservative measure**		
WATER BALANCE		
1,453	Envisaged MAX Daily Quarry Discharge (max)	m^3/day
530,345,000	Quarry Discharge	litres/yr
NITROGEN COMPOUND CONCENTRATIONS***		
Residual NO_3	***0.0034***	***mg/l/d***
Residual NH_4	***0.0008***	***mg/l/d***
Residual NO2	***0.0002***	***mg/l/d***
*** Calculation of Residual Concentrations = (kg/yr*10^6 = mg/yr)/(litres/yr)		

7.6.5 INDIRECT IMPACTS

There is a considerable history of quarrying on-site, which began prior to the 1970s, and which has had no identifiable indirect impact on the hydrological or hydrogeological environment of the area. The development will have no indirect impact on the local or regional hydrological or hydrogeological environment of the area.

Hydrological survey for receiving waters capacity suggests that discharge to the west's system can be accommodated with no risk of flooding.

Hydrochemical assimilation capacity simulation for receiving waters capacity suggests that discharge to the west's system can be accommodated and maintain compliance with the Surface Water Objective's Good Status Objectives.

7.6.6 CUMULATIVE IMPACTS

There are no nearby mineral extraction or industrial developments, such that it is unlikely that the current development will lead to significant adverse impacts in combination with other developments—the nearest being the Lagan Clay Products Facility at Swan. Thus, no negative cumulative impacts on the hydrological/hydrogeological environment were identified.

7.6.7 TRANSBOUNDARY IMPACTS

The EIA Directive 2014-52-EU invokes the Espoo Convention on Environmental Impact Assessment in a Transboundary Context, 1991, and applies its definition of transboundary impacts Given the location (c. 135 km from the border with N. Ireland), the nature, size and scale of the proposed development, it is expected that the impacts of the development would not have any significant transboundary effects with respect to water bodies.

7.6.8 RESIDUAL IMPACTS

Residual impacts on the hydrological or hydrogeological environment are not envisaged to result from the proposed quarry extension in the vertical plane and the site's mitigation measures. The bedrock at depth in the proposed development area has little porosity, and this has been demonstrated by field measurement in the course of this work. The sump area will be managed by duty and standby pumps at the site. Residual Impacts are presented for all phases in Table 7.40.

As a result of the proposed mitigation and enhancement measures incorporated in the design, no significant, adverse residual impacts are predicted in terms of the hydrological and hydrogeological environment during the operational phase.

It is considered that following full restoration and closure of the site that there will also be no significant, long-term, adverse impacts in terms of the hydrological and hydrogeological environment. The restored quarry will provide a more manageable environment than is currently the case, but with a change in land-use from the original agricultural use to mineral extraction and ultimately to a future beneficial use as a wildlife amenity.

7.6.9 WORST CASE IMPACTS

It is only if the base of the contact is intercepted that the maximum future dewatering potential of 1,454 m^3/d might occur. For the purposes of evaluating the worst-case scenario, it is that 'end of life' dewatering volume that has been simulated.

Hydrological survey for receiving waters capacity suggests that discharge to the west's system, for the worst-case scenario discharge volume, can be accommodated with no risk of flooding.

Hydrochemical assimilation capacity simulation for receiving waters capacity suggests that discharge to the west's system, for the worst-case scenario discharge volume, can be accommodated and maintain compliance with the Surface Water Objective's Good Status Objectives.

7.7 MITIGATION MEASURES

The predicted impacts presented in Table 7.37 can be resolved under the mitigation measures set out in Table 7.39.

Table 7.39 Mitigation Measures

Construction Activity	Attribute	Character of Impact	Mitigation	Residual Impact
1. Fuel storage/ usage on site	Groundwater Subsoils Local Rivers Clogh and Owveg (Nore)	Accidental spillage of contaminants during site operations could cause short to long term, moderate to significant impacts to soils, groundwater and the surface water environment, if not stored and used in an environmentally safe manner.	• Lagan's SOPs have been designed to ensure responsible activity on their sites. • There will be no bulk fuels stored on-site. Hazardous wastes, such as waste oil, chemicals and preservatives, will be stored in sealed containers. Fuelling, lubrication and storage areas and site offices will not be located within 30 m of drainage ditches or settlement sumps. • All waste containers (including all ancillary equipment such as vent pipes and refuelling hoses) will be stored within a secondary containment system (*e.g.,* a bund for static tanks or a drip tray for mobile stores and drums). The bunds will be capable of storing 110 % of the tank capacity. Where more than one tank is stored, the bund must be capable of holding 110 % of the largest tank or 25 % of the aggregate capacity (whichever is greater). Drip trays used for drum storage must be capable of holding at least 25 % of the drum capacity. Where more than one drum is stored the drip tray must be capable of holding 25 % of the aggregate capacity of the drums stored. • Regular monitoring of water levels within drip trays and bunds due to rainfall will be undertaken to ensure sufficient capacity is maintained at all times. • A wheel wash facility exists near the site offices and the roads have sprinkler systems. • Regular monitoring and maintenance of silt traps will be undertaken in accordance with the manufacturer's specifications. • Oil that accumulates within hydrocarbon interceptors shall be regularly removed by an appropriately licenced contractor. In addition, the hydrocarbon interceptor shall be appropriately maintained in accordance with the manufacturer's specifications. • Regular visual monitoring of the attenuation sump and wetland area will be undertaken to ensure no visual oil or fuel contamination is present. • An oil interceptor shall be fitted with the capacity to deal with 1,500 m^3/d. The location of the hydrocarbon interceptor is presented in Plate 7.12.	Neutral
2. Excavation works and vehicle movement on site	Groundwater Bedrock Local Rivers Clogh and Owveg (Nore)	Excavation works will result in the same vulnerability of groundwater at the site as is now experienced by the open bedrock.	• There will be no bulk fuels stored on-site. • Excavations of rock will follow best management practices for maintenance of machinery.	Neutral

Construction Activity	Attribute	Character of Impact	Mitigation	Residual Impact
3. Surface Water Runoff & Discharge from the site	Groundwater Local Rivers Clogh and Owveg (Nore)	Road surface runoff or drainage systems have potential, if not correctly designed, to result in contamination of surface waters and groundwater. Accidental spillage could contaminate the aquifer by direct percolation or via the superficial water network. Monitoring results and existing system evaluation suggest that this is not the case at the site.	The settlement sumps and the floor of the quarry have sufficient volumetric capacity to accommodate all waters for the required residence time. Discharge will be of a quality that will not impact water quality. Assimilation capacity simulations have been completed and appropriate Emission Limit Values have been proposed. A flow meter has been proposed for the discharge. Telemetric recording and observation shall be maintained.	Neutral
4. Increased Dewatering	Castlecomer GWB	Lowering the quarry bench could lead to a small increase of groundwater component in the sump, which will need to be dewatered. This could lead to an increase of water being discharged to the discharge.	The quarry floor and its sump settlement system are to be adequately sized to handle the water volumes they will receive. Discharge has been calculated to intercept < 0.1 % of the regional groundwater flow volume. Water management and discharge have been designed in cognisance of enacted Irish Regulations concerning Groundwater, Surface Water, Birds, Habitats and Pearl Mussels. There will be no significant net loss or gain in the GWB system because volume intercepted and managed at the site represents, by calculated water balance, <0.1 % of the regional groundwater flow volume. Hydraulic response testing of the bedrock suggests that the radial effect will not impact local wells.	Neutral
Blasting	Water Environment	Use of explosives at the site could add Nitrogen to the water environment.	Blasts are Industry Standard Regulated and controlled. Modern methods ensure controlled systems. Calculations have been completed to demonstrate no potential for impact.	Neutral

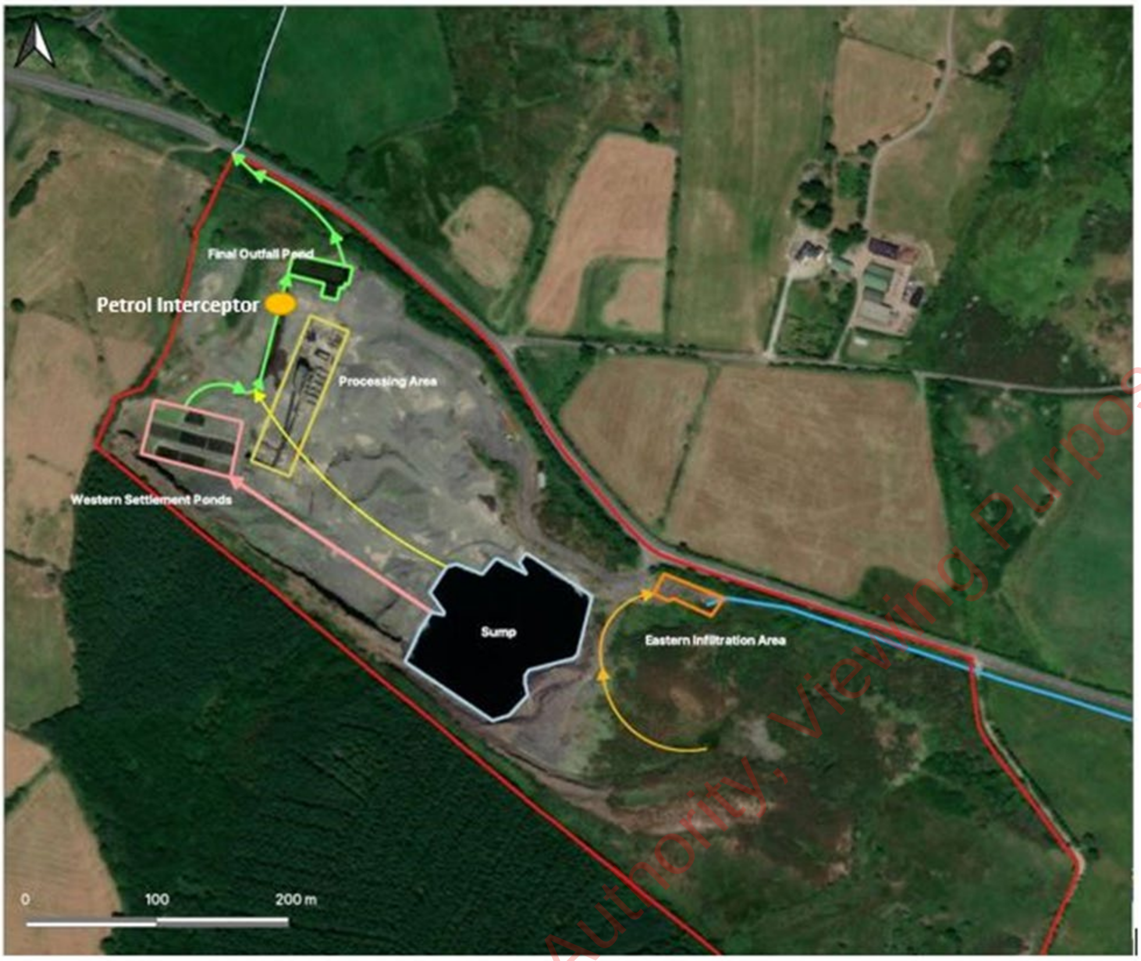


Plate 7.12 Mitigation Measure: Proposed Location of Hydrocarbon Interceptor

Table 7.40 Residual Effects

Spink Quarry Residual Effect Evaluation	No.	Potential Impact	Potential Effect	Description of Effect						Mitigation Required?	Residual Effect
				Quality	Significance	Extent	Probability	Duration	Type		
Construction Phase	1	Generated suspended solids in runoff	Surface water quality	Negative	Significant	Local	Likely	Temporary	Irreversible	Yes. The lagoon system already in place is oversized with respect to Suspended Solids retention.	**No**
	2	Accidental leaks/spills of fuels or oils	Surface water quality	Negative	Significant	Local	Unlikely	Temporary	Irreversible	Yes (Fuels & oils will not be stored within quarry, refuelling of construction vehicles will only be permitted outside the void, spill kits will be maintained on site to stop the migration of any accidental spillages)	**No**
Operational Phase	1	Increased drawdown	a) Garrintaggart Stream	Negative	Imperceptible	Local	Likely	Medium-Term	Reversible	No	**No**
			b) Owveg River	Negative	Imperceptible	Local	Likely	Medium-Term	Reversible	No	**No**
			b) Clough River	Negative	Imperceptible	Local	Likely	Medium-Term	Reversible	No	**No**
			c) Groundwater Bodies	Negative	Imperceptible	Local	Likely	Medium-Term	Reversible	No	**No**
	2	Discharge to surface water	a) Flooding	Negative	Imperceptible	Local	Unlikely	Medium-Term	Reversible	No	**No**
			b) Surface water quality	Negative	Imperceptible	Local	Unlikely	Medium-Term	Irreversible	ELVs for the site's discharge.	**No**
	3	Blasting	Groundwater quality	Negative	Significant	Local	Unlikely	Medium-Term	Irreversible	Yes Industry Standard practice.	**No**
	4	Accidental leaks/spills of fuels or oils	Surface water quality	Negative	Significant	Local	Unlikely	Temporary	Irreversible	Yes (bunding of petroleum-based products, regular plant inspections, no refuelling in quarry void, spill kits, interceptors, settlement lagoon)	**No**
Post-Operational Phase	1	**None identified**									

7.8 APPLICATION OF EA HYDROGEOLOGICAL RISK ASSESSMENT METHODOLOGY

In addition to the usual impact assessment, description of likely impacts and mitigation measures presented above, Hydro-G presented a UK EA's 'best practice' approach to a hydrogeologically focused assessment for quarries (Boak et al. 2007) in the 'Study Methodology' Section. The following represents the application of the best practice hydrogeological methodologies in this assessment. There is no Irish based hydrogeological risk assessment guidance. As previously outlined, the approach of Boak et al. (2007) suggests a step-wise thought process. Following on from the completed desk and field studies, Hydro-G answers to each of the steps can now be summarised as follows:

- *Step 1:* Establish the regional water resource status:
    - Poor and Locally Important (moderate) Aquifers. Site mostly underlain by the Castlecomer GWB, assigned Good Status (EPA 2013–2018 https://gis.epa.ie/EPAMaps/Water).
- *Step 2:* Develop a conceptual model for the abstraction and the surrounding area:
    - The areas proposed for rock excavation at the site present groundwater <u>inflow</u> primarily by collection at the base of the sandstones.
    - At times of winter rainfall recharge, there are likely to be some very small subsoil/bedrock transition zone ingresses of recent rainfall. However, Hydro-G's attendance at the site during extremely wet weather for three consecutive PW drilling days in February 2021 revealed little evidence of water ingress high up in the walls. Groundwater ingress in the floor of the void in the north-western section of the site at Borehole PW2 is in the 210–217 m OD zone which is significantly lower than the current quarry floor in this area. There is no excavation planned in this part of the site. This part of the site is dedicated to water management and accommodates the existing ponds. It is proposed to main an 80 m buffer zone to Production Well PW2. With respect to protecting the river systems to the east of the site, the proposed quarry design makes provision for a 50 m buffer zone set back from the boundary with the R430 Regional Road. There will be no quarrying and no construction activity in this area. The Clogh_010's rising was mapped by the EPA to occur within 30 m of the R430 route. Therefore, an appropriate protection zone is afforded;
    - . Groundwater ingress in the south-eastern portion of the proposed development, which is currently elevated scrubland, is predominantly along changes in bedding at 10 m bgl, 20 m bgl with small strikes and a more significant water strike zone at 50 m bgl. No conduits or fractures were encountered in the proposed working area of the site. The application site will be extracted down to final proposed floor levels in a step wise fashion following the dip in the sandstone base. These will range from a proposed

floor level of 200 m OD in the northwest, deepening to an elevation of 190 m OD in the southeast of the proposed extraction area.

- Groundwater ingress is expected to be different in the phases, as follows:
    - Phase 1 expects a rainfall-runoff and shallow groundwater contribution of 256 m^3/d.
    - Phase 2 expects the discharge volumes to range from 450 m^3/d to 960 m^3/d.
    - It is only if the base of the contact is intercepted that the maximum future dewatering potential of 1,453 m^3/d might occur. For the purposes of evaluating the worst-case scenario, it is that 'end of life' dewatering volume that has been simulated.

The conceptual model, based on drilling and hydraulic response testing, envisages that there will be a range of groundwater flow encountered from 200 to 1,453 m^3/d. The porosity of the bedrock in the proposed deepening zone is 10^{-6} m/d. This is very low. The surrounding area's groundwater flow continues as usual because the groundwater that enters the void is recharged back to groundwater via a subsoil wetland area at original ground level. Including the amount of waters directed from the sump to the creation of concrete product at the site, the site's water balance accounts for < 0.1 % of the Castlecomer groundwater body's water balance. That percentage is of no significance and supports the finding that the site poses no risk.

- *Step 3:* Identify all potential water features that are susceptible to flow impacts:
    - *Castlecomer GWB*
    - *Spring discharging to Clogh 010*
    - *Garrintaggart Stream*
    - *Owveg River*
    - *River Nore SAC*
    - *River Barrow (listed, but deemed highly unlikely by Hydro G)*
- *Step 4:* Apportion the likely flow impacts to the water features.
    - *None,*
        - *Overriding figure of significance is that the interception amount at the quarry represents < 0.1 % of the Castlecomer groundwater body's water balance.*
        - *Detailed hydrological survey, monitoring and evaluation have determined that there is flow and assimilation capacity in the proposed receiving waters.*
        - *The finding is that there will be no likely flow impact on any water receptors.*
- *Step 5:* Allow for the mitigating effects of any discharges to arrive at net flow impacts:

- *no mitigation effects, no net flow impact.*

- *Step 6:* Assess the significance of the net flow impacts.
  - *no net flow impacts.*
- *Step 7:* Define the search area for drawdown impacts.
  - Area of 500 m radius assessed.
  - The potential radius of influence upon completion of works is 346 m from the centre of the sump. There are no active groundwater receptors which may be at risk of impact from groundwater drawdown within that 350 m radius of the centre of the sump. The radius of influence comes close to the borehole at Property No. 2. Given the information obtained during the well search, the borehole at Property No. 2 must be abstracting groundwater from a deeper bedrock formation because it was drilled deep and the pump is set deep. Information supplied to the project is that it is drilled to approximately 100–120 m below surface, and is not deemed to be at risk of impact due to the proposed dewatering elevation of 190 m OD, which is at least 40 m above the borehole water strike at Property 2. Given that the groundwater flow has been shown to be controlled by the boundary contact layers between differing formations, the potential for impact is very low for this difference in elevation and the dipping slopes on the geological bedding planes found at the site.
- *Step 8:* Identify all features in the search area that could be impacted by drawdown.
  - *11 local domestic wells*
  - *Clogh River*
  - *Garrintaggart Stream*
  - *Owveg (Nore) river.*
- *Step 9:* For all these features, predict the likely drawdown impacts.
  - *None predicted because bedrock hydraulic conductivity is very low for all of the site that is proposed for development.*
- *Step 10:* Allow for the effects of measures taken to mitigate the drawdown impacts.
  - *Not relevant.*
- *Step 11:* Assess the significance of the net drawdown impacts.
  - *Not applicable.*
- *Step 12:* Assess the water quality impacts.
  - *Surface water assimilation capacity simulations have been completed and demonstrate no significant change in resultant concentrations.*
  - *Additional calculations have been completed with respect to explosive residues and no water quality impact is predicted.*

- *Laboratory analysis of the discharge waters (sump mix of rainfall-runoff and groundwater) supports the contention that there has been no impact on either surface or groundwater quality over the past lifespan of the quarry. Management measures are proposed for future environmental protection.*

- *Step 13:* If necessary, redesign the mitigation measures to minimise the impacts.
  - *Not necessary.*
- *Step 14:* Develop a monitoring strategy.

PW1, PW2 and PW3 can be retained as Monitoring Points. No excavation is planned in any of those areas. Groundwater Monitoring is suggested to have a seasonal frequency.

Groundwater monitoring Parameters of relevance are specified in Schedule 5 of the Groundwater Regulations (2010 as amended). The parameters of specific relevance to Quarry Assessments, and the Groundwater Regulation Threshold Value (TV) ranges, could be specified so that the groundwaters at the site must comply with the Threshold Values, as follows:

- Electrical Conductivity TV = 1875 ug/l @ 25oC
- Chloride TV = 187.5 mg/l Cl
- Sulphate TV = 187.5 mg/l SO_4
- Nitrate TV = 37.5 mg/l NO_3
- Nitrite TV = 375 ug/l NO_2
- Ammonium N TV = 175 ug/l N
- Total Petroleum Hydrocarbons TV = 7.5 ug/l

Monthly monitoring of the discharge waters is proposed for the parameters and suggested appropriate ELVs, as follows:

- 6–9 pH
- Ambient Temperature 10°C
- < 2 mg/l BOD
- < 10 mg/l SS
- < 0.07 mg/l Ammonium N as NH_4 N
- < 0.04 mg/l MRP-P
- < 10 ug/l DRO

The quarry's discharge should be fitted with an in-line flow meter.

Monitoring results should be reported to Laois County Council in an Annual Environmental Report.

Accidents or unusual results should be reported to Laois County Council.

7.9 SAC PROTECTION MEASURES

The main risk associated with the proposed extension to depth for a portion of the existing quarry at Spink, Co. Laois, is the potential adverse impact it could have on receiving surface and groundwaters. However, dewatering volumes are relatively low, envisaged to range from 256 to 1,453 m^3/d, approximately, in the course of development. Furthermore, the competent solid nature of the rock and the GSI's classification on groundwater recharge suggest that the site's potential interference in the wider groundwater catchment's water balance **is insignificant.** Groundwater enters the quarry primarily through accumulations at the base of the sandstones. There might be some small transition zone ingresses at times of heavy rainfall, but primarily, actual groundwater enters through the base of the sandstones. This groundwater will settle in the sump at the lowest level of the quarry and will be pumped to the water management ponds prior to discharge. Monitoring results suggest no potential to negatively affect groundwater or surface water quality.

Assimilation capacity simulations have been completed for a potential maximum envisaged discharge volume of 1,453 m^3/d. However, that volume will not be encountered all at once. The planned extraction rate and lifetime of the quarry suggests that a maximum of 1,453 m^3/d will be encountered in the future close to end of life of the site. The ELVs proposed for the discharge will meet the requirements of all surface water receptors for the maximum discharge volume. The ELVs proposed are justifiable in the context that they are calculated to result in concentrations that comply with the Surface Water Regulation's EQS concentrations and this ensures maintaining favourable habitat in local surface water receptors of groundwater. This is because the discharge quality will be good.

Excellent pond and settlement systems exist already at the site to ensure no change in resultant Suspended Solids concentrations at the point of mixing for the discharge in the Owveg_010. It is worth noting that, as previously stated, the discharge point is 20 km, approximately, upstream of the point of interest for the closest downstream pearl mussel populations to the site, which is in the vicinity of Ballyragget, Co. Kilkenny. The river at the approximate location of the pearl mussels has a land mass catchment area of ~1000 km^2 feeding to it. The catchment area in which the quarry sits and whose surrounding lands contribute also to the surface water system is ~1 km^2 land mass of the pearl mussels. It is clear, beyond scientific doubt, that there is so much land mass and recharge area between the site and the pearl mussels and there is such a level of engineering and control at the quarry site, there is no potential for impact and no special protection measures required other than those already prescribed in the design for the site.

With respect to protecting the river systems to the east of the site, the quarry's proposed Management Plan makes provision for a 50 m buffer zone set back from the boundary road. There will be no quarrying and no construction activity in this area. The rising of the Clogh River is in this zone and is thereby protected.

7.10 MONITORING

PW1, PW2 and PW3 can be retained as Monitoring Points. No excavation is planned in any of those areas.

Groundwater hydrochemical monitoring is suggested to have a seasonal frequency. Groundwater level monitoring should be continuous by submerged datalogger sensors.

Parameters of relevance are specified in Schedule 5 of the Groundwater Regulations (2010 as amended). The parameters of specific relevance to Quarry Assessments, and the Groundwater Regulation Threshold Value (TV) ranges, could be specified as follows:

- Electrical Conductivity TV = 1875 ug/l @ 25oC
- Chloride TV = 187.5 mg/l Cl
- Sulphate TV = 187.5 mg/l SO_4
- Nitrate TV = 37.5 mg/l NO_3
- Nitrite TV = 375 ug/l NO_2
- Ammonium N TV = 175 ug/l N
- Total Petroleum Hydrocarbons TV = 7.5 ug/l

Monthly monitoring of the discharge waters is proposed for the parameters and suggested appropriate ELVs, as follows:

- 6–9 pH
- Ambient Temperature 10°C
- < 2 mg/l BOD
- < 10 mg/l SS
- < 0.07 mg/l Ammonium N as NH_4 N
- < 0.04 mg/l MRP-P
- < 10 ug/l DRO

7.11 CONCLUSIONS

With respect to the primary question of note:

> ***Will continuation of quarrying and deepening of the quarry present any risk of an adverse effect on groundwater flow, local groundwater wells or the downstream regional receptors?***

Hydro-G's overall conclusion is that there is ***no potential for impact***.

This conclusion is supported by the following:

1. Groundwater Body and Total Aquifer water balance calculations suggests a < 0.1 % value, which places the site in the 'insignificant' and 'unlikely to pose risk' categories using WFD hydrogeological Assessment methodologies—Guidance on the Assessment of the Impact of Groundwater Abstractions) (WFD 2004);
2. Water quality monitoring presents a high-quality water arising on the floor;
3. Drilling experience of and hydraulic conductivity results: These suggest a solid competent bedrock in the application zone and little primary porosity. For the purposes of conservative evaluation, assimilation capacity simulations have been conducted for the maximum envisaged future volume of 1,453 m^3/d and that is justifiable in terms of Regulatory compliance.
4. Flow Modelling and Flood Assessments suggest that the surface waters surrounding the site can accommodate the maximum envisaged discharge in addition to extreme flow events and include a factor for Climate Change.

The finding of no potential for impact is a confident assertion because no significant net loss of water is envisaged. Waters arising in the sump are recirculated to the natural systems. Only a minor amount is used in product and dust suppression.

No potential for drawdown nor potential for impact on local wells is predicted. No Public Supply nor GWS abstractions within the radius of influence of the quarry have been identified. No other quarry nor other developments are within a significant distance to affect a cumulative impact.

It is concluded that all risks are mitigated and that the proposed development shall have no impact on receiving waters and designated sites, if mitigating measures are implemented.

Hydro-G and Envirologic support this evaluation by virtue of the following works:

- Desk study & consideration of previous assessments and comments by competent authorities;
- On-site evaluation, by bedrock drilling and hydraulic conductivity response testing, of the characteristic of the bedrock;
- Supporting information from Apex Geophysics (2021) in specific relation to the hydrogeological conditions encountered during drilling of Production Wells;
- On-site evaluation of the walls and floor of the excavation;

- The development of a confident Conceptual Groundwater Site and Regional Flow Model;
- Local catchment area survey and channel surveying for carrying capacity and Flood Risk Assessment;
- Water quality data;
- Assimilation capacity simulation results for the resultant groundwater concentrations for the discharge at the site;
- Settlement systems and proposed ELVs for the discharge so as to ensure no change in the proposed receiving water's quality (namely the Owveg_01 to the west of the site);
- Natural setting that suggests that the quarry and the discharge points surface water catchment is 1%, approximately, of the 1000 km^2 surface water catchment of the closest downstream pearl mussel population at Ballyragget, Co. Kilkenny. No impact is possible at this ratio, distance and the magnitude of the land mass in between the site and the pearl mussel receptor; and
- With respect to protecting the river systems to the east of the site, the proposed quarry design makes provision for a 50 m buffer zone set back from the boundary with the R430 Regional Road. There will be no quarrying and no construction activity in this area. The Clogh_010's rising was mapped by the EPA to occur within 30 m of the R430 route. Therefore, an appropriate protection zone is afforded.

The findings of this hydrogeological assessment and conclusions concur with the findings for the previous assessment by the Board with respect to "Rock Quarry Development (18 hectares) and Tarmacadam Plant Knockbaun, Spink, near Abbeyleix, Co. Laois" (An Bord Pleanála Ref.: PL 11.130640; Laois Reg. Ref.: 01/1947).

It has previously been concluded by Laois County Council and An Bord Pleanála that the continuation of quarrying was feasible at the site. Herein, it is again concluded, in light of demonstrated compliance with the requirements of the Groundwater and Surface Water Regulations, as well as aiding the objectives of the Water Framework Directive's implementation in the region, that there are no 'Water' impediments to the proposed development.

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7.13 FIGURES

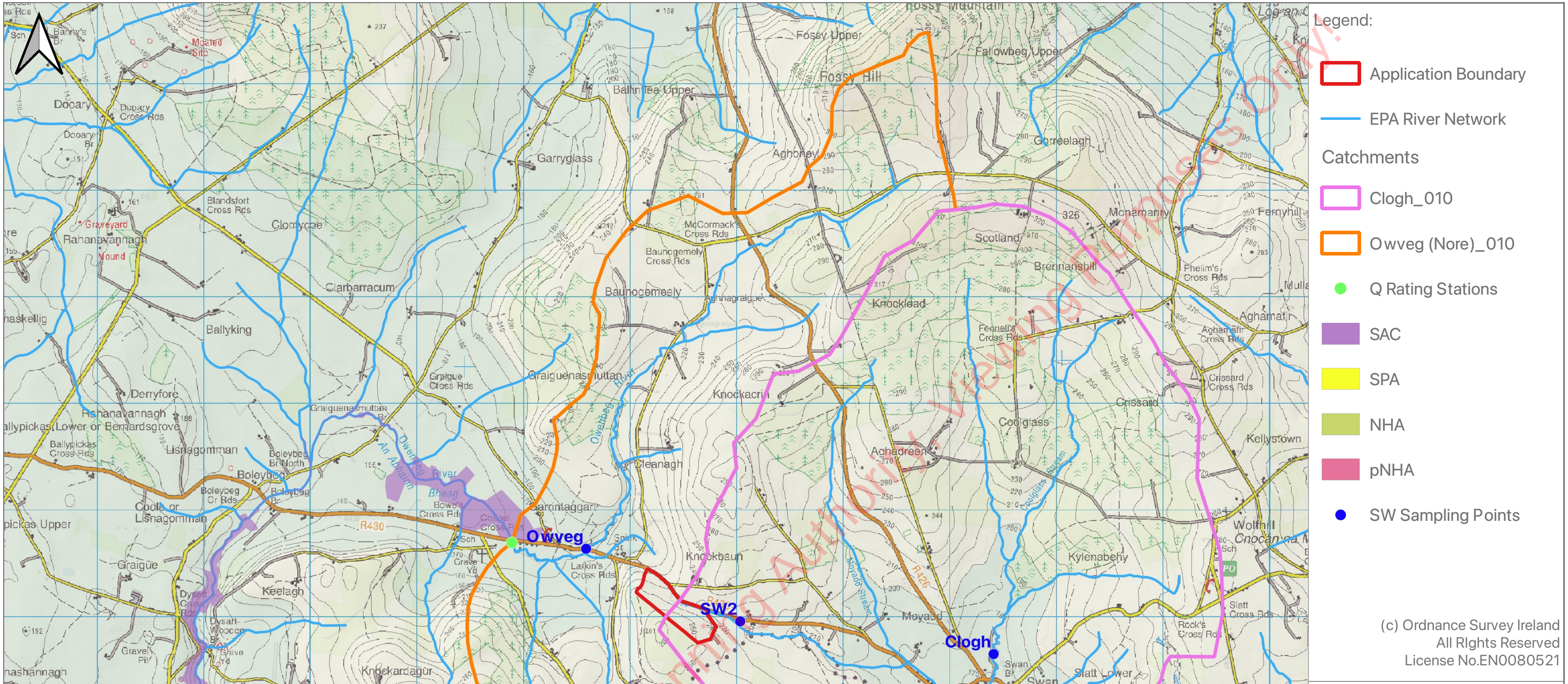


Figure 7.1:	Site Location
Date:	May 2021
Project:	161352/1890
Author:	COR
Scale:	1: 50,000 @ A4
Client:	Lagan
Project:	EIAR Chapter: Water
Location:	Knockbaun, Spink, Co. Laois

Hydro-G

Legend:

- Application Boundary
- EPA River Network
- Drainage Networks

Water Management Features

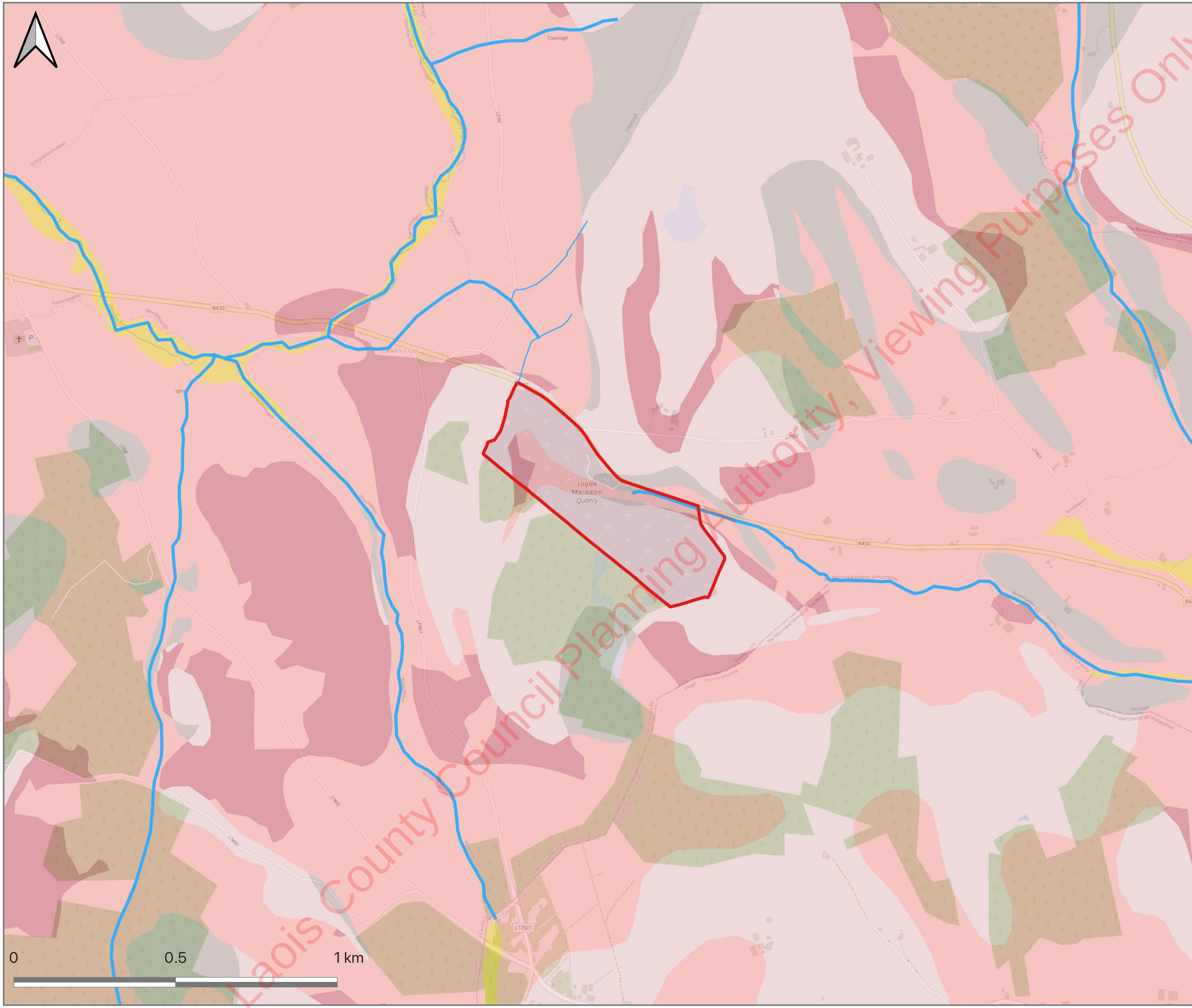
- Eastern Infiltration Area
- Final Outfall Pond
- Processing Area
- Sump
- Western Settlement Ponds

Surface Water Flow Lines

- Discharge Route
- Historical Pumping Route
- Spring Discharge
- Current Sump Overflow

Figure 7.2:	Site Layout
Date:	May 2021
Project:	161352/1890
Author:	COR
Scale:	1: 3,500 @ A4
Client:	Lagan
Project:	EIAR Chapter: Water
Location:	Knockbaun, Spink, Co. Laois

Hydro-G



Legend:

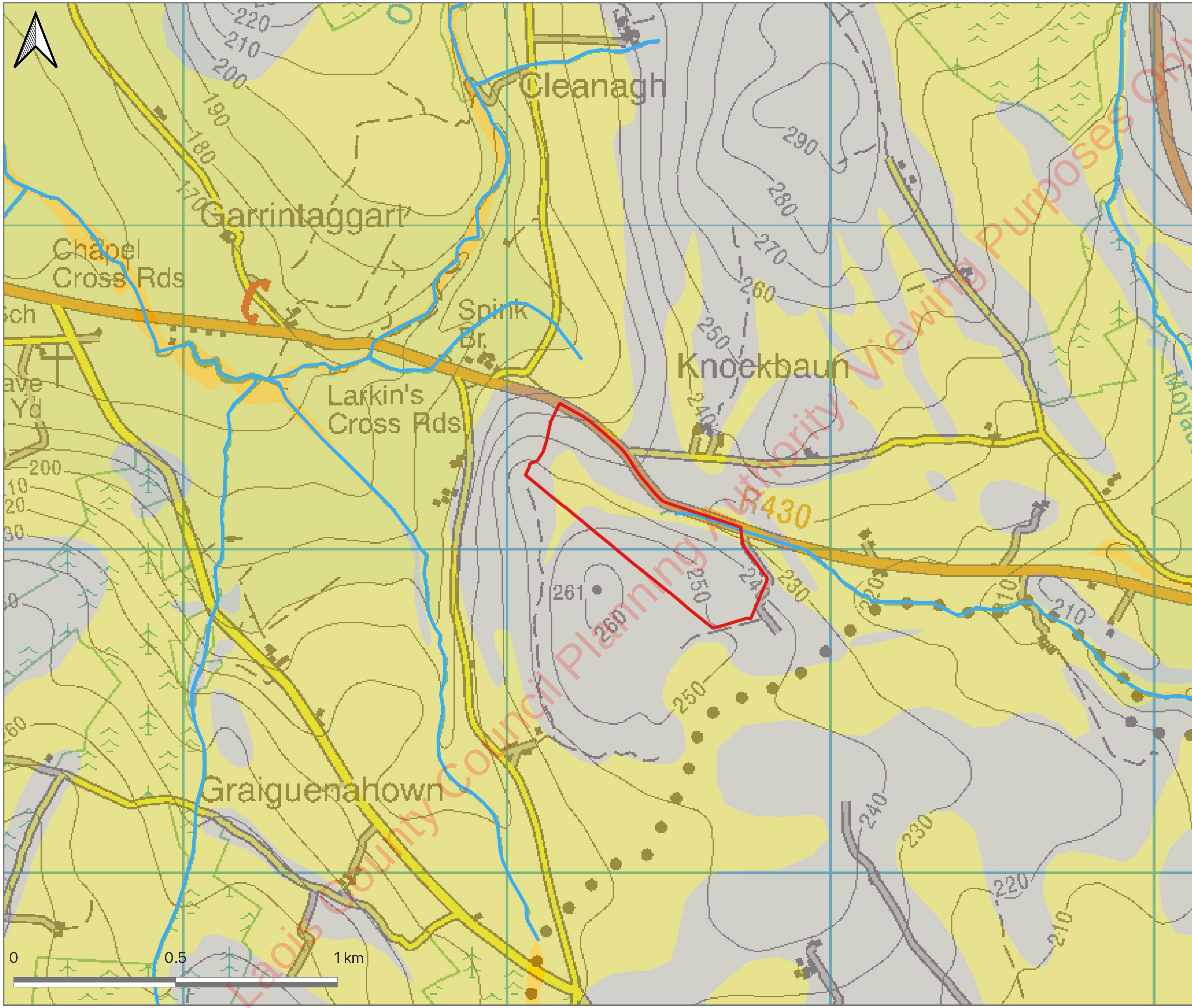
- Application Boundary
- EPA River Network
- Drainage Networks

Soils

- Alluvium (mineral)
- Deep, well-drained, acidic
- Deep, poorly-drained, acidic
- Shallow, poorly-drained, acidic
- Shallow podzol with peaty topsoil
- Shallow, well-drained (A)

Figure 7.3:	Soils Classification
Date:	May 2021
Project:	161352/1890
Author:	COR
Scale:	1: 15,000
Client:	Lagan
Project:	EIAR Chapter: Water
Location:	Knockbaun, Spink, Co. Laois

Hydro-G



Legend:

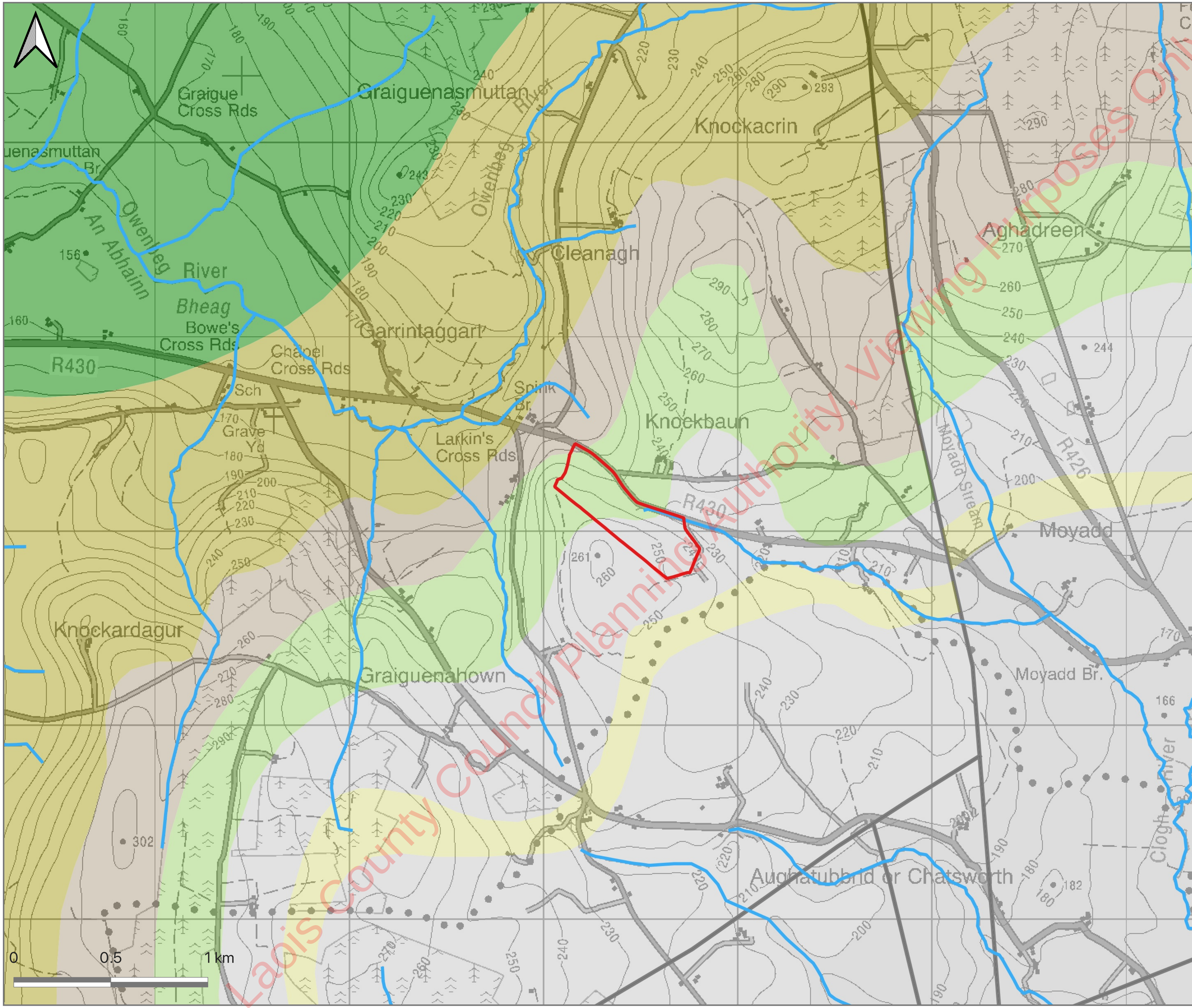
- Application Boundary
- EPA River Network

Quaternary Sediments

- Alluvium
- Bedrock outcrop
- Till derived from Namurian sandstones and shales

Figure 7.4:	Quaternary Deposits
Date:	May 2021
Project:	161352/1890
Author:	COR
Scale:	1: 15,000
Client:	Lagan
Project:	EIAR Chapter: Water
Location:	Knockbaun, Spink, Co. Laois

Hydro-G



Legend:

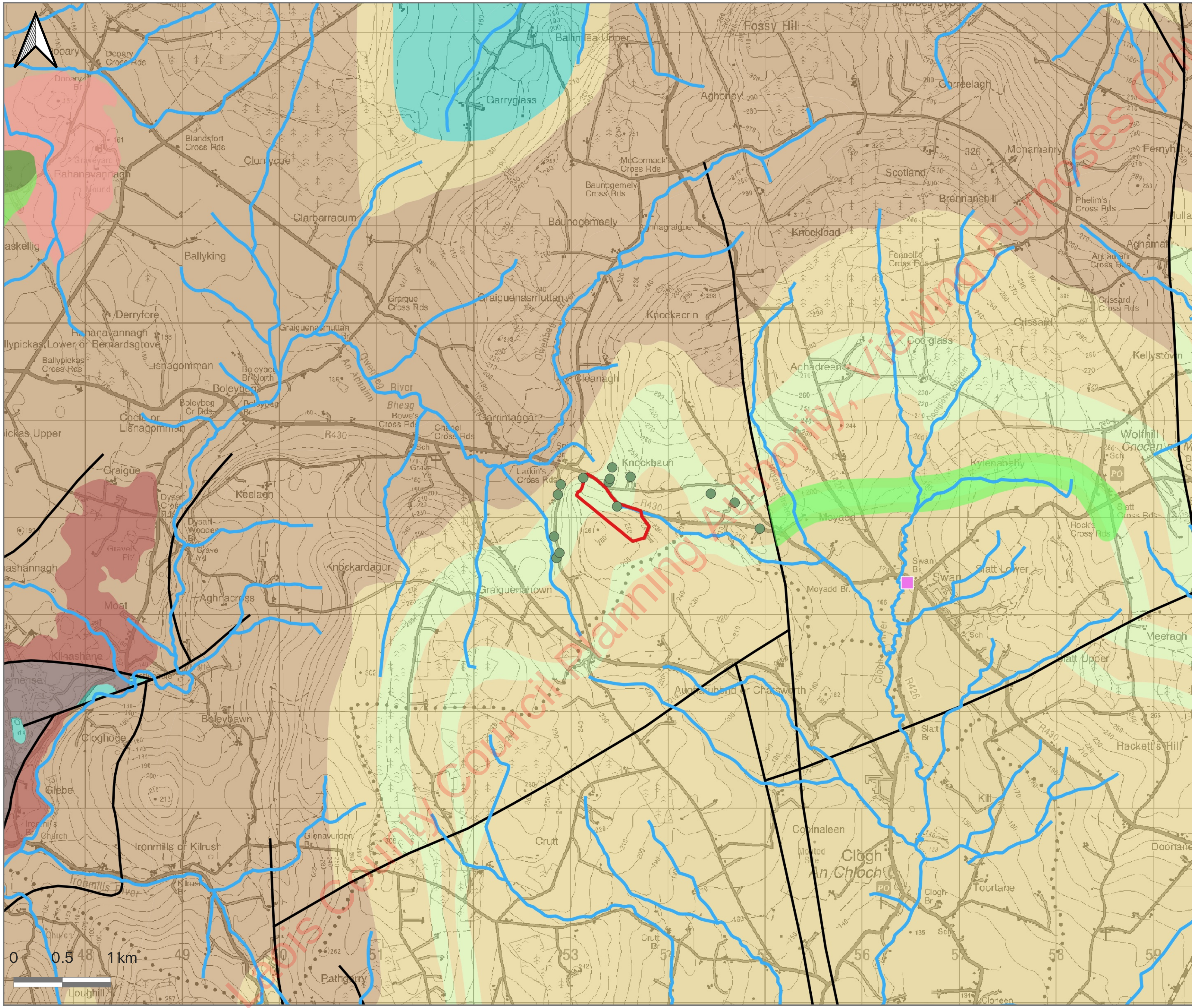
- Application Boundary
- EPA River Network

Bedrock Units

- Bregaun Flagstone Formation
- Clay Gall Sandstone Formation
- Coolbaun Formation
- Killeshin Siltstone Formation
- Moyadd Coal Formation
- Swan Sandstone Member
- Structural Faulting

Figure 7.5:	Bedrock Geology
Date:	May 2021
Project:	161352/1890
Author:	COR
Scale:	1: 25,000
Client:	Lagan
Project:	EIAR Chapter: Water
Location:	Knockbaun, Spink, Co. Laois

Hydro-G



Legend:

- Application Boundary
- EPA River Network

Bedrock Aquifer

- Locally important, moderately productive (Lm)
- Poor, unproductive except for local zones (Pl)
- Poor, generally unproductive
- Regionally important, karstified (diffuse)
- Structural Faulting

Sand & Gravel Aquifer

- Locally important gravel aquifer (Lg)
- Regionally important gravel aquifer (Rg)

Irish Water Source Protection Areas

- SI
- SO
- Swan PWS Source BH
- 25 inch OSI Map Springs

Figure 7.6:	Bedrock Aquifer & ZOCs
Date:	May 2021
Project:	161352/1890
Author:	COR
Scale:	1: 50,000
Client:	Lagan
Project:	EIAR Chapter: Water
Location:	Knockbaun, Spink, Co. Laois

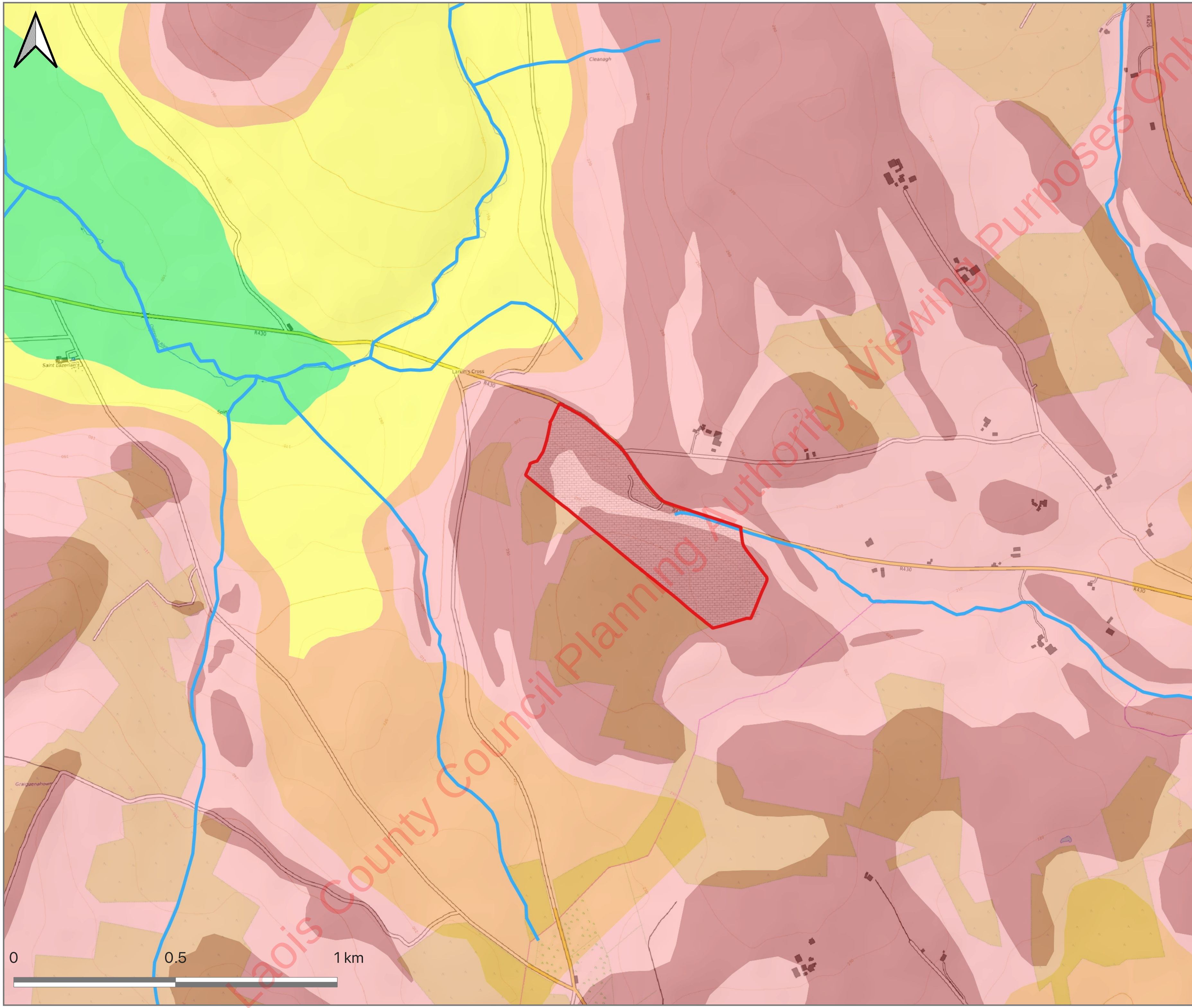
Hydro-G

Legend:

- Application Boundary
- EPA River Network
- 25 inch Map Springs
- 25 inch Map Wells
- On-Site Pumping Test Wells
- On-Site Rotary Core Holes

Figure 7.7:	OSI Wells & Springs
Date:	March 2021
Project:	161352/1890
Author:	COR
Scale:	1: 11,000 @ A4
Client:	Lagan
Project:	Hydrogeological Assessment
Location:	Knockbaun, Spink, Co. Laois

Hydro-G



Legend:

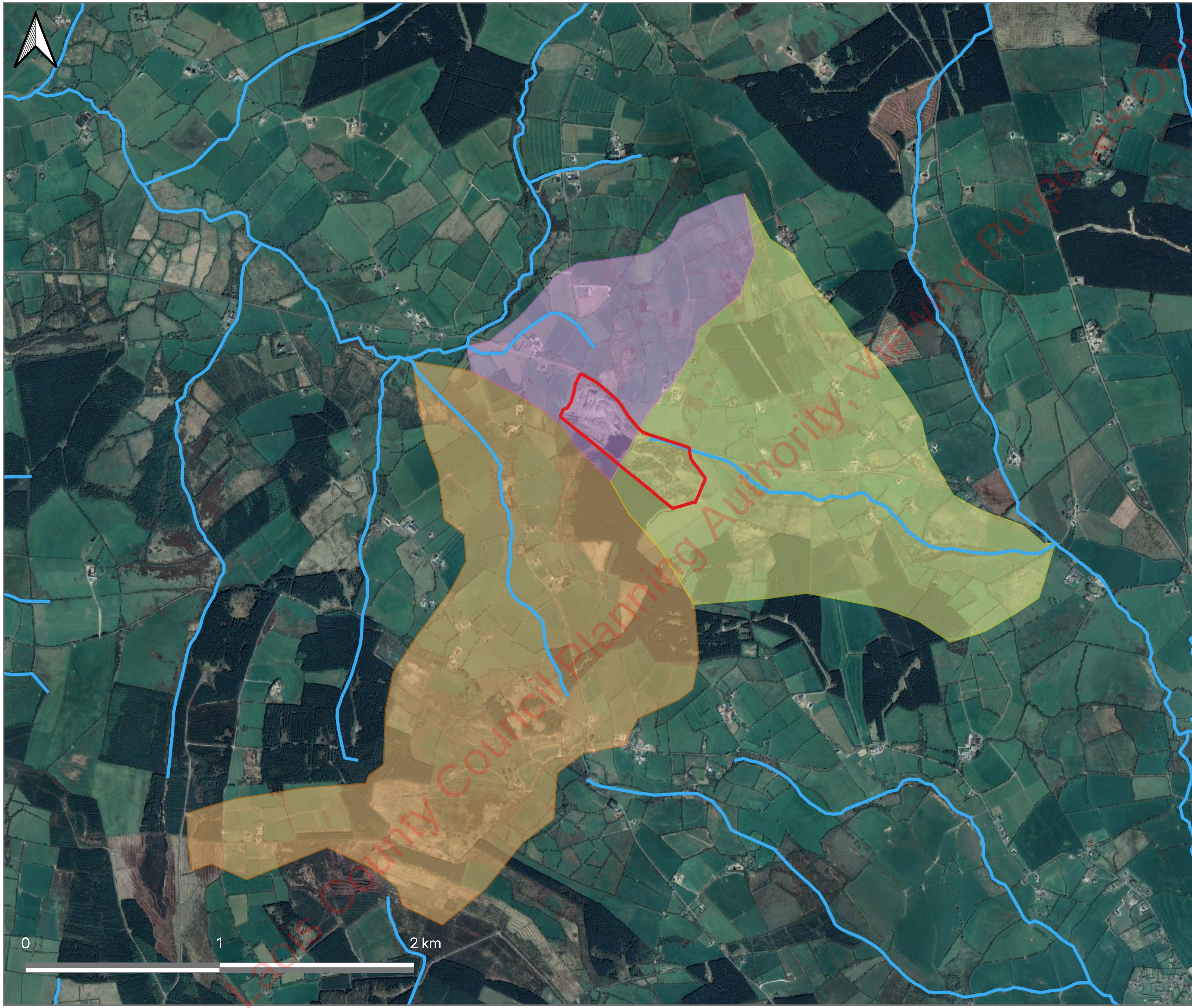
- Application Boundary
- EPA River Network

Vulnerability

- Extreme (X)
- Extreme (E)
- High (H)
- Low (L)
- Moderate (M)

Figure 7.8:	Groundwater Vulnerability
Date:	May 2021
Project:	161352/1890
Author:	COR
Scale:	1: 25,000
Client:	Lagan
Project:	EIAR Chapter: Water
Location:	Knockbaun, Spink, Co. Laois

Hydro-G



Legend:

- Application Boundary
- EPA River Network
- Garrintaggart Catchment
- Aughatubbrid Catchment
- Knockbaun Catchment

Figure 7.9:	SW Catchments
Date:	May 2021
Project:	161352/1890
Author:	COR
Scale:	1: 25,000 @ A4
Client:	Lagan
Project:	Hydrogeological Assessment
Location:	Knockbaun, Spink, Co. Laois

Hydro-G

Legend:

Application Boundary

EPA River Network

3rd Party Well Survey Dwellings

Figure 7.10: Third Party Well Survey	
Date:	May 2021
Project:	161352/1890
Author:	COR
Scale:	1: 10,000 @ A4
Client:	Lagan
Project:	Hydrogeological Assessment
Location:	Knockbaun, Spink, Co. Laois

Hydro-G

Legend:

Application Boundary

EPA River Network

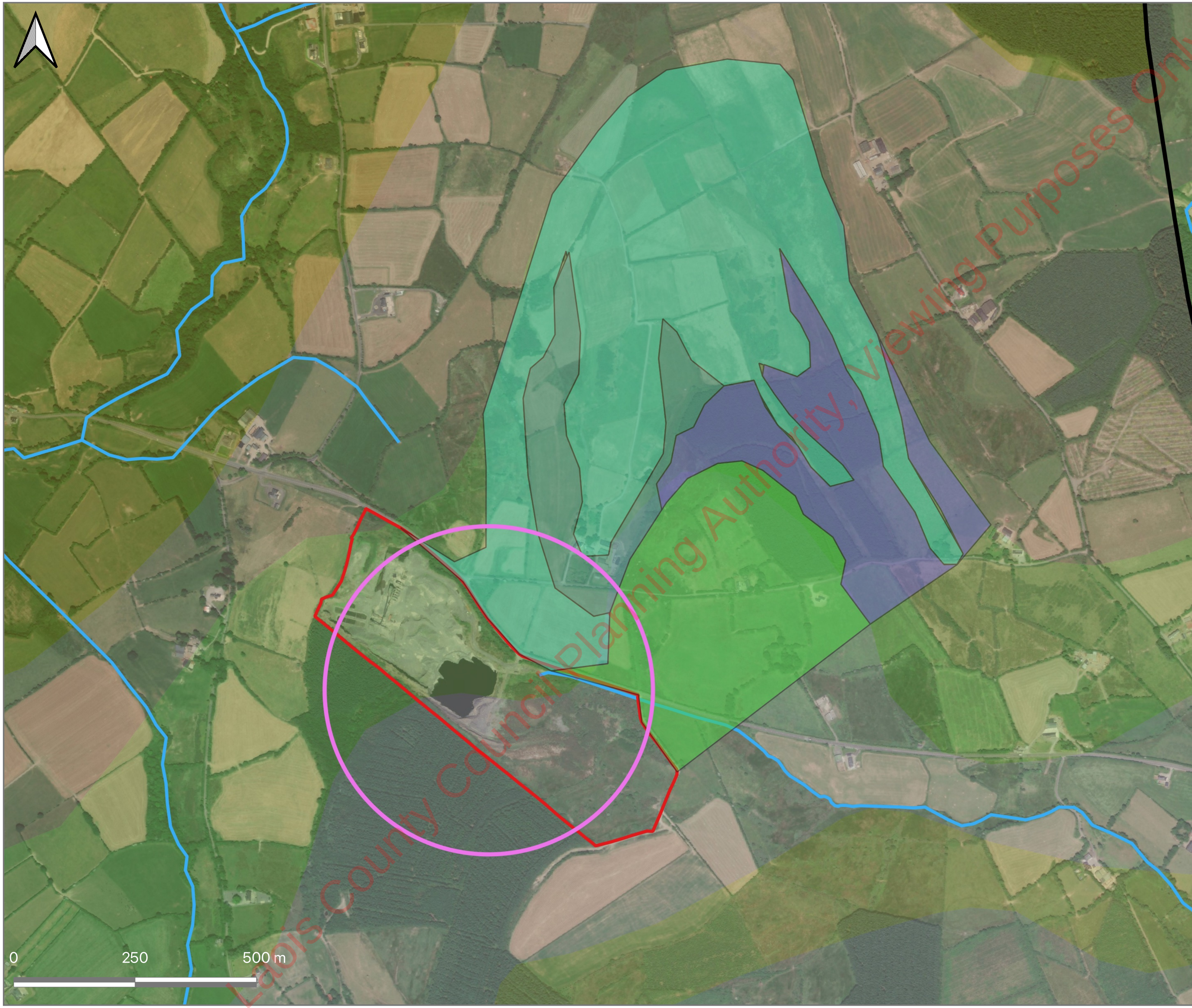
Groundwater Elevation, mOD 24/05/21

Inferred GW Flow Direction

Figure 7.11: Groundwater Levels

Date:	May 2021
Project:	161352/1890
Author:	COR
Scale:	1: 7,500 @ A4
Client:	Lagan
Project:	Hydrogeological Assessment
Location:	Knockbaun, Spink, Co. Laois

Hydro-G



Legend:

Application Boundary

EPA River Network

Radius of Influence

Annual Recharge, mm/yr

100

145

403

571

Bedrock Units

Bregaun Flagstone Formation

Clay Gall Sandstone Formation

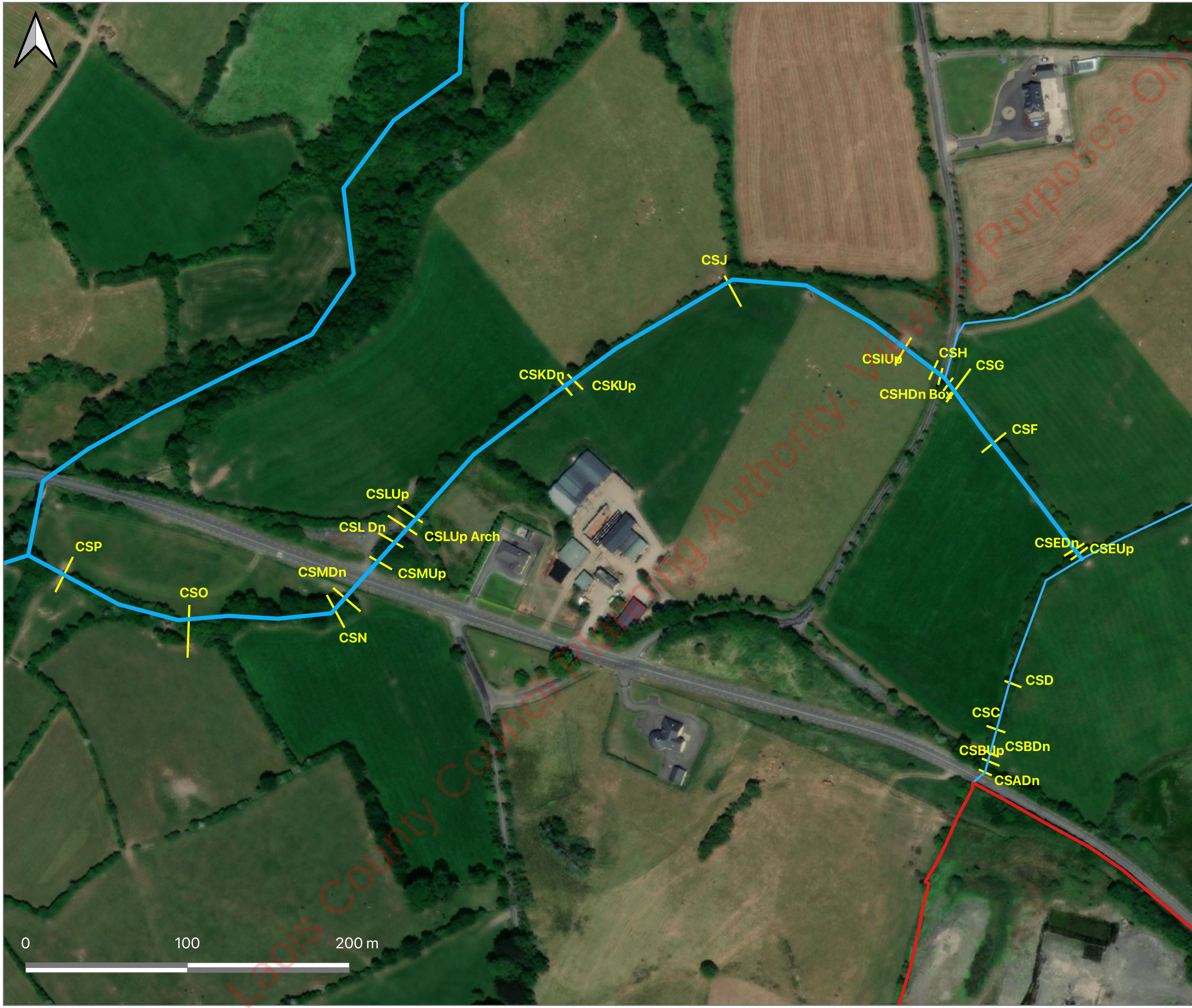
Coolbaun Formation

Moyadd Coal Formation

Swan Sandstone Member

Figure 7.12:	Predicted Recharge Area
Date:	May 2021
Project:	161352/1890
Author:	COR
Scale:	1: 10,000
Client:	Lagan
Project:	EIAR Chapter: Water
Location:	Knockbaun, Spink, Co. Laois

Hydro-G

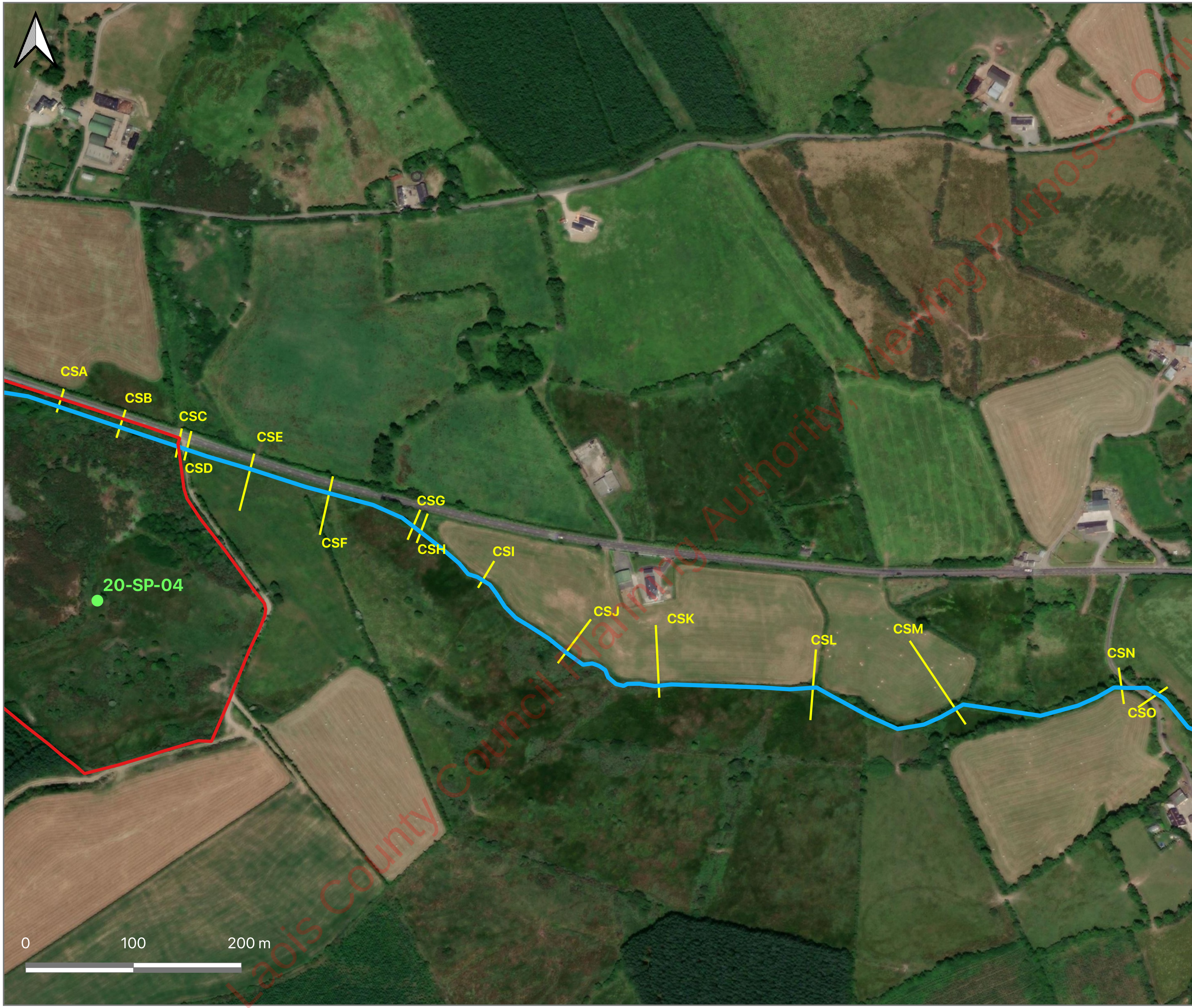


Legend:

- Application Boundary
- Drainage Networks
- EPA River Network
- Western Route Cross Sections

Figure 7.13:	Western Discharge Route
Date:	May 2021
Project:	161352/1890
Author:	COR
Scale:	1: 3,000 @ A4
Client:	Lagan
Project:	Hydrogeological Assessment
Location:	Knockbaun, Spink, Co. Laois

Hydro-G



Legend:

- Application Boundary
- EPA River Network
- Eastern Route Cross Sections

Figure 7.14:	Eastern Discharge Route
Date:	May 2021
Project:	161352/1890
Author:	COR
Scale:	1: 4,500 @ A4
Client:	Lagan
Project:	Hydrogeological Assessment
Location:	Knockbaun, Spink, Co. Laois

Hydro-G