10. Hydrogeology

10.1 Introduction

As set out in Chapter 1 of this updated EIAR, this is an update to Chapter 10 of the EIAR submitted to An Bord Pleanála in October 2018 as part of the application for approval of the proposed N6 GCRR pursuant to Section 51 of the Roads Act 1993 (as amended). It forms part of the response to the request by ABP for further information in December 2023 where they requested GCC to "*Update the Environmental Impact Assessment Report".* This chapter of this updated EIAR consists of an appraisal of the Project under the heading of hydrogeology. Where there have been any changes to the assessment and or any updates since the 2018 EIAR, these have been set out in this updated chapter.

This chapter initially sets out the methodology followed in carrying out the appraisal for this update (Section 10.2), describes the hydrogeological receiving environment whilst noting any significant changes (Section 10.3) and summarises the main characteristics of the Project which are of relevance for hydrogeology (Section 10.4). The evaluation of effects of the Project on hydrogeology are described (Section 10.5and measures are proposed to mitigate these effects (Section 10.1). The residual effects are also described (Section 10.7) and cumulative effects are described (Section 10.8). The chapter concludes with a summary (Section 10.9) and reference section (Section 10.1).

This chapter has utilised the information gathered during the constraints and route selection phases of the proposed N6 GCRR, the studies to inform the 2018 EIAR, the information gathered and used in the 2019 Response to Request for Further Information and the information and data presented during the 2020 oral hearing together with data gathered during site visits undertaken in 2023 and 2024 to further inform the hydrogeology impact appraisal. Sections 4.5, 6.5.3 and 7.6.3 of the Route Selection Report for the proposed N6 GCRR considered the hydrogeology constraints within the scheme study area and compared the potential hydrogeology effects of the proposed route options respectively. These sections of the Route Selection Report contributed to the design of the proposed N6 GCRR which forms a major part of the Project that this chapter appraises.

A number of questions arose at the oral hearing in 2020 specifically in relation to adequacy of investigations and conceptual model, overly conservative nature of the drawdown calculations, impact on water quality at groundwater dependant habitat, impacts on wells, groundwater flooding at Lackagh Quarry and structural stability due to groundwater drawdown, and these are specifically referred to and dealt with in the appropriate location throughout this updated chapter. Further the errata/corrigendum handed in during the Oral Hearing in 2020 have also been reflected in this updated chapter and where appropriate the appendices to this updated chapter. The figures presented in this updated EIAR have considered all comments, corrigenda and errata that were identified during the Oral Hearing process. The assessment process remains valid and unchanged between the 2018 EIAR and this updated EIAR.

The key changes to the chapter since the 2018 EIAR involve updating:

- the methodology to take account of updated guidelines
- the description of the receiving environment to take account of changes including additional wells (7 No.) and karst feature (1 No.) identified during site visits, updated ecological habitat mapping, new developments, etc.
- the evaluation of the effect on hydrogeology
- the appendices and figures associated with Chapter 10
- to take account of points raised from the Brief of Evidence presented to An Bord Pleanála (ABP) at the oral hearing in 2020 and from the ABP Inspector's Report dated June 2021

10.2 Methodology

10.2.1 Introduction

This section outlines the methodology used to prepare this chapter of this updated EIAR and is founded on current legislation and guidelines, some of which are new since the 2018 EIAR.

10.2.2 Regulations, Legislation and Guidelines

This chapter is prepared having regard to the requirements of Section 50 Subsection (2 and 3) of the Road Act 1993 as amended, and with the following guidance (all of which remain relevant today to this updated assessment) including new guidance since the 2018 EIAR:

- Environmental Protection Agency (EPA). Guidelines on the Information to be Contained in Environmental Impact Assessment Reports (hereafter referred to as the EPA Guidelines) (EPA 2022)
- Environmental Impact Assessment of Projects Guidance on the preparation of the Environmental Impact Assessment Report (European Commission 2017)
- Environmental Impact Assessment of National Road Schemes – A Practical Guide (NRA 2008b)
- Institute of Geologists of Ireland (IGI) Guidelines for the Preparation of Soils, Geology and Hydrogeology Chapters of Environmental Impact Statements (hereafter referred to as the IGI Guidelines) (IGI 2013)
- National Roads Authority (NRA) Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes (hereafter referred to as the TII Guidelines) (TII 2009)
- Strive Report Series No. 100. Evaluating the Influence of Groundwater Pressures on Groundwater-Dependent Wetlands. Strive EPA Programme 2007 - 2013 (EPA 2011)
- Environmental Research Centre Report Series No. 12. A Framework for the Assessment of Groundwater-Dependent Terrestrial Ecosystems under the Water Framework Directive. Strive EPA Programme 2007 – 2013 (EPA 2008)

Though the NRA is now known as Transport Infrastructure Ireland (TII), for the purpose of this Chapter the guidelines mentioned above are referred to as the TII Guidelines.

Water resource management in Ireland is dealt with in the following key pieces of legislation:

- Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy
- Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration
- European Union (Drinking Water) Regulations 2023 (S.I. No. 99/2023)
- European Union Environmental Objectives (Groundwater) Regulations 2016 (S.I. No. 366 of 2016), as amended
- European Union Environmental Objectives (Surface Waters) Regulations 2019 (S.I. No. 77 of 2019) as amended
- European Communities (Quality of Salmonid Waters) Regulations, 1988 (S.I. No. 293/1988)
- European Union (Water Policy) (Abstractions Registration) Regulations 2018 (SI no. 261 of 2018)
- European Communities (Assessment and Management of Flood Risks) Regulations 2010 (S.I. No. 122/2010)
- Water Environment (Abstractions and Associated Impoundments) Regulations 2024

- The EU Floods Directive, 2007/60/EC
- Water Services Acts 2007 to 2017
- Directive 2000/60/EC Water Framework Directive (WFD)
- Directive 2006/118/EC Groundwater Directive

10.2.3 Consultations

Consultation was carried out with relevant bodies to identify any hydrogeological features which may be impacted by the Project. Consultation was undertaken by the design team with additional consultation undertaken by the project hydrogeologists with hydrogeology specialists in the Geological Survey of Ireland, Environmental Protection Agency and the National Federation of Groundwater Schemes.

Those consultations relevant to the hydrogeology impact assessment are, noting that updated consultation took place in the period 2023 and 2024 with these consultees to ensure that the most recent information is included in this updated EIAR:

- Geological Survey Ireland (GSI) (Department of Communications, Climate and Environment (DoCCE)) Groundwater Division
- Local Area Engineers in Galway County Council and Galway City Council. The Water Services Section confirmed the location of the nearest public supply schemes
- National Parks and Wildlife Services (NPWS) part of the Department of Housing, Local Government and Heritage
- Landowners potentially affected by the Project
- Environmental Protection Agency (EPA) – EPA was consulted to determine the location of any waste licence or groundwater monitoring locations within the hydrogeology study area. There are no EPA groundwater monitoring sites within the hydrogeology study area of the Project. There are a number of EPA monitoring sites on the River Corrib and one on the Terryland River as outlined in Chapter 11, Hydrology
- Teagasc
- Office of Public Works (OPW)
- National Federation of Group Water Schemes (NFGWS)

Additional consultation was also undertaken in 2023/2024 with other environmental experts on the project team in order to assess the potential impact of the interaction with other environmental factors. This included discussions on the following:

- Biodiversity – Consultation on the potential impact on groundwater dependant habitats
- Soils and Geology – Consultation on geotechnical and contaminated land issues
- Hydrology – Consultation on the potential impact on surface water systems
- Drainage – Consultation on design of runoff and groundwater management
- Material Assets – Consultation on the impact on private wells

10.2.4 Hydrogeology Study Area

In accordance with the TII Guidelines, the area of hydrogeological study should include all features which may be impacted from the Project. The hydrogeology study area extent is dependent on the hydrogeological characteristics of the bedrock aquifer that the Project traverses e.g. the potential study area for a poor aquifer will be significantly smaller than the study area for a regionally important karst aquifer.

Based upon the screening undertaken at route selection stage the extent of the hydrogeology study area was conservatively taken as being 250m from the proposed fenceline of the proposed N6 GCRR for the western section of the proposed N6 GCRR (west of the N59 Moycullen Road), where the aquifer is classified as being poorly productive. This was reviewed further in 2023 and deemed to be appropriate and correct.

The eastern section of the Project (east of the N59 Moycullen Road) includes regionally important karstified aquifers and the extent of the hydrogeology study area was taken as the extent of the groundwater catchments, or sub-catchments as appropriate, that the Project traverses. This was reviewed further in 2023 and was extended to include the full extents of Galway Racecourse as well as the limestone aquifer from the racecourse to Lough Atalia and the coast at Roscam.

Groundwater catchments, referred to as groundwater bodies (GWB) have been mapped and named by the GSI. The boundaries for these groundwater divides have been refined as part of this assessment to provide a full assessment of all receptors that have the potential to be impacted by the Project.

For some GWB, the project data demonstrates that parts of the GWB are hydrogeologically separate from the rest of the GWB and this has allowed the GSI GWB to be refined and in some cases divided into sub catchments. The refined GWB and identification of sub-catchments are presented as part of the description of the conceptual model in Section 10.3.4 for both the Galway Granite Batholith and the Visean Undifferentiated Limestone. The description of hydrogeological features within the hydrogeology study area are presented Section 10.3.5. Note the refined GWB and sub-catchments remain unchanged from the 2018 EIAR.

10.2.5 Data Sources and Baseline Data Collection

The existing baseline ground conditions within the hydrogeology study area of the Project have been interpreted from desk studies, field studies and commissioned ground investigations. The data sources for each of these are described below.

10.2.5.1 Desk Study

The following sources of information were reviewed in order to evaluate the hydrogeology of the Project:

- Current and historical Tailte Éireann maps available for the hydrogeology study area (1:2,500 and 1:10,560 scales)
- Aerial imagery from Google (imagery from 2003 to 2024) and Bing accessed in 2025
- Geological and hydrogeological maps of the site area produced by the GSI (www.dcenr.gov.ie, accessed 2025)
- EPA maps and datasets of waterbody status, pressures and groundwater abstractions (www.epa.ie, accessed 2025)
- National Parks and Wildlife Service (NPWS) maps of designated sites (www.npws.ie, accessed 2025)
- National Monuments Service Historic Environment Viewer (www.archaeology.ie, accessed 2025)
- MacDermot, C.V., McConnell, B. and Pracht, M. (2003) *Geology of Galway Bay 1:100,000 scale Bedrock Geology Map Series*, Sheet 14, Galway Bay, Geological Survey of Ireland
- Pracht, M. and Somerville I.D., 2015. A Revised Mississippian lithostratigraphy of County Galway (western Ireland) with analyses of Carbonate lithofacies, biostratigraphy, depositional environments and palaeogeography reconstructions utilising new borehole data. Journal of palaeogeography. Volume 4, Issue 1, January 2015, Pages 1-26
- Teagasc and the Environmental Protection Agency Irish Soil Information System (http://gis.teagasc.ie/soils/index.php, accessed 2017
- Ground investigation reports held by the GSI for the hydrogeology study area (refer Appendix A.9.1)

- Flood, P. and Eising, J. (1987). *The use of vertical band drains in the construction of the Galway Eastern Approach Road*. Proceedings of the 9th European Conference on Soil Mechanics and Foundation Engineering, Dublin, Ireland
- Lidar elevation data commissioned by OPW
- N6 Galway City Outer Bypass Scheme (2006 GCOB):
  - Galway City Outer Bypass R336 Western Approach Constraints Study Report 2000
  - N6 Galway City Outer Bypass Constraints Study Report (2000)
  - Galway County Council Galway City Outer Bypass Preliminary Ground Investigation, 2006
  - N6 Galway City Outer Bypass Environmental Impact Statement (2006)
- Data available from the Geological Survey of Ireland:
  - R1340 Galway County Council Eastern Approach Road Galway (N6) (Ballybane – Doughiska), 1993
  - R1365 Thos. Garland and Partners Digital Limited, Galway Industrial Estate, 1983
  - R3176 Dermot Rooney and Associates I.D.A Business Park, Daingean, Galway, 1997
  - R5906 Irish Linen Proposed Irish Linen Factory, Rahoon, Galway, 2005
  - R6136 Galway County Council Residential Development, Headford Road, Galway, 2006
  - R6898 Storm Technology Office Block Development, Daingean, Galway, 2006

10.2.5.2 Field Studies

As part of the environmental studies a number of surveys and walkovers were undertaken between 2014 and 2024 to assess the hydrogeological environment. These surveys are presented in the following reports:

- Ground investigation reports (Appendix A.9.1)
- Well condition reports (Appendix A.10.1)
- Karst survey report (Appendix A.10.2)

Geophysical surveys were commissioned across the route of the proposed N6 GCRR to provide additional detail on the subsurface ground conditions. These, along with the ground investigations discussed in Section 10.2.5.3 were used to develop the hydrogeological conceptual model for the hydrogeology study area. The data for the geophysics surveys are presented in Appendix A.9.1.

A well condition survey was undertaken in 2014 to determine the condition of existing monitoring wells which were installed as part of the 2006 Galway City Outer Bypass (2006 GCOB) studies. This survey allowed historic wells, some of which required remediation, to be incorporated into the monitoring network for the proposed N6 GCRR. The 2023 to 2024 groundwater sampling programme used the same wells as sampled during the 2015 to 2017 sampling programme. Prior to the wells being sampled for the 2023 to 2024 sampling programme a well condition survey was completed. The 2014 and 2023 reports on the condition of these wells are detailed in Appendix A.10.1, which confirm that the wells remained in satisfactory condition for sampling.

Detailed karst surveys were completed for the constraints and route selection studies for the proposed N6 GCRR in 2014. The karst survey was updated in July 2016 following completion of site walkovers and ground investigations. The karst survey was then updated in 2024 following completion of additional walkovers, including those at the Galway Racecourse. The karst survey is presented in Appendix A.10.2. includes the 2014 original survey together with 2016 and 2024 survey results.

10.2.5.3 *Commissioned Ground Investigations*

Nine ground investigations were commissioned for the Project. These ground investigations included boreholes, trial pits and window sampling, which are fully described in Chapter 9, Soils and Geology. The ground investigations also included groundwater monitoring and groundwater testing. Eight of these ground investigations were undertaken to inform the 2018 EIAR. As the design of the proposed N6 GCRR has not changed since the 2018 EIAR, no additional intrusive investigations were undertaken. However, groundwater monitoring at the previously installed installations was undertaken to provide updated groundwater level and groundwater quality data. As additional works are proposed at Galway Racecourse as part of the Project, additional ground investigations were undertaken to inform the impact assessment of these works.

The full list of investigation is detailed in the following appendices:

- Groundwater Level Monitoring Report (July 2018 & March 2025) (Appendix A.10.3)
- Water Quality Monitoring Report (July 2018 & March 2025) (Appendix A.10.4)
- Aquifer Test Report (July 2018 & March 2025) (Appendix A.10.5)
- N6 GCTP Phase I Ground Investigation Contract I, November 2014. Factual Report (Appendix A.9.1.2)
- N6 GCTP Phase II Ground Investigation Contract I, November 2015. Factual Report (Appendix A.9.1.3)
- N6 GCTP Phase III Ground Investigation Contract I, June 2017. Factual Report (Appendix A.9.1.4)
- N6 GCTP Phase III Ground Investigation Contract II, May 2016. Factual Report (Appendix A.9.1.5)
- N6 GCTP Phase III Ground Investigation Contract III, April 2017. Factual Report (Appendix A.9.1.5)
- Galway Racecourse Ground Investigation, July 2024, Factual Report (Appendix A.9.1.6)

In summary, the total hydrogeological investigations for the Project comprised of the following project specific groundwater installations and testing, noting that the increase since the 2018 EIAR is due to the additional investigations carried out during 2023 and 2024:

- 37 No. Groundwater monitoring wells
- 20 No. Groundwater level monitoring rounds [1]
- 14 No. Groundwater quality monitoring rounds
- 15 No. Infiltration test
- 16 No. Small scale pumping test and variable head permeability tests
- 8 No. Packer tests
- 2 No. Pumping tests

All investigation locations were sited based on the location of Project design elements. Groundwater level, groundwater quality and aquifer testing were focused on locations of cuttings, structures and receptors.

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[1] Groundwater monitoring of water level and water quality was undertaken between February 2015 and April 2017. This was repeated also between November 2023 and July 2024

The February 2015 to April 2017 monitoring included a total of 16 groundwater monitoring rounds. Water level measurements on individual wells were also taken during commissioning, well testing and spot checks. In total 54 individual wells were regularly measured, which comprised of 34 project specific wells, 16 (2006 GCOB wells) and 4 private wells. Contractors also undertook a period of monitoring following the well installation for this project and their data is presented in the Ground Investigation Reports in Appendix A.9.1 Groundwater sampling was undertaken in 18 groundwater monitoring wells (refer to Appendix 10.4 for details)

The November 2023 to July 2024 included a total of four rounds of the wells that were sampled for water quality during 2015 to 2017. This comprised of 18 wells, which were the same as those sampled in 2015 to 2017 (refer to Appendix 10.4 for details)

10.2.6 Technical Limitations

The data included in the hydrogeology assessment includes existing information from earlier investigations in the region as well as dedicated field surveys, walkovers and ground investigations commissioned for the Project. The data collected provides a comprehensive hydrogeological dataset along the route of the Project. As is standard for hydrogeological studies the dataset comprises of point data (boreholes), linear data (geophysics) and surface data (topography, water courses and karst) to develop a conceptual model of the hydrogeology study area.

Where groundwater dependent receptors were identified, the locations were investigated to determine the hydrogeological regime. Due to the ecologically sensitive nature of sites the investigation methodologies selected were those that would not impact on the hydrogeology of a European site. In the absence of site-specific data in these sensitive locations, a conservative approach was taken in appraising any potential impacts.

Based on the comparability of the ground investigation and the baseline data collection the information is deemed sufficient to complete the hydrogeology evaluation.

10.2.7 Impact Assessment Methodology

The TII Guidelines (2009), provide criteria for ranking of the identified hydrogeological features within the assessment hydrogeology study area.

The rating of potential impacts on the hydrogeological environment has been assessed by:

- Classifying the importance of the relevant attributes (Table 10.1)
- Quantifying the likely magnitude of any impact on these attributes (Table 10.2)
- Determining the resultant significance (Table 10.3)

Table 10.1 Criteria for Rating Site Attributes - Estimation of Importance of Hydrogeology Attributes (TII, 2009)

Importance	Criteria	Typical Example
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 or value on a regional or national scale	Regionally important aquifer with multiple well fields. Groundwater supports river, wetland or surface water body ecosystem protected by national legislation NHA status Regionally important potable water source supplying >2500 homes. Inner source protection area for regionally important water source
High	Attribute has a high quality or value on a local scale	Regionally Important Aquifer Groundwater provides large proportion of baseflow to local rivers Locally important potable water source supplying >1000 homes Outer source protection area for regionally important water source Inner source protection area for locally important water source
Medium	Attribute has a medium quality or value on a local scale	Locally Important Aquifer Potable water source supplying >50 homes Outer source protection area for locally important water source
Low	Attribute has a low quality or value on a local scale	Poor Bedrock Aquifer Potable water source supplying <50 homes

Table 10.2 Criteria for Rating Impact Significance at EIA Stage - Estimation of Magnitude of Impact on Hydrogeology Attributes (TII, 2009)

Magnitude of Impact	Criteria	Typical Examples[1]
Large Adverse	Results in loss of attribute and/or quality and integrity of attribute	Removal of large proportion of aquifer Changes to aquifer or unsaturated zone resulting in extensive change to existing water supply springs and wells, river baseflow or ecosystems Potential high risk of pollution to groundwater from routine run-off[2] Calculated risk of serious pollution incident during operation >2% annually[3]
Moderate Adverse	Results in impact on integrity of attribute or loss of part of attribute	Removal of moderate proportion of aquifer Changes to aquifer or unsaturated zone resulting in moderate change to existing water supply springs and wells, river baseflow or ecosystems Potential medium risk of pollution to groundwater from routine run-off[2] Calculated risk of serious pollution incident during operation >1% annually[3]
Small Adverse	Results in minor impact on integrity of attribute or loss of small part of attribute	Removal of small proportion of aquifer Changes to aquifer or unsaturated zone resulting in minor change to water supply springs and wells, river baseflow or ecosystems Potential low risk of pollution to groundwater from routine run-off[2] Calculated risk of serious pollution incident during operation >0.5% annually[3]
Negligible	Results in an impact on attribute but of insufficient magnitude to affect either use or integrity	Calculated risk of serious pollution incident during operation <0.5% annually[3]

[1] Additional Examples are provided in the TII Guidance Document

[2] refer to Method C, Annex I, Annex I of HA”16/06

[3] refer to Method D, Appendix B3/Annex I of HA216/06

Table 10.3 Rating of Significant Environmental Impacts (TII, 2009)

		Magnitude of Impact			
		Negligible	Small Adverse	Moderate Adverse	Large Adverse
Importance of Attribute	**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

The 2009 TII impact assessment methodology was developed based on EPA publication guidelines at that time. It should be noted the EPA guidelines (most recent publication update being 2022) have subsequently been updated to include two additional 'Significance' rankings to the earlier EPA guidance and the TII 2009 guidelines, which remain the current guidance for road projects. The two additional EPA ratings of 'Not Significant' and 'Very Significant' have not yet been incorporated by TII into the Significance ranking matrix (refer to Table 10.3). The rating of significance used in this updated EIAR follows TII 2009 significance nomenclature and as such does not include 'Not Significant' nor 'Very Significant'. Where 'Not Significant' would apply based on EPA (2022) then Imperceptible is used for TII (2009) and where 'Very Significant' would apply based on EPA (2022) then Profound is used for TII (2009).

These ratings are comparable to the EPA 2022 guidance as shown in Table 10.4.

Table 10.4 Comparison of Significance of Impact Criteria used in this Assessment with the EPA 2022 Guidance

<table>
<tr><th>Significance as per EPA 2022</th><th>Rating of Significance used in this Appraisal (TII 2009)</th></tr>
<tr><td>Imperceptible</td><td rowspan="2">Imperceptible</td></tr>
<tr><td>Not Significant</td></tr>
<tr><td>Slight</td><td>Slight</td></tr>
<tr><td>Moderate</td><td>Moderate</td></tr>
<tr><td>Significant</td><td>Significant</td></tr>
<tr><td>Very Significant</td><td rowspan="2">Profound</td></tr>
<tr><td>Profound</td></tr>
</table>

The rating of significant environmental impacts also considers the duration and frequency when assessing the magnitude of impact. With each impact described as being momentary, brief, temporary, short-term, medium-term, long-term or permanent. The frequency of effects is also described either in terms of reoccurrence (one, rarely, occasionally, frequently, constantly) or timing (hourly, daily weekly, monthly, seasonally or annually). If an effect is reversible, for example through remediation or restoration, then this is also described.

Description of the durations are listed below:

- Momentary effects last from seconds to minutes
- Brief effects last less than one day
- Temporary effects last less than one year
- Short-term effects last one to seven years
- Medium-term effects last seven to fifteen years
- Long-term effects last fifteen to sixty years
- Permanent effects last over sixty years

In line with guidelines, following the assessment of potential impacts, specific mitigation measures are presented to avoid, reduce and remedy any negative impacts on the hydrogeological environment. These are described in Section 10.1 below. Residual impacts which are the potential impacts which result after mitigation measures have been fully established and are described in Section 10.7 below. The length of time it takes for each mitigation measure to take effect varies but they are designed to ensure that predicted impacts are minimal.

10.3 Receiving Environment

10.3.1 Introduction

This section provides a characterisation of the hydrogeological receiving environment. This section has been updated since the 2018 EIAR to take into account all additional groundwater monitoring undertaken during 2023 and 2024, an additional karst feature which was identified during 2023 and 2024 site walkovers, 2024 ground investigations at Galway Racecourse, and updated information available from EPA, GSI and OPW. This section provides an up-to-date assessment of the hydrogeological receiving environment. Importantly, the overall conceptualisation of the hydrogeological environment remains the same and critical determinations, such as maximum groundwater levels, remain unchanged.

On conclusion of the 2020 Oral Hearing the following summary was provided in the ABP inspectors' report (ABP-302885-18 & ABP-302848-18) Section 11.9.64:

> *Mr Dodds states that, in his professional opinion, appropriate interpretation of the findings of the investigations have been undertaken, enabling the applicant to develop a robust conceptual model which demonstrates a sufficient understanding of the hydrogeological environment. Having reviewed the information submitted by the applicant in the EIAR and at the oral hearing, I would concur with Mr Dodds that the applicant has demonstrated a clear and comprehensive understanding of the relatively complex and varied hydrogeological environment and I consider that this allows for the potential impacts of the PRD* to be properly understood and assessed.*
>
> **Proposed Road Development*

This update to the Receiving Environment includes karst feature K328 south of the proposed N6 GCRR and seven groundwater supply wells. No additional Groundwater Dependant Terrestrial Ecosystems (GWDTE) have been identified since the 2018 EIAR.

The hydrogeological environment is presented firstly in the regional context using publicly available information and then secondly in detail for the hydrogeology study area based on information obtained specifically for the Project.

The description of the receiving environment will document the hydrogeological characteristics of aquifer classification, groundwater vulnerability, recharge, and groundwater receptors including aquifers, groundwater abstractions and groundwater dependant habitats.

The hydrogeology data on which this section is founded is provided in the following appendices:

- Appendix A.10.1 Well condition reports
- Appendix A.10.2 Karst survey report
- Appendix A.10.3 Water level monitoring report
- Appendix A.10.4 Groundwater quality monitoring report
- Appendix A.10.5 Aquifer test reports

Appendix A.10.1 Well condition reports comprise of two reports, one from 2014 and one from 2023. Both well condition reports were undertaken and completed prior to the start of groundwater monitoring campaigns to assess the suitability of wells as part of the groundwater monitoring network. The 2014 report was included in the 2018 EIAR whilst the 2023 report presents new current data. The 2023 report was undertaken so that this updated EIAR could be updated with winter and summer groundwater levels for the 2023/2024 hydrometric year.

Appendix A.10.2 Karst survey report has been updated to include details of karst feature K328, which is a swallow hole located in the southern area of Galway Racecourse. Karst feature was not included in the 2018 EIAR and has been documented as part of site walkover at Galway Racecourse. Except for the inclusion of feature K328, no other additional karst features have been included.

Appendix A.10.3 Water level monitoring report is a new addition to this updated EIAR. In the 2018 EIAR the appendix included data only. Appendix A.10.3 comprises of Project data, public data and the interpretation thereof. The Project data comprises of both the first (2014-2017) and second water (2023-2024) groundwater monitoring campaigns. The Appendix also includes summary for all data including maximum and minimum values for all monitoring wells across both the Galway Granite Batholith and the Visean Undifferentiated Limestone. Interpretation of these data sets is also included in the appendix. The groundwater levels in the area between the River Corrib and the N83, i.e. Section 3, are more complex than elsewhere along the Project. In order to aid the description of the groundwater levels and flow directions in this Section 3, groundwater contours have been interpreted for minimum and maximum groundwater levels and are included as figures in Appendix A.10.3. For completeness, the appendix also includes details and full records of OPW river level data for both the River Corrib at Dangan and for the Terryland River. Groundwater level summaries are provided in the main body of this updated EIAR based on the data that is presented in Appendix A.10.3. The conclusions of the 2018 EIAR remain valid for this updated EIAR.

Appendix A.10.4 Water quality monitoring report has been updated for this updated EIAR. In the 2018 EIAR the data presented was from the 2015 to 2017 groundwater monitoring campaign. For this updated EIAR the groundwater quality data from the 2023 to 2024 groundwater quality campaign has been included. The conclusions of the 2018 EIAR remain valid for this updated EIAR.

Appendix A.10.5 Aquifer test reports provide the details of all pumping test results and data from aquifer tests undertaken on the Project. The 2018 EIAR included one pumping test (PW01), 15 variable head tests and eight packer tests. The data that informed the 2018 EIAR is also included in Appendix A.10.5 of this updated EIAR and has been updated to include one additional pumping test undertaken at Galway Racecourse (TW101).

10.3.2 Regional Hydrogeology

The hydrogeology study area is divided into two main regions based on the contrasting aquifer properties for the two main geological rock types in the region. As described in Chapter 9, Soils and Geology, the bedrock geology may be divided into:

- The Galway Granite Batholith (comprising of granite and orthogranite) underlies the western section of the proposed N6 GCRR from the R336 west of Bearna Village to the N59 Moycullen Road
- The Visean Undifferentiated Limestone, which underlies the eastern section of the proposed N6 GCRR from the N59 Moycullen Road to existing N6 at Coolagh and also includes the proposed development at Galway Racecourse

10.3.2.1 Western Section

The GSI bedrock aquifer map for the western section is presented in Figure 10.1.001. The GSI classification of the granite and orthogranite (including multiple dolerite dykes) of the Galway Granite Batholith are all classified to be Poor Aquifers that are only productive in local zones (Pl). Poor Aquifers generally provide little groundwater for water supply or for baseflow to surface water bodies. However, they are sometimes used for local supplies to individual houses/farms. The GSI assessment of the Galway Granite Batholith being a Pl aquifer is based on the low occurrence of high yielding groundwater wells and the abundance of surface water features as well as man-made drainage ditches.

Under the Water Framework Directive, the GSI have delineated several groundwater bodies (GWB) in the Project area and the Galway Granite Batholith includes two GWB which are of relevance to the Project. Both of these GWB have been assigned a status pursuant to Article 4 of the WFD. The boundaries and extents of the GWB are determined based on topography and surface watersheds (refer to Figure 10.2.001). The two groundwater bodies and their 2021 WFD status are presented in Table 10.5.

Table 10.5 EPA WFD Groundwater Body Status and Risk in the Western Section

Water Feature	European Code	WFD Risk	WFD Status (2016 - 2021)	Location
Spiddal GWB	IE_WE_G_0004	Not at risk	Good	Underlying the Project
Maam - Clonbur GWB	IE_WE_G_0006	Not at risk	Good	Underlying the Project

The GSI describe both groundwater bodies as being overlain by blanket peat except in urban areas where the bedrock is overlain by man-made fill. Where the blanket peat is present then the overburden thickness is generally less than 3m.

The vulnerability of the groundwater body is the term used to describe the ease with which the groundwater in the area can be contaminated by human activities. The vulnerability is determined by many factors including the travel time, the quantity of contaminants and the capacity of the deposits overlying the bedrock to attenuate contaminants. These factors in turn are based on the thickness and permeability of the overburden e.g. groundwater in bedrock which is exposed at the surface. The criteria for determining groundwater vulnerability, as described by the GSI, is shown in Table 10.6 below.

Table 10.6 GSI Groundwater Vulnerability Mapping Guidelines (DoELG 1999)

Vulnerability Rating	Hydrogeological Conditions				
	Subsoil Permeability (Type) and Thickness			Unsaturated Zone	Karst Feature
	High permeability (sand/gravel)	Moderate permeability (e.g. Sandy subsoil)	Low permeability (e.g. Clayey subsoil, clay, peat)	(Sand/gravel aquifers only)	(<30m radius)
Extreme (E)	0 - 3.0m	0 - 3.0m	0 - 3.0m	0 - 3.0m	-
High (H)	>3.0m	3.0 - 10.0m	3.0 - 5.0m	>3.0m	N/A
Moderate (M)	N/A	>10.0m	5.0 - 10.0m	N/A	N/A
Low (L)	N/A	N/A	>10.0m	N/A	N/A

Notes: (1) N/A = not applicable.

(2) Precise permeability values cannot be given at present.

(3) Release point of contaminants is assumed to be 1-2m below ground surface.

The GSI data on groundwater vulnerability (see Figure 10.3.001) shows that bedrock is at or near surface (X or E category) for approximately 25% of the western section of the Project. Where cover is present on the granite bedrock it is generally thin (<3m), with rock outcropping on higher ground, and thick subsoil deposits (up to 6m) on lower ground. Peat bogs occur in a number of locations across the granite landscape, generally in low lying areas or hollows where surface water ponding is present. Where peat is present it will generally allow very limited recharge to bedrock and instead will promote horizontal flow to drains, ditches and water courses.

The combination of poor aquifer and Blanket bog cover, where rock is not exposed, limits the quantity of recharge that can infiltrate to ground. The recharge quantities are estimated by the GSI and are shown on Figure 10.4.001.

Met Éireann reports an annual average of 1,250mm of rainfall for the area and with losses by evapotranspiration accounted for (450mm/yr).

Based on these data sources, the available effective rainfall is calculated to be 800mm (Table 10.7 below). Given that the GSI indicate a recharge cap of 100mm/yr for the Galway Granite Batholith then only 12.5% of effective rainfall is available as recharge, with the remaining balance of 700mm/yr flowing to streams as either overland flow or shallow flow through the subsoil. Based on the aquifer properties and recharge characteristics described, then the groundwater catchments are expected to match surface water drainage divides.

Table 10.7 Recharge assessment for the Galway Granite Batholith (Pl) (av mm/yr Met Éireann)

Vulnerability	Rainfall (mm/yr)	PE (mm/yr)	Effective Rainfall (mm/yr)	Recharge (mm/yr)	Runoff (mm/yr)
Granite and Orthogranite (irrespective of vulnerability)	1,250	450	800	100	700

Based on the poor aquifer properties and the low likelihood of local productive zones, the actual recharge quantities for Galway Granite Batholith will not vary significantly from Table 10.7.

The GSI overburden thickness for the area shows that rock outcrops on topographic highs but in low lying areas the soils and subsoils are thicker, generally up to 5m thick. Generally, the aquifer properties (hydraulic conductivity and storage) will be low for the Galway Granite Batholith, especially on higher ground, where the rock is most competent. In low lying areas the aquifer properties remain poor but hydraulic conductivity may be locally productive due to weathering along fault lines.

Effective rainfall will generally run off to surface water by means of drains and ditches. In elevated areas the effective rainfall will rapidly run off the steeper gradient. In low lying areas the slight topographic gradients and thicker overburden is likely to cause impoundment of effective rainfall causing perching above the rock head with local ponding to surface.

The GSI descriptions of the Spiddal GWB and Maam - Clonbur GWB (GSI 2004a and 2004b) state that the water table is shallow in the Galway Granite Batholith and yields from wells are low. Groundwater flow paths are only in fractured and weathered zones, typically in the vicinity of faults. These pathways will be short and flow directions will follow topography towards watercourses. The GSI report flow paths in the Spiddal GWB to be up to 100m long whilst the Maam - Clonbur GWB to be 30-300m. Groundwater will discharge to streams and rivers but the baseflow contribution will be relatively low.

10.3.2.2 Eastern Section

The GSI bedrock aquifer map for the eastern section is presented in Figures 10.1.001 and 10.1.002. The GSI classify the Visean Undifferentiated Limestone as being a regionally important karstified aquifer, which is dominated by conduit flow (Rkc).

Regionally important aquifers are important groundwater resources. A regionally important bedrock aquifer is capable of supplying regionally important abstractions (e.g. large public water supplies), or ‘excellent’ yields (>400 m^3/d). The assessment by the GSI is based upon the occurrence of high yielding groundwater wells, the presence of karst landforms and features but also the relatively low abundance of surface water features and man-made drainage.

The Visean Undifferentiated Limestone of the hydrogeology study area (refer to Figures 10.2.001 and 10.2.002) includes three GWB that are named specifically to highlight that groundwater from that GWB supports ecology (all three include GWDTE in their name) (note that GWDTE Lough Corrib Fen 3 & 4 is one GWB). Groundwater Dependant Terrestrial Ecosystems (GWDTE) can be sensitive to changes in the groundwater environment and are considered as specific receptors in this chapter. The EPA WFD groundwater body status and risk for all the GWBs in the eastern section is presented below in Table 10.8, noting that all of these GWB have been assigned a status pursuant to Article 4 of the WFD.

Table 10.8 EPA WFD Groundwater Body Status and Risk in the Eastern Section

Water Feature	European Code	WFD Risk	WFD Status (2016 - 2021)	Location
GWDTE Lough Corrib Fen 1 (Menlough)	IE_WE_G_0119	Not at risk	Good	Underlying the Project
GWDTE Lough Corrib Fen 2	IE_WE_G_0109	Not at risk	Good	Underlying the Project
GWDTE Lough Corrib Fen 3 & 4	IE_WE_G_0106	Not at risk	Good	Underlying the Project
Clarinbridge	IE_WE_G_0008	Not at risk	Good	Underlying the Project
Clare-Corrib	IE_WE_G_0020	Not at risk	Good	Underlying the Project
Ross Lake	IE_WE_G_0010	Not at risk	Good	Underlying the Project

The GSI national dataset for groundwater vulnerability (Refer to Figures 10.3.001 and 10.3.002) shows that the subsoil cover has a variable thickness across the Visean Undifferentiated Limestone. Generally, on higher ground the limestone either outcrops or is near surface but there are areas where significantly deeper overburden is identified, such as Coolagh Lakes, Ballindooley Lough, Terryland River and Lough Atalia. During the ground investigation for the 2006 Galway City Outer Bypass (GCOB, 2006) a number of areas with thick overburden were investigated by geophysics and drilling, these included areas near the River Corrib at Menlough as well as the north edge of Ballindooley Lough (Appendix A.9.1 and A.9.2).

Adjacent to Ballindooley Lough, geophysics undertaken for the 2006 GCOB identified that whilst bedrock was near surface in the fields to the northwest and southeast of Ballindooley, in the valley floor itself the overburden was greater than 18m deep. Similar features of bedrock being near surface at one location but then a short distance away being significantly deeply buried were also encountered near the River Corrib at Menlough where drilling proved the overburden to be up to 70m thick. In these areas at Ballindooley and Menlough the morphology of the bedrock topography and burial by overburden can be described as a buried valley, which is often referred to in academic texts as a palaeo-landscape.

Related to the vulnerability mapping is the GSI recharge mapping. Figures 10.4.001 and 10.4.002 show the GSI quantification of recharge for the eastern section. Based on the GSI mapping the limestone aquifer has a significantly high infiltration capacity.

Areas of outcrop are attributed a recharge rate of 85% (greater if karst present), with areas of thin overburden attributed 60% if the subsoil is of a moderate or high permeability. Those areas where the overburden is thicker and of low permeability, such as Coolagh Lakes, Ballindooley Lough, Terryland River and Lough Atalia then the recharge coefficient is estimated by the GSI as 15% or less. Due to the generally high recharge acceptance of the Rkc aquifer the GSI do not apply a recharge cap to the annual quantity of recharge. Table 10.9 below presents regional estimates on recharge and run-off for the eastern section.

Table 10.9 Recharge Assessment for the Visean Undifferentiated Limestone (Rkc) (av mm/yr Met Éireann)

Vulnerability	Recharge Coefficient	Rainfall (mm/yr)	PE (mm/yr)	Effective Rainfall (mm/yr)	Recharge (mm/yr)	Runoff (mm/yr)
Limestone at (X) or near (E) surface	60-100%	1250	450	800	480-800	0-320
Moderate (M) or high (H) vulnerability	15-60%	1250	450	800	120-800	320-680
Low (L) vulnerability	<15%	1250	450	800	120	680

Conduit flow dominated karstified landscapes are often characterised by an underground drainage network of interconnected fissures/conduits that have been enlarged by dissolution, which can be several kilometres long. Groundwater often discharges at springs and there are strong connections between the groundwater and surface water. Karst landscapes are associated with features such as springs, enclosed depressions (dolines), caves and swallow holes which may provide enhanced recharge (point input) at these locations.

Regionally important karstified aquifers are important groundwater resources and can supply regionally important abstractions (e.g. large public water supplies) or ‘excellent’ well yields (>400 m^3/d). Karstification of the aquifers is typically distributed unevenly throughout the bedrock where groundwater velocities in the conduits/fissures may be high but the aquifer storage may be low. Based on the Rkc classification the bulk permeability of the aquifer is likely to be high but local areas of low or moderate permeability will exist where the aquifer has not developed karst enhancement.

Flow by fractures can be variable but typically will range between $1x10^{-4}$m/s to $1x10^{-6}$m/s. Karst flow can be significant if conduits are present and generally flow in conduits is $1x10^{-3}$m/s or lower (Waltham, 2005).

On the basis of the Rkc classification by the GSI the bulk permeability of the aquifer is likely to be high but local areas of low or moderate permeability will exist where the aquifer has not developed karst enhancement. Karst features are also discussed in Chapter 9, Soils and Geology.

It should be noted that more karst features are identified in this chapter than Chapter 9, Soils and Geology and that this is solely due to the larger study area in the east for the hydrogeological assessment for hydrogeology, noting that the study area in the east has enlarged since 2018 EIAR due to the increase in the Assessment Boundary.

The hydrogeological assessment considers all karst features which are either supporting the hydraulic regime of the area or specific receptors e.g. ecological features and these have been identified and discussed in the conceptual model presented in Section 10.3.4.

As well as supporting specific receptors, karst features such as enclosed depressions support the hydrogeology of an area by providing enhanced recharge (point input) at those locations.

As outlined in Section 10.2.5.2, a detailed karst survey of the hydrogeology study area was undertaken as part of the constraints and route selection studies for the proposed N6 GCRR and was updated for this updated EIAR. The karst survey report is presented in Appendix A.10.2.

10.3.3 Local Hydrogeology

As highlighted in Section 10.3.1 the footprint of the Project is divided into two main geological units, which have contrasting aquifer, vulnerability and recharge characteristics.

The western section of the Project is underlain by the poorly productive (Pl), low recharge aquifer of the Galway Granite Batholith and the eastern section is underlain by the regionally important karstified (Rkc), high recharge aquifer of the Visean Undifferentiated Limestone.

When examining the receiving environment of the hydrogeology study area, the Project has been divided into four sections to allow for ease of presentation and description of the underlying ground conditions due to the volume of information available. To allow for consistency, these sub-divisions were also applied in Chapter 9, Soils and Geology. The four sections are as follows and are as per the 2018 EIAR:

- Section 1: R336 to the N59 Moycullen Road
- Section 2: N59 Moycullen Road to the River Corrib
- Section 3: River Corrib to the N83 Tuam Road[2]
- Section 4: N83 Tuam Road to the existing N6 at Ardaun, Coolagh

The ground investigations undertaken in each of the four sections were tailored to provide data that will allow hydrogeological assessment specific for the Project in that section. For example, aquifer testing, and groundwater monitoring wells were sited where cuttings would be required by the Project whereas geophysics was used to determine the depth to bedrock or as an indicator for karst.

The information presented in this section forms the basis for Section 10.3.4, which develops a conceptual site model for the hydrogeology study area.

10.3.3.1 Section 1 – R336 to N59 Moycullen Road (Ch. 0+000 – 8+500)

Section 1 of the proposed N6 GCRR is situated on the Galway Granite Batholith. The topography of Section 1 is undulating with the highest point of 100mOD forming part of a northwest to southeast ridge at Letteragh. This ridge also marks the watershed for surface water and groundwater sub catchments. West of the ridge all the surface water drainage and the Spiddal GWB drain southwards to Galway Bay North, whilst east of the ridge all surface water and the Maam-Clonbur GWB drain eastwards to the Corrib (Figure 10.2.001).

Bedrock Aquifer

As identified in the section on regional hydrogeology, the Galway Granite Batholith is a poor aquifer (Pl) that is locally productive in local zones such as faults (Figure 10.1.001). Where faults are present then these tend to form areas of deeper subsoil in low lying ground.

The geophysics undertaken included electrical resistivity tomography (ERT) and seismic surveying, this data is presented in Appendix A.9.1. As presented in the Chapter 9, Soils and Geology, the ERT survey shows that the bedrock is generally shallow and of high resistivity, indicating competent rock. There are shallow zones where lower resistivity is measured. These may indicate areas of increased weathering along vertical features such as faults where there is a localised linear feature that may have localised storage of groundwater.

Shallow features (<10m) can be observed on the mainline of the proposed N6 GCRR at Ch. 5+500 and Ch. 7+750, as well as a deeper feature (c.20m) on the N59 Link Road North (LNR) at Ch. 0+250 LNR. These features are narrow zones of limited lateral extent, some of which may have localised storage of groundwater. The unconformity contact between the Galway Granite Batholith and the Visean Undifferentiated Limestone is marked by a sharp change in slope at Ch. 8+890, which also conforms to a deep vertical feature in the ERT profile at Ch. 8+920. This feature is developed in the limestone side of the contact with the granite and as such is described in Section 10.3.3.2.

The seismic survey is used to identify the top of competent bedrock and as such is a good indicator for the thickness of the combined overburden and weathered layer. The seismic data shows that competent bedrock is generally 2-3m in depth, being slightly deeper (up to 5m) in some low-lying areas.

Aquifer Properties

Aquifer testing was undertaken in five monitoring boreholes in the Galway Granite Batholith. These tests were small scale pumping tests so that observation could be made on the drawdown in the well in addition to the monitoring of the water level recovery, as a rising head test. The data from the test and analysis of the

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[2] Formally known as the N17 Tuam Road

rising head test are presented in Appendix A.10.5. This data shows that the water level in the wells was drawn down rapidly at a low abstraction rate, which is indicative of low hydraulic conductivity. Measurement of the recovery of the wells indicates a range of hydraulic conductivity in the Galway Granite Batholith between 9.7×10^{-7} and 4.6×10^{-6}m/s.

Groundwater Vulnerability

Comparison of GSI vulnerability mapping and information from GI and walkover surveys identifies that bedrock is at or very near surface at topographic highs. Borehole records confirm that the depth to bedrock increases away from topographic highs. The ground investigation and walkover surveys confirm with the vulnerability mapping by the GSI for the Galway Granite Batholith (Figure 10.3.001). Approximately 40% of the route of the Project in Section 1 has rock at or near surface based upon GSI vulnerability mapping.

As presented in the regional hydrogeology, recharge quantities are low, which is due to the blanket bog cover and also due to the relatively thin weathered zone and low aquifer properties. The GSI recharge cap of 100mm/yr is considered appropriate based on-site observation and the aquifer tests undertaken (Figure 10.4.001).

Groundwater Levels

Groundwater level monitoring in the Galway Granite Batholith indicates that the groundwater level is generally near surface across the Project area, with only small scale seasonal variation. Where the topography forms rocky ridges then the water table may be slightly deeper below ground level.

Groundwater flow generally follows topography and drains towards rivers, streams and the coast. Water level data and interpretation thereof is presented in Appendix A.10.3.

Water Quality

Water sampling from monitoring wells in the Galway Granite Batholith indicates that the groundwater is generally of good quality with moderate levels of calcium and magnesium. There are local detections of bacteria such as faecal coliform, which is most likely agricultural or from poorly operating domestic wastewater treatment plants. Water quality data is presented in Appendix A.10.4.

10.3.3.2 Section 2 - N59 Moycullen Road to River Corrib (Ch. 8+500 – 9+400)

Between the N59 Moycullen Road and the River Corrib there is a narrow section of limestone (Figure 10.1.001). This strip of limestone bedrock comprises the Ross Lake GWB (Figure 10.2.001), which extends 3km northwest to Kentfield.

Input to the aquifer comprises of recharge to the limestone area ($1.5km^2$), and also runoff from the granite slopes of the Maam-Clonbur GWB ($3km^2$), which flows down slope and onto the limestone. There is a significant amount of urban development in this area and it is likely that some streams are culverted below developments to the River Corrib, others may infiltrate into the limestone.

Bedrock Aquifer

The contact between the Galway Granite Batholith and the Visean Undifferentiated Limestone is an unconformity (GSI Geology Memoir). The ERT geophysics data for the contact is shown in geophysics profile 3/5 (GP3/5) confirms the contact between granite and limestone at Ch. 8+890 to be vertical and sharp. The geophysics profile matches a distinct change in the topography and indicates that the contact slopes steeply eastwards.

The depth to rock in the limestone is significantly more variable than the granite bedrock. The vertical nature of the low resistivity feature and general vertical steps in the rock topography indicates that the limestone may be locally faulted and/or fractured.

Groundwater flow is likely to be dominated by fracture flow but the low resistivity feature in the limestone near the contact between granite and limestone indicates likely karstification and possible conduit flow. There are a number of small scale karst landforms located between the N59 Moycullen Road and the River Corrib, which include small enclosed depressions (K10, K11 and K12) and small springs (K2, K7 and K9).

No site-specific groundwater level or aquifer properties data were collected in Section 2. As outlined in Section 10.2.5.3 groundwater level, aquifer properties and groundwater quality monitoring was focused on areas of cutting, where dewatering of the bedrock aquifer would be required or groundwater receptors. This section of the proposed N6 GCRR is entirely on embankment and geophysics was the primary investigative tool used, with boreholes (BH3/23 and BH3/24) installed to calibrate the geophysical data.

Groundwater Vulnerability

The criteria for determining groundwater vulnerability, as described by the GSI, is shown in Table 10.6 Groundwater vulnerability as mapped by the GSI is presented in Figure 10.3.001. Comparison of GSI vulnerability and information from GI and walkover surveys indicate that the data sets are consistent in this area.

Key inferences from the vulnerability mapping are confirmation that the depth of rock head increases towards the River Corrib and that recharge is higher where the bedrock is shallower (this infers that effective rainfall increasingly runs off to surface water closer to the river) (Figure 10.4.001).

10.3.3.3 Section 3 - River Corrib to N83 Tuam Road (Ch. 9+400 – 14+000)

Section 3 of the proposed N6 GCRR comprises the area between the River Corrib and the N83 Tuam Road. This area encompasses the GWDTE Lough Corrib Fen 1 GWB, GWDTE Lough Corrib Fen 2 GWB, GWDTE Lough Corrib Fens 3 and 4 GWB and the Clare Corrib GWB (Figure 10.2.002). The use of GWDTE in naming for these groundwater bodies by the GSI does not signify that the GWB is a GWDTE but rather because GWDTE do receive groundwater from these GWB.

The topography of Section 3 is undulating with the highest point being 40m OD immediately west of Lackagh Quarry. There are also extensive lowland areas less than 10m OD at Coolagh Lakes, Ballindooley Lough and Terryland River.

Bedrock Aquifer

As identified by the regional hydrogeology the eastern section of the Project is underlain entirely by the Visean Undifferentiated Limestone, which is a regionally important karst aquifer (Rkc) (Figure 10.1.002).

The GSI karst database includes a national record of all karst landforms, which identifies that turloughs, dolines, stream sinks and one cave have been recorded in the Project area. The karst survey (Appendix A.10.2) provides a description of the landforms.

Aquifer Properties

The Visean Undifferentiated Limestone aquifer is a regionally important aquifer that is associated with high permeability and numerous groundwater abstraction wells. Abstraction rates of wells identified in the hydrogeology study area are high and confirm the characteristics of the aquifer.

The GSI have characterised the aquifer as having a high recharge coefficient (85%) with high infiltration rates and no recharge cap. The Rkc characterisation by the GSI is due to the presence of karst landforms and underground pathways. Although karst is present (refer to Appendix A.10.2 Karst survey report) observations from quarries and bedrock exposure also indicate a moderate to high frequency of fracturing in the bedrock. Based on the relatively high fracture frequency then fracture flow will also be a common pathway in the limestone aquifer.

Aquifer testing was undertaken in six monitoring boreholes in Section 3. These tests were small scale pumping tests so that observation could be made on the drawdown in the well as in addition to monitoring the recovery as a rising head test. The data from the drawdown test and analysis of the rising head test, are presented in the aquifer testing data in Appendix A.10.5. This data shows a relatively wide range of response to the drawdown and recovery.

Measurement of the recovery of the wells has a range of hydraulic conductivity in the Visean Undifferentiated Limestone between 3.1×10^{-4} and 5×10^{-9}m/s. The higher permeability is likely to be testing karst flow in the aquifer, whilst the lower permeability values indicate the borehole mainly represents matrix flow.

Section 3 includes surface karst features, including enclosed depressions (dolines), turloughs, limestone pavement, springs, sinks, estavelles and one cave. Karst features are presented in Figure 10.1.002 and detailed in the Karst Survey Report (Appendix A.10.2). The karst features located in Section 3 can be divided into those between Menlough and Ballindooley as well as those associated with the Terryland River.

There are a number of karst features between Menlough and Ballindooley including springs, turloughs and enclosed depressions. There are two karst springs (K17 and K25). Of these K17 is a small spring that contributes to the River Corrib, whilst K25 (referred to as Western Coolagh Spring) is a more significant spring and is the main groundwater supply to the Upper Coolagh Lake.

During the site workover, a ditch out falling to the Upper Coolagh Lake was identified as being a potential spring and this is referred to as the Eastern Coolagh Spring (K45). However, the subsequent ground investigation (including geophysics) confirmed that the feature lies on thick clay subsoil and not limestone bedrock. Monitoring of the water level between 2014 and 2018 at the Eastern Coolagh Spring showed the water level is static showing no seasonality and no connectivity with groundwater levels in bedrock. Based on this assessment the Eastern Coolagh Spring (K45) is assumed to represent local subsoil seepage with surface water runoff. This assumption remains valid based on local groundwater level data collected between November 2023 and 2024.

There are three turloughs between Menlough and Ballindooley, two near Menlough (K20 and K31) and one (K72) near Ballindooley. There are also several enclosed depressions across the area, which are sometimes associated with limestone pavement (for locations of limestone pavement refer to Chapter 8, Biodiversity). Other karst features in the area include a small estavelle adjacent to Ballindooley Lough (K86) and a dug karst feature (K92) that, like K86, has a standing water surface that fluctuates seasonally with the groundwater levels.

The Terryland River bifurcates from the River Corrib at the Corrib Loop of Jordan’s Island. From Jordan’s Island the Terryland River drains eastwards through the old Terryland waterworks and into the low-lying ground of the Terryland basin. Historically the Terryland basin was flooded by the River Corrib. However, during the 1850’s a flood embankment was constructed along the eastern section of the River Corrib as part of the Corrib Drainage and Navigation Scheme. As the old Terryland waterworks are abandoned it is not clear if there is leakage from the River Corrib to the Terryland River. For this assessment it is assumed that there is connectivity between Corrib and Terryland rivers.

The Terryland stream in the present day is principally fed by groundwater and discharges from storm water outfalls which service the surrounding urbanised areas. Under normal conditions the Terryland River sinks at the eastern end of the basin at two stream sinks, named Pollavurleen West and East (K87 and K96) (Refer to karst study in Appendix A.10.2).

Section 3 also includes extensive linear areas of very thick subsoil. The identification of these thick soils is from a combination of investigations for this Project as well as the 2006 GCOB. These areas, which are focused in the areas of Corrib, Menlough, Ballindooley Lough and N83 are interpreted as being buried landscapes, i.e. rock landscapes (valleys, canyons and cliffs) that have been naturally buried by sediments. Based on geophysics and drilling from the project specific ground investigation, buried landscapes have been identified in the townland of Coolagh (Menlough), Coolagh Lakes, Ballindooley Lough, Castlegar and the N83 Tuam Road (refer to Chapter 9, Soils and Geology). Some of these buried landscapes are palaeokarst features, i.e. karst that had developed in the bedrock but subsequently was buried by thick accumulations of sediment.

Groundwater Vulnerability

The GSI vulnerability mapping for Galway is presented in Figure 10.3.002. Across most of the proposed N6 GCRR in Section 3 the groundwater vulnerability is extreme which is due to rock being at or close to surface, as well as the presence of karst features. However, where buried features have been identified, then the vulnerability will be low. These areas also have significantly reduced recharge and a corresponding increase in run-off (Figure 10.4.002).

Groundwater Levels

Groundwater level monitoring in the limestone aquifer between Menlough and Ballindooley area shows a seasonal groundwater level with lowest levels generally occurring during August and September and peak levels typically occurring during December and January. The groundwater levels also show rapid response to storm events. These data confirm the high recharge rate that the GSI report. Interpretation of the groundwater levels for winter peak and summer low are presented together with all groundwater level data in Appendix A.10.3.

Based on the groundwater levels presented in Appendix A.10.3, the extent of the limestone GWB can be refined. Furthermore, sub catchments have been identified within these limestone GWB of Section 3, which are based on identification of buried valleys that act as barriers to groundwater flow and compartmentalise the aquifer. Based on the groundwater level interpretation undertaken for the Project, the extents of the limestone GWB as shown by the GSI (Refer to Figure 10.2.002) have been refined and sub catchments have been identified. The refined GWB of Section 3 are shown on Figure 10.5.002. The GSI GWB that have been refined are: GWDTE Lough Corrib Fen 1 (Menlough) GWB, GWDTE Lough Corrib Fen 2 GWB, GWDTE Lough Corrib Fen 3 & 4 GWB and the Clare-Corrib GWB.

- GWDTE Lough Corrib Fen 1 (Menlough)- has been renamed Lough Corrib Fen 1, its boundary has been refined and the GWB has been split into two sub catchments: Menlough and Lackagh
- GWDTE Lough Corrib Fen 2- is renamed Lough Corrib Fen 2 and the boundary has been refined
- Clare Corrib- has been split into three sub catchments: Terryland, Ballindooley West and Ballindooley East
- GWDTE Lough Corrib Fen 3 & 4- has been renamed Lough Corrib Fen 3&4 and the boundary has been refined. Note that as the boundary has moved further north this GWB no longer underlies the Project

The main groundwater high in Section 3 lies to the west of Lackagh Quarry near monitoring borehole BH04 (Refer to Appendix 3 for the Water Level Monitoring Report). At this location the water table forms a divide between westward groundwater flow towards Coolagh Western Spring, which feeds Coolagh Lakes, and eastward flow to Ballindooley Lough and monitoring well RP-2-03.

Section 3 of the Project includes one active quarry at Two-Mile-Ditch quarry. An Bord Pleanála (ABP) inspectors report for this quarry QD07.QD0021 (2016) states in Section 9.6 that water is managed on site by discharge to ground under licence. The 2016 ABP Inspector’s report for the quarry extension identified that groundwater levels will continue to be locally drawn down in the surrounding Visean Limestone by dewatering in the quarry void, which will maintain the existing groundwater regime. The proposed restoration plan (Planning Condition 10) will result in a rebounding of groundwater levels in the quarry void to specified maximum of 11m AOD, which will form a large, enclosed quarry lake.

Water Quality

Water sampling from monitoring wells in the Menlough and Ballindooley area indicates that the groundwater is generally of good quality with high levels of calcium and magnesium. There are local detections of bacteria such as faecal coliform, which is most likely agricultural or from poorly operating domestic wastewater treatment plants. Water quality data is presented in Appendix A.10.4.

10.3.3.4 Section 4 – N83 Tuam Road to existing N6, Coolagh (Ch. 14+000 – 17+500)

Section 4 of the Project extends between the N83 Tuam Road and the existing N6 at Coolagh, Briarhill. This section of the Project traverses the GSI (Figure 10.2.002) GWDTE Lough Corrib Fens 3 & 4 GWB and the Clarinbridge GWB.

There is a significant amount of urban development in this area, which includes Galway Racecourse. There are no surface water features apart from seasonal pluvial flooding on the existing N83 Tuam Road during winter.

The ground investigation identified that the subsoil at the crossing of the N83 Tuam Road has a thickness in excess of 30m which is confirmed by boreholes (RC-3-62 & BH-3-35) and geophysics (GP-3-13 and GP-3-14) (Appendix A.9.2). There is significant thickness of subsoil in the valley floor (below the fields) but bedrock is shallow along the School Road in Castlegar (BH3/33 and BH3/34) and Galway Racecourse (BH3/36, BH3/47). This indicates that a significant buried landscape is located along the existing N83 Tuam Road. The pluvial flooding that occurs seasonally along the N83 Tuam Road occurs where the areas of thick subsoil are present. Trial pits and soakaway tests into the valley floor of the N83 Tuam Road (SW3/02, SW3/15, SW3/16, SW3/17, SW3/18) confirm that the subsoil is of clay and as such of low permeability.

The buried valley identified at the N83 Tuam Road with a number of smaller features splaying off from it (such as at Galway Racecourse) is the main feature observed in Section 4 of the Project. East of the feature the bedrock rises steeply and forms high ground that forms Galway Racecourse and business parks in Ballybrit and Parkmore.

Bedrock Aquifer

Section 4, like Section 2 and Section 3 is classified by the GSI as being a regionally important karst aquifer with conduit (Rkc) (Figure 10.1.002). Ground investigations (GI) include geophysics, drilling and trial pitting, groundwater monitoring wells have been installed into boreholes and included as part of the groundwater monitoring network. The karst features recorded in Section 4 are listed below and shown in Figure 10.1.002. It is noted that, except for the swallow hole (K328) near Ballybrit castle, Section 4 is generally absent of significant karst features. Those features listed below are all small and slight.

- Two small, enclosed depressions west and north of Galway Racecourse (K104 and K131)
- Three small shallow enclosed depressions north of the existing N6 Coolagh Roundabout ((K172, K175 and K179)
- Small seepages and small enclosed depressions west of the existing N6 Coolagh Roundabout (K126, K129, K130, K132, K134 and K135)
- Further south and downgradient of the existing N6 Coolagh Roundabout an old quarry has some small-scale inflows (K160 and K173), there are some shallow enclosed depressions (K112, K140, K142, K145, K151, K152, K154, K159, K163) and there is one spring (K182)
- Further east and downgradient of the existing N6 Coolagh Roundabout there are several small karst features, including enclosed depressions (K198, K201, K202, K203, K213, K211, K222 and K215) and one small spring K215

Aquifer Properties

The Visean Undifferentiated Limestone aquifer is a regionally important aquifer that is associated with high permeability and highly productive groundwater abstraction wells. The 2024 surveys identified the following information:

- The trial well drilling (TW101) identified a karst cavern (5m in height) located at a depth of 220mbgl.
- Monitoring of the deep trial wells (TW101 and TW103) confirmed the presence of a deep water table (45mbgl) and monitoring of the shallower boreholes (BH01, BH02 and BH03) confirmed a shallow perched water table at the subsoil/bedrock interface.

Aquifer testing was undertaken in five monitoring boreholes located in Section 4 in 2024 surveys. These tests consisted of three small scale pumping tests and two 72-hour pumping tests. One pumping test was undertaken in the shallow aquifer at Galway Racecourse Tunnel and one pumping test in the deep aquifer at Galway Racecourse. The data indicates that the Racecourse Tunnel is in a shallow limestone aquifer, whilst supply wells located further south at Galway Racecourse are in a deeper aquifer. The data from and analysis of the tests is presented in the aquifer testing report Appendix A.10.6.

It is noted that the 72-hour test undertaken at the shallow aquifer at the site of Galway Racecourse tunnel in December 2016 failed to last the intended duration as the well became dry after a short period and did not recharge.

A pumping test was completed on a trial well (TW101) in Galway Racecourse which was drilled to prove sufficient yield at the proposed location for the replacement wells. The testing schedule included a 1-day step test, 72hr constant rate test and recovery test. The test well intercepted a large (5m) cavity at 220mbgl. The

72hr test was completed at the maximum pump capacity for the trial well size (430m^3/d). There was only a minor drawdown in the water table (0.38m) indicating a highly productive well. The estimated transmissivity for the aquifer based on the pumping test results was 1,387m^2/d, which represents a bulk permeability of $9.1x10^{-5}$m/s, however most of this permeability is provided from the 5m cavity at the base of the hole (220m).

This aquifer data shows a range in hydraulic conductivity in the Visean Undifferentiated Limestone of Section 4 between $9.1x10^{-5}$m/s and $4.2x10^{-7}$m/s. The higher permeability was calculated by a pumping test (TW101) with test zone down to 220m bgl. All other permeability results, which range between 1.7x10-6m/s to 4.2x10-7m/s, are from testing in the top 20m and are in the shallow aquifer. The higher permeability value from the deep aquifer indicates karst flow and fracture flow, whilst the lower permeability values indicate mainly matrix flow with only small-scale fractures intersected.

The results indicate that the shallow aquifer has significantly lower permeability than the deeper aquifer and, based on groundwater levels, it is likely that they are separate aquifer units. These aquifer properties and the concept of a shallow and deep aquifer in Section 4 of the proposed N6 GCRR are discussed below in the conceptual model.

Groundwater Vulnerability

The criteria for determining groundwater vulnerability, as described by the GSI, is shown in Table 10.6. Groundwater vulnerability as mapped by the GSI is presented in Figure 10.3.002.

GSI vulnerability shows the rock within three meters of surface at the N83 Tuam Road to Galway Racecourse and then mainly at or near surface from Briarhill to the existing N6. Information from ground investigations and walkover surveys indicates that the bedrock is significantly deeper than this at N83 Tuam Road where the deep buried valley is present. At Briarhill and Galway Racecourse the bedrock is generally nearer surface but small scale palaeo-valleys are also present which are interpreted as being part of the main buried valley feature at the N83.

The GSI show that recharge estimates indicate a recharge coefficient of 30% for the limestone with thicker subsoil and 85% for the limestone at or near surface, with no recharge cap applied. Recharge acceptance of the Briarhill area is considered to have high recharge acceptance of 172-649mm/yr.

Groundwater Levels

Groundwater level data and interpretation is presented in Appendix A.10.3.

Groundwater level monitoring in Section 4 indicates that a perched water table is close to surface in the Briarhill area but that a deeper groundwater table exists below Galway Racecourse. Interpretation of the hydrogeological data indicates that the perched aquifer is a low permeability limestone which locally forms a cap rock that causes runoff and reduces recharge. However, to the east of Briarhill the perched aquifer is absent, and the groundwater table lies 45m below surface. Based on the groundwater levels presented as part of this Project, the Groundwater Bodies as delineated by the GSI have been revised. Owing to the presence of a significant palaeo-valley along the line of the N83 Tuam Road, as proven by project GI (refer to Figures 10.6.009 and 10.6.010), the southern extent of the GWDTE Lough Corrib Fen 3 & 4 GWB has been moved northwards and based on the project data does not occur in Section 4 of the Project (refer to Figure 10.5.002).

The karst features recorded in Section 4 of the proposed N6 GCRR fit well with the hydrogeological differences between Briarhill and Galway Racecourse. Only small-scale karst features are found in the low permeability cap rock limestone at Briarhill, whilst a swallow hole (K328) is present near Galway Racecourse, at Ballybrit Castle.

Drilling investigation at Galway Racecourse indicates high permeability limestone with karst pathways. The limestone below Galway Racecourse is similar to that encountered in Section 3 albeit hydraulically separated by Section 3 by the major buried valley below the N83 Tuam Road.

Water Quality

Water sampling from monitoring wells in Section 4 indicates that the groundwater is generally of good quality with high levels of calcium and magnesium. There are local detections of bacteria such as faecal coliform, which is most likely agricultural or from poorly operating domestic wastewater treatment plants. Water quality data is presented in Appendix A.10.4.

10.3.4 Conceptual Model

This section considers all desk study data together with the Project specific surveys and ground investigations to develop a conceptual model for the hydrogeology study area. The conceptual model includes a refinement of the existing GSI groundwater bodies map based on interpretation of the Project data. The updated map as developed for the 2018 EIAR showing revised extents of groundwater bodies is used in the individual assessments for groundwater receptors, which follows this section.

The Galway Granite Batholith and Visean Undifferentiated Limestone contrast strongly in terms of aquifer classification, recharge and flow pathways and as such are considered as two distinct aquifer units.

The Galway Granite Batholith is classified as a poor aquifer (Pl) by the GSI and the investigation undertaken as part of this Project confirms this. Aquifer testing has shown that the rock type generally has a low permeability but can locally have zones where permeability is higher.

The Visean Undifferentiated Limestone is classified by the GSI as a regionally important karst aquifer (Rkc) that includes conduits. The ground investigation has shown that the Visean Undifferentiated Limestone has a wide permeability range and whilst there are zones of karst there are also areas where no karst features exist.

An overview of the Galway Granite Batholith and Visean Undifferentiated Limestone aquifer is presented below, which is based on the regional description presented in Section 10.3.2 and local setting described in Section 10.3.3. The hydrogeology for the Galway Granite Batholith and the Visean Undifferentiated Limestone are then discussed in detail individually below.

Groundwater flows can be more complex in limestone than granite due to karst pathways and the ground investigation data includes aquifer testing of both rock types to calculate their range of hydraulic conductivity. The aquifer testing is presented in Plate 10.1 below for granite and limestone. This data shows that whilst the granite has a relatively narrow range of values, the limestone spans a significantly wider range. For the limestone areas, this data (as well as the spatial distribution of karst features) is used to identify those areas where karst flow paths through the aquifer are likely but also areas where such pathways are not present. These assessments are based on a combination of trial pits, window samples, drilling, surface geophysical surveys, pumping test and groundwater monitoring and interpretation.

The karst survey (Figure 10.1.002) undertaken is used as an indicator that karst pathways are present within groundwater bodies. The observation of conduit flow at Western Coolagh Spring (K25) and presence of karst features in the area are indicative that karst pathways are present across the sub catchments of the Lough Corrib Fen 1 GWB (Figure 10.5.002). Similarly, the karst survey identifies karst landforms across the sub catchments of the Clare-Corrib GWB (Figure 10.5.002), which is also likely to have conduit pathways in the GWB. However, the survey identified only small-scale karst features in the Clarinbridge GWB, which comprised of small or shallow enclosed depressions and seepages rather than springs.

Aquifer testing was undertaken for both the Galway Granite Batholith and Visean Undifferentiated Limestone across the Project. The data from two pumping tests, 15 variable head tests and eight packer tests are presented in Appendix A.10.5. Plate 10.1 below shows the distribution of hydraulic conductivity and Table 10.10 shows the distribution for both granite and limestone. This data shows the Galway Granite Batholith and the Visean Undifferentiated Limestone within the shallow aquifer of the Clarinbridge GWB (particularly at Briarhill) have a relatively narrow range of hydraulic conductivity.

In contrast the Visean Undifferentiated Limestone aquifer has significant karst in the sub catchments of the following GWB: GWDTE Lough Corrib Fen 1 GWB, the GWDTE Lough Corrib Fen 2 GWB, the Clare-Corrib GWB and the deep part of the Clarinbridge GWB. In these areas where karst is present then the range of hydraulic conductivity is wider. Notably the maximum hydraulic conductivity is an order of magnitude higher. The highest recorded value for hydraulic conductivity is measured in Section 3 where the limestone has karst (5.3×10^{-4}m/s).

Table 10.10 Distribution of Calculated Hydraulic Conductivity (Packer tests, variable Head tests and Pumping tests)

Geological Unit	GWB	Min hydraulic conductivity m/s	Max hydraulic conductivity m/s
Galway Granite Batholith	Spiddal Maam - Clonbur	9.7 x10^{-7}	4.6 x10^{-6}
Visean Limestone Undifferentiated	Lough Corrib Fen 1 Clare-Corrib Clarinbridge (deep aquifer)	5.0 x10^{-9}	5.3 x10^{-4}
Visean Limestone Undifferentiated	Clarinbridge (shallow aquifer)	4.2 x10^{-7}	1.7 x10^{-6}

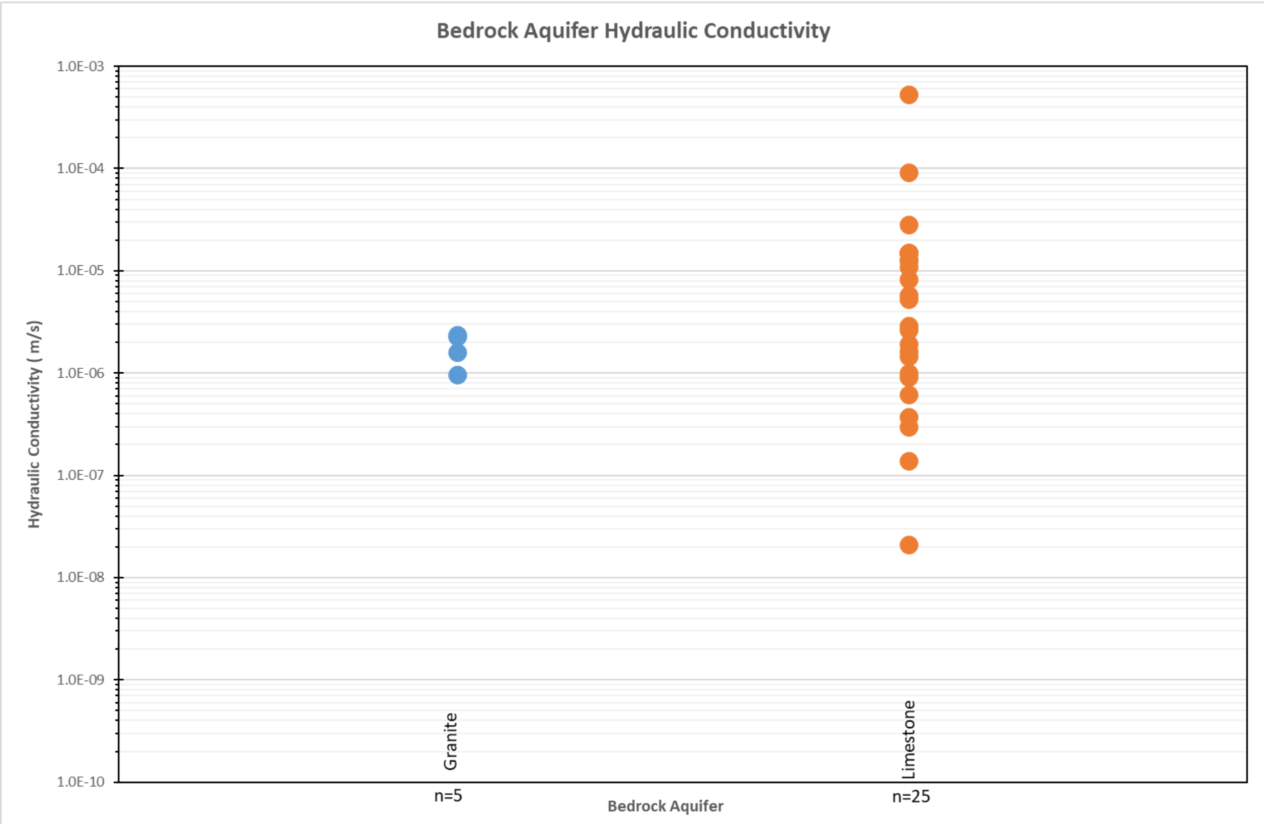

Plate 10.1 Distribution of Calculated Hydraulic Conductivity

10.3.4.1 The Galway Granite Batholith Aquifer

The GSI descriptions for groundwater bodies in the Galway Granite Batholith such as the Spiddal GWB (GSI 2004a) and the Maam-Clonbur GWB (2004b), describes the bedrock as being a poor aquifer with low storage and short groundwater pathways.

The water level data presented in Appendix A.10.3, identifies that the groundwater table remains close to the surface and generally follows topography. On this basis groundwater levels will lower towards the coast and the River Corrib. The groundwater divide between the GSI Spiddal GWB and Maam-Clonbur GWB matches the watershed between Galway Bay and the River Corrib, which extends along the high ground at Letteragh and west of Dangan.

The GSI vulnerability data and ground investigation data for the project confirm that subsoil overlying the granite thins on higher ground and is up to 3m thick in low lying ground.

The soil and subsoil comprises of glacial tills with high fines content, which is confirmed by particle size distribution (PSD) data that is presented in Appendix A.9.1. This data indicates that the permeability or the subsoils is in the low to moderate range (DELG, 1999).

The groundwater level data collected for this project agrees with the GSI division of groundwater bodies. Based on GSI (2004a and 2004b), groundwater flow in the Galway Granite Batholith is isolated to weathered zones and fracture zones. None of the groundwater level data presented is indicative of high permeability zones.

The Galway Granite Batholith includes areas where there is poor drainage and water ponding at the surface, these areas include the Moycullen Bogs (NHA) and a number of other wetland areas (refer to Chapter 8, Biodiversity). The Moycullen Bogs comprise a main area, in the west near Lough Inch, and two isolated areas at Tonabrocky and Letteragh (refer Figure 10.5.001). Where the surface water ponding occurs, there is often little or no seasonal variation in the water level, with most areas remaining ponded throughout the summer.

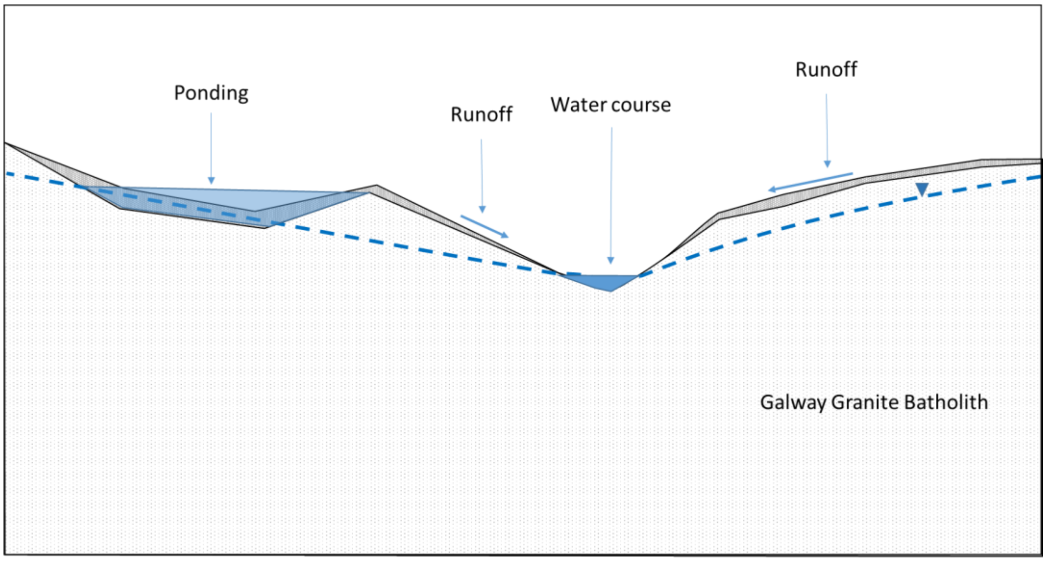

Plate 10.2 Hydrogeological Conceptualisation of Runoff and Surface Water Ponding on the Galway Granite Batholith

The undulating topography of the Galway Granite Batholith includes areas of topographic highs where bedrock is near surface and topographic lows where the subsoils are thicker (up to c.3m). On the topographic highs rainfall runs off as overland flow whilst on low lying ground or naturally impounded areas surface ponding tends to occur.

The GSI vulnerability data and the project ground investigation data together with the Tailte Éireann topographic data show that the granite has an undulating rock topography (Plate 10.2). As the granite is of low permeability it will perch surface water and where drainage is poor, surface water can be impounded and ponded.

Connectivity between the bedrock aquifer groundwater and the ponded surface water will be slight due to the low permeability of the peaty soils. The water ponding on the surface at the Moycullen Bogs is perched water primarily derived from rainfall collected within low points on the ground surface.

10.3.4.2 The Visean Undifferentiated Limestone Aquifer

Based on the Project GI the Visean Undifferentiated Limestone has been divided into the following groundwater bodies, listed below. These GWB are revised from the original GSI GWB and are presented in Figure 10.5.001 and 10.5.002. Where a GWB is further divided then the sub catchment name is presented in brackets after the GWB name for example Lough Corrib Fen 1 is divided in (Menlough) and (Lackagh).

- Lough Corrib Fen 1
- Lough Corrib Fen 2

- Lough Corrib Fen 3 & 4
- Clarinbridge
- Clare-Corrib
- Ross Lake

Each of the groundwater bodies are characterised below and discussed in terms of their interaction with surface water. In all cases the extent of the GWB is reviewed based on the project ground investigation and groundwater monitoring data. In most cases there has been refinement to the extent of groundwater bodies. The GWB retain the names provided by the GSI, however, the prefix of GWDTE is removed from those GWB named so by the GSI.

Ross Lake Groundwater Body

The Ross Lake GWB encompasses the limestone on the western side of the River Corrib. The extent of the Ross Lake GWB was revised based upon the ground investigation for the Project and the revised extent is presented in Figures 10.5.001 and 10.5.002.

The GWB receives recharge from rainfall but also runoff from the adjacent granite. There are several drains and ditches that cross from the granite and onto the Ross Lake GWB. As such, the surface catchment for the Ross Lake GWB includes runoff within the local catchment for the River Corrib. As the GWB boundary conditions are physical (i.e. bedrock contact and river) they do not fluctuate seasonally.

Lough Corrib Fen 1 Groundwater Body

Lough Corrib Fen 1 GWB extends east from the River Corrib to the townland of Coolough. The eastern extent of the GWB has been revised westwards to the townland of Coolough (Figure 10.5.002) to accommodate the groundwater divide identified between it and the Clare-Corrib GWB.

Lough Corrib Fen 1 GWB has been divided into two sub catchments, namely Menlough and Lackagh on the basis of the thick silt and clay subsoils (up to 106m deep) that occur in the townland of Coolough. These thick subsoils deposits, which underlie Coolagh Lakes and form a deep valley fill/palaeokarst feature west of Lackagh Quarry, compartmentalise the GWB so that Lough Corrib Fen 1 (Menlough) lies north of Coolagh Lakes and Lough Corrib Fen 1 (Lackagh) forms a small sub catchment ($<0.04km^2$) between Coolagh Lake and Lackagh Quarry. It is noted that Lackagh Quarry entirely lies within the revised Clare-Corrib GWB and not the revised Lough Corrib Fen 1 (Menlough) GWB or Lough Corrib Fen 1 (Lackagh) GWB (Figure 10.5.002).

Groundwater flows westwards within the Lough Corrib Fen 1 (Menlough) GWB from the groundwater divide with the Clare-Corrib GWB to the Coolagh Lakes and the River Corrib. Lough Corrib Fen 1 (Menlough) GWB supplies groundwater to Coolagh Lakes via the Western Coolagh Spring (K25).

Due to the compartmentalisation of the aquifer by buried valleys/palaeokarst, the groundwater in Lough Corrib Fen 1 (Lackagh) GWB is largely contained, with potential for small scale seepage from the limestone aquifer through the clayey subsoil to the Eastern Coolagh Spring but due to the low permeability and thickness of the clayey subsoil, these potential seepages are very small. Groundwater flow from Lough Corrib Fen 1 (Lackagh) may flow eastwards to Lackagh Quarry during peak groundwater levels.

If present, seepages from the subsoil to the Eastern Coolagh Spring would represent a very small fraction of the groundwater contribution to Coolagh Lakes compared to the karst inflow at Western Coolagh Spring (K25), which provides the main groundwater contribution flow to Coolagh Lakes. As described in Section 10.3.2.2 the Eastern Coolagh Spring (K45) is not a karst spring because it sits on thick clay subsoil as evidenced by ground investigations (GI).

Coolagh Lakes lie in a low-lying area that are shown by GSI data as well as records from 2006 GCOB GI and observations from the site walkover to be underlain by thickness of low permeability overburden and that the overburden adjacent to Upper Coolagh Lake comprises of silt and clay. On this basis, groundwater inflows through the base and margins of the lakes will be at a low seepage rate but around the full periphery they may provide a significant wetted margin. The only significant karst inflow to Coolagh Lakes is via the Western Coolagh Spring (K25).

Groundwater contribution to Coolagh Lakes from the Eastern Coolagh Spring and any other potential seepages (such as underwater springs from the margin of the Clare-Corrib GWB) are very limited due to the thick clay subsoil that fills the buried valley and forms a very low permeability barrier to the limestone aquifer. Plate 10.3 and Plate 10.4 below show the interactions between the Coolagh Lakes and Western Coolagh Spring at high and low groundwater levels.

During periods of high groundwater levels groundwater contributes flow to the lakes (Plate 10.3), while during the summer the groundwater level lowers to just above the lake level and the springs have minimal flow. Plate 10.4 below, shows the relationship between groundwater levels and surface water levels in the springs that feed Coolagh Upper Lake.

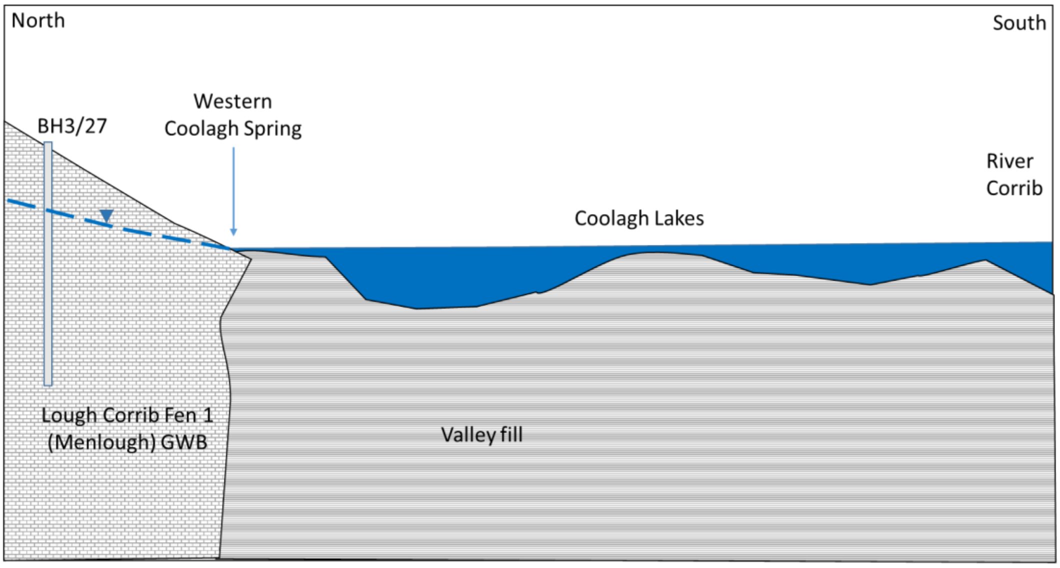

Plate 10.3 Schematic north south Cross-section through Coolagh Lakes (Groundwater High)

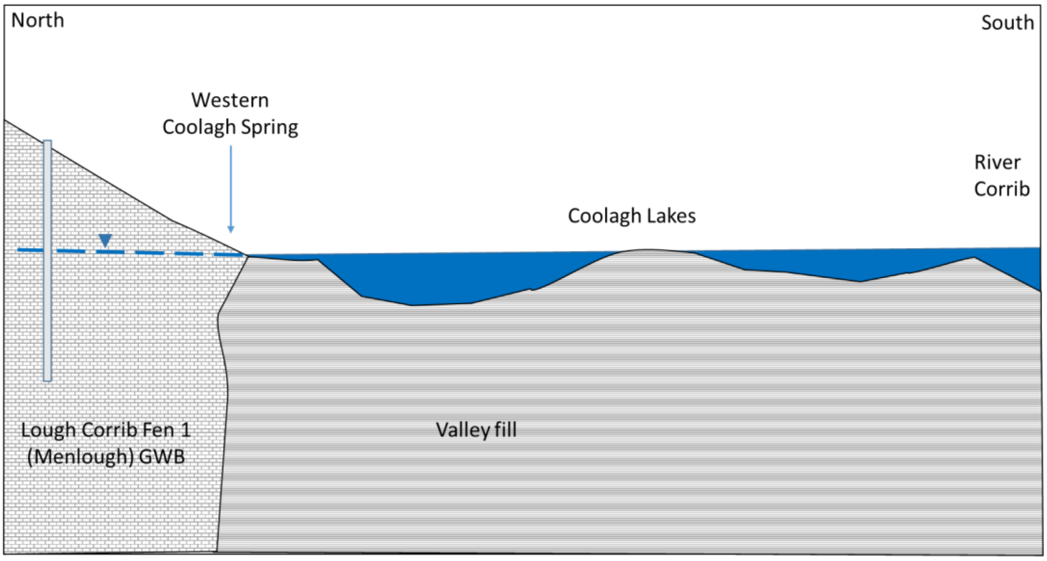

Plate 10.4 Schematic north south cross-section through Coolagh Lakes (groundwater low)

Groundwater hydrographs for the GWB are presented below (Plate 10.5) and show the groundwater responses in the aquifer locally as well as levels at the Western Coolagh Spring and Eastern Coolagh Spring. The data presented in these hydrographs is presented in Appendix A.10.3 – Groundwater Level Monitoring Database. Plan and Profile cross-sections along the alignment of the proposed N6 GCRR centreline are presented in Figures 10.6.001 to 10.6.0012, which also show minimum and maximum groundwater levels.

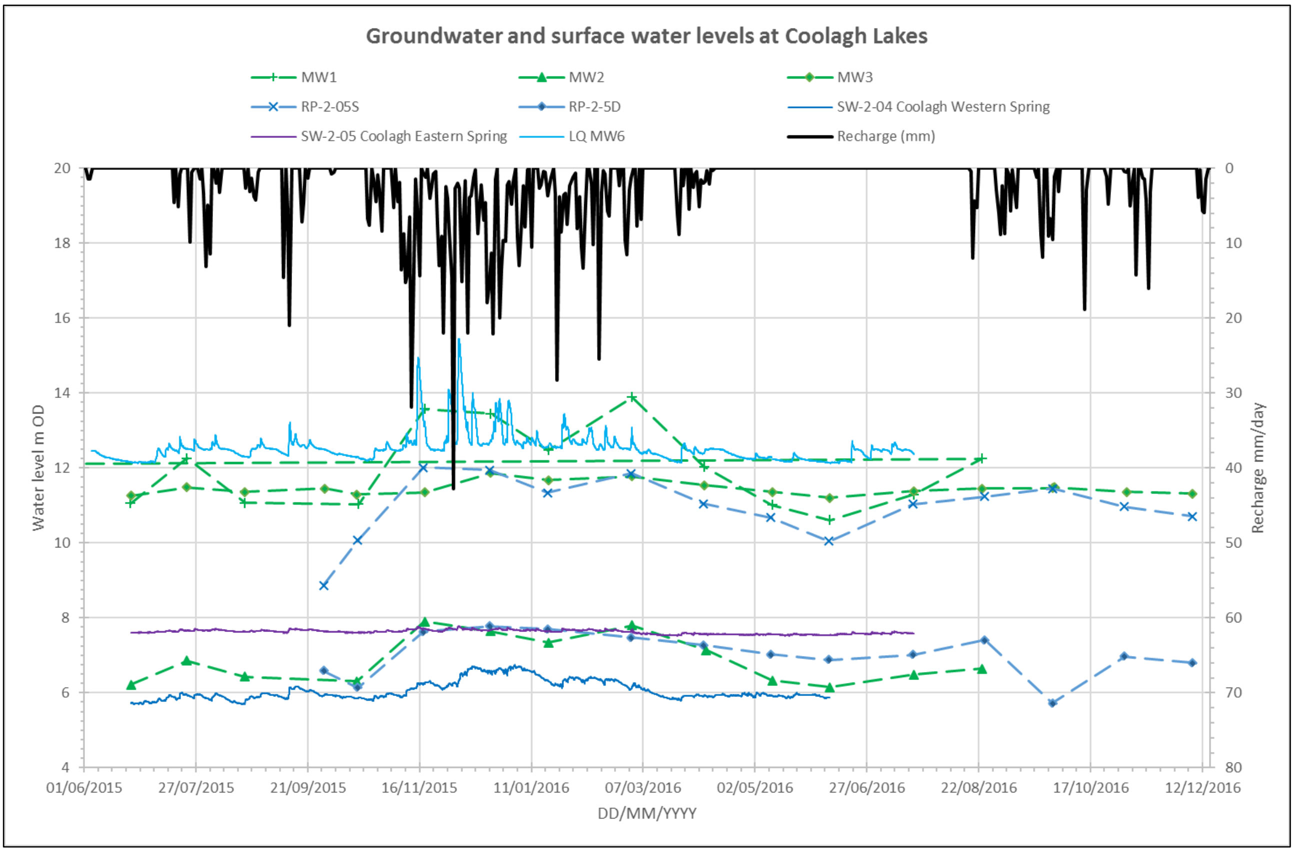

Plate 10.5 Groundwater and Surface Water levels at Coolagh Lakes

Western Coolagh Spring is the main water inflow to Coolagh Lakes and has a seasonal variance in water level of 0.7m. Western Coolagh Spring is a karst resurgence in the eastern side of a shallow valley at the head of Upper Coolagh Lake. At this location groundwater flow rises from conduit in limestone bedrock. Flow is turbulent, with flow velocity up to 0.3m/sec (flow of 35l/s) estimated during the winter of 2016. During the summertime the flow at the spring is low (<1l/min). There are a number of small springs associated with Western Coolagh Spring in the western side of the shallow valley. Western Coolagh Spring is the collective name given to the main spring and the associated smaller springs.

Eastern Coolagh Spring is separate from Western Coolagh Spring, being located 850m away in a north eastward direction, and 3m higher in elevation. It has a very slight seasonal variable of 0.1m and with no measurable flow. Due to the geological setting of the Eastern Coolagh Spring with clayey subsoil, this feature is not considered a karst feature. As discussed, there is potential for seepage from the clayey subsoil to Coolagh Lakes at Eastern Coolagh Spring. However, even if seepages are present, the potential seepages rates for Eastern Coolagh Spring will be very low when compared to Western Coolagh Spring.

It is assumed that groundwater seepage occurs from the subsoil around the full periphery of the Coolagh Lakes. Although seepages were not observed, the shore remains wet all year round and, as such, there is potential that groundwater seepage occurs from the limestone aquifer via subsoil where thin enough and into the Coolagh Lakes.

The extent of the Lough Corrib Fen 1 (Menlough) GWB is shown in Figure 10.5.002. The GWB is bound to the west by the River Corrib, to the east by a groundwater divide with the Clare-Corrib GWB, north by a divide with the Lough Corrib Fen 2 GWB and south by thick clayey subsoil deposits on which the Coolagh Lakes have formed.

The Lough Corrib Fen 1 (Lackagh) GWB is relatively small in size (0.7km^2) and is also internally subdivided by features such as the thick clayey subsoil deposits that infill the palaeokarst west of Lackagh Quarry. The boundaries, as well as thick subsoil deposits within the GWB, isolate the potential surface catchments for both the Western Coolagh Spring and Eastern Coolagh Spring, and on this basis their catchments can be defined.

The sub catchment for Western Coolagh Spring is defined as the surface area of the Lough Corrib Fen 1 (Menlough) GWB from the eastern GWB boundary (BH4) to the topographic high at MW3 (refer to Appendix A.10.3 and Figures 10.6.007 and 10.6.008.

At MW3 there is a small groundwater ridge that allows a divide between groundwater that flows to Western Coolagh Spring and groundwater that flows the River Corrib. As MW3 lies 200m east of the River Corrib the extent of the groundwater sub catchment that drains to the River Corrib is limited to the 200m wide strip adjacent to the river (less than 0.1km^2).

The pond at Eastern Coolagh Spring has the potential to receive seepage from the subsoil surrounding the feature. The extent of the catchment is restricted to the area in the valley floor. Any groundwater flow from the limestone aquifer to the Eastern Coolagh Spring would have to seep through the clayey subsoil and hence be of a very low quantity.

The groundwater levels presented in Plate 10.5 show that the Western Coolagh Spring has the lowest groundwater level in the GWB sub-catchment. On this basis the Western Coolagh Spring (as well as Coolagh Lakes and River Corrib) is the main receiving water. Based on the descriptions presented, the Western Coolagh Spring is a significant groundwater contributor to Coolagh Lakes.

The western boundary of the Lough Corrib Fen 1 (Menlough) GWB is physically bound by a river. The seasonal variance is very slight due to the level of the river. However, the eastern boundary of the Lough Corrib Fen 1 (Menlough) GWB is a groundwater divide and the seasonal fluctuation in groundwater levels has the potential to cause the divide to shift laterally.

Due to the compartmentalisation of the Lough Corrib Fen 1 (Lackagh) GWB, flow is prevented from draining to Western Coolagh Spring and only small-scale seepage via the clayey subsoil is possible at the Eastern Coolagh Spring. The compartmentalisation of the aquifer means that during peak levels the groundwater in the Lough Corrib Fen 1 (Lackagh) may flow eastwards towards Lackagh Quarry.

Maximum and minimum groundwater levels data are presented in Appendix A.10.3 and plotted on Figure 10.6.007 to Figure 10.6.010. The data shows that the groundwater divide between Lough Corrib Fen 1 (Menlough) and Lough Corrib Fen 1 (Lackagh) occurs at BH4 during the winter. During the summer the groundwater table gradient flattens and the divide migrates north westwards by an estimated 250m (based on the seasonal groundwater level data for BH4 and LQMW4, refer to Appendix A.10.3).

Based on the above descriptions, the Lough Corrib Fen 1 (Menlough) GWB is a significant groundwater contributor (via Western Coolagh Spring (K25)) to Coolagh Lakes. The Coolagh Lakes discharge to the River Corrib, both of which are part of the Lough Corrib SAC and therefore the Lough Corrib Fen 1 (Menlough) GWB contributes to this SAC. As the River Corrib discharges into Galway Bay this GWB also contributes (indirectly) to Galway Bay Complex SAC and Inner Galway Bay SPA. The generalised hydrogeology of the area, with flow directions, was presented graphically in the 2019 RFI to explain the interaction of groundwater with the European sites and is shown in Plate 10.6. This has been updated slightly since 2019 due to the small boundary change of the Lough Corrib SAC.

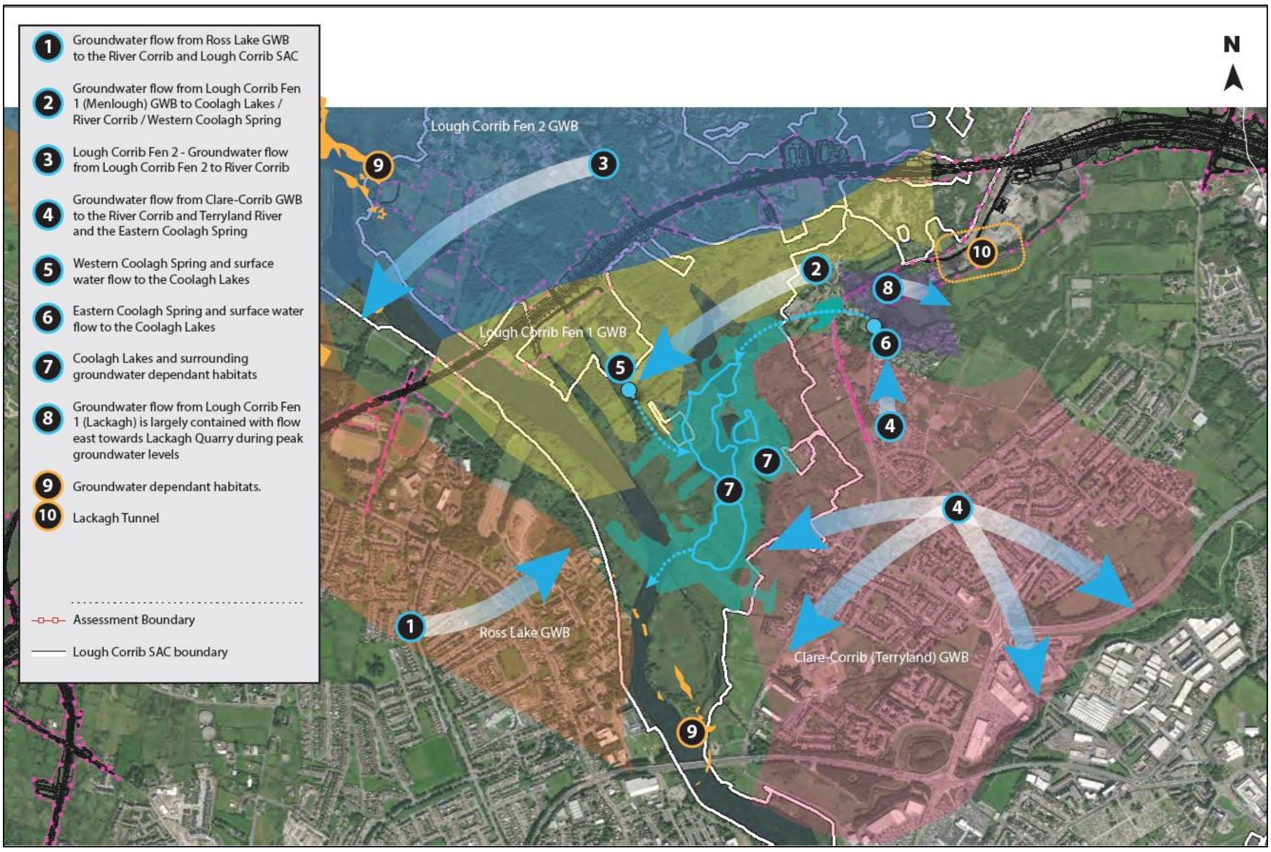

Plate 10.6 Generalised Hydrogeology Interactions with European sites

Lough Corrib Fen 2 Groundwater Body

Based on the groundwater level data collected for the Project, the southern boundary of the GWB as per GSI is set 0.3km too far south. Using the water level data for the Project the GWB extent has been updated and is shown in Figure 10.5.002.

Although the Project does not extend into this GWB (Figure 10.5.002) the divide between the GWB and the adjacent Lough Corrib Fen 1 (Menlough) GWB sub catchment lies near it. On this basis of the proximity the Lough Corrib Fen 2 GWB is considered as one of the GWB traversed by the Project.

The seasonal fluctuation in the GWB is 2.5m, as recorded in monitoring well RC133 (refer to Appendix A.10.5), which is located close to the groundwater divide with Lough Corrib Fen 1 (Menlough). Based upon this relatively slight seasonal variation and relatively low hydraulic gradients in the area, the groundwater divide between Lough Corrib Fen 2 and Lough Corrib Fen 1 (Menlough) is stable across the seasons and does not fluctuate laterally.

Lough Corrib Fen 2 GWB contributes directly to Lough Corrib. The only surface water recorded in the GWB is Turlough K20 and spring K17 (Refer to Appendix A.10.2 and Figure 10.1.002).

Lough Corrib Fen 3 and 4 Groundwater Body

Based on groundwater level data collected for the Project, the southern extent of the GSI Lough Corrib Fen 3 and 4 GWB has been reduced and been moved north by over 2km. The revised groundwater bodies are presented in Figure 10.5.002, although it is noted that based on the revised extent, this GWB Lough Corrib Fen 3 and 4 no longer extends onto the figure and is not visible on it.

Clare-Corrib Groundwater Body

Based on the groundwater level data collected for the Project, the extent of the Clare-Corrib GWB has been revised with the GWB extended further west, as far as the townland of Coolough, near Menlough, and further east to the N83 Tuam Road (Figure 10.5.002). As presented earlier the GWB is divided into three sub catchments, named Terryland, Ballindooley West and Ballindooley East.

There are a number of features in the GWB that have ponded surface water and these have the potential to interact with groundwater.

These pond features include Ballindooley Lough (which comprises of the main Ballindooley Lough and a number of smaller surface water bodies immediately to the south), a small surface water body at Ballinfoyle, an enclosed depression referred to as K97 in the karst survey (refer to Appendix A.10.2), and the Terryland River, including adjacent ecology have been identified in the Chapter 8, Biodiversity as being potential water dependant habitats. The hydrogeological aspects of these features are presented below.

Ballindooley Lough

Geophysics undertaken south of Ballindooley Lough for this project and north of the Ballindooley Lough for 2006 GCOB indicate that thick subsoils underlie the extents of Ballindooley Lough. From this data it is inferred that a feature, such as a buried valley, underlies the length of the lake. The subsoils below the lake explain the permanent perching of the surface water level when groundwater levels are low.

The groundwater data shows that Ballindooley Lough lies up gradient of the Project. The data also shows the lough to be perched during the summer when groundwater levels (RP-2-01 & RC1104) drop below the lake water level (Plate 10.7 and Plate 10.8). On this basis, during low groundwater levels the perched water in Ballindooley Lough and the groundwater in the limestone aquifer form separate and distinct water bodies.

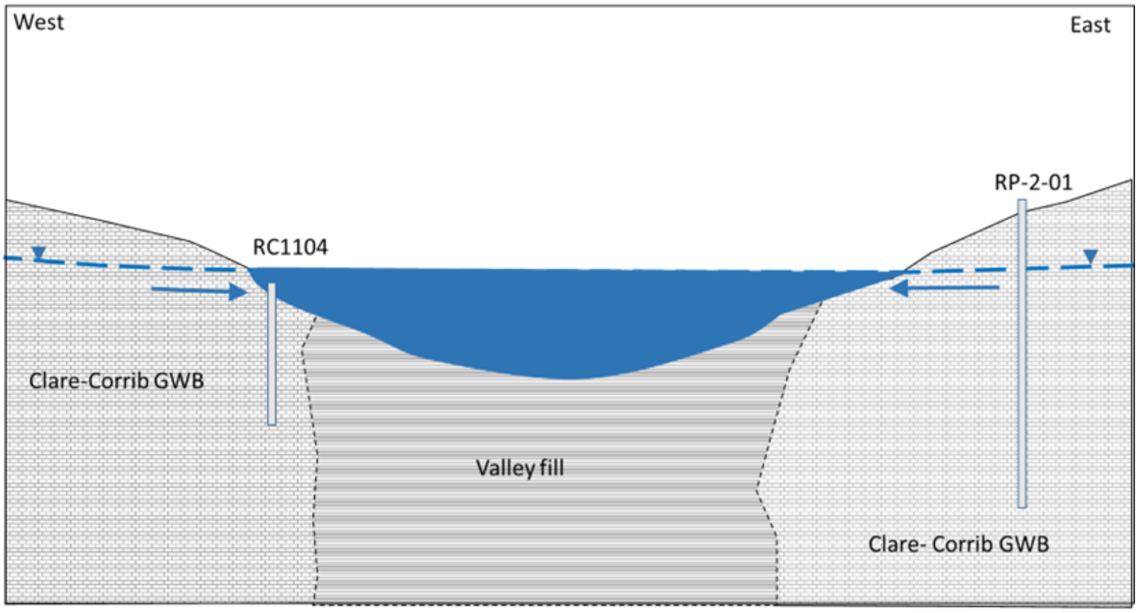

Plate 10.7 Schematic east west Cross-section through Ballindooley Lough showing the Interaction of Groundwater with the Lake during High Groundwater Levels

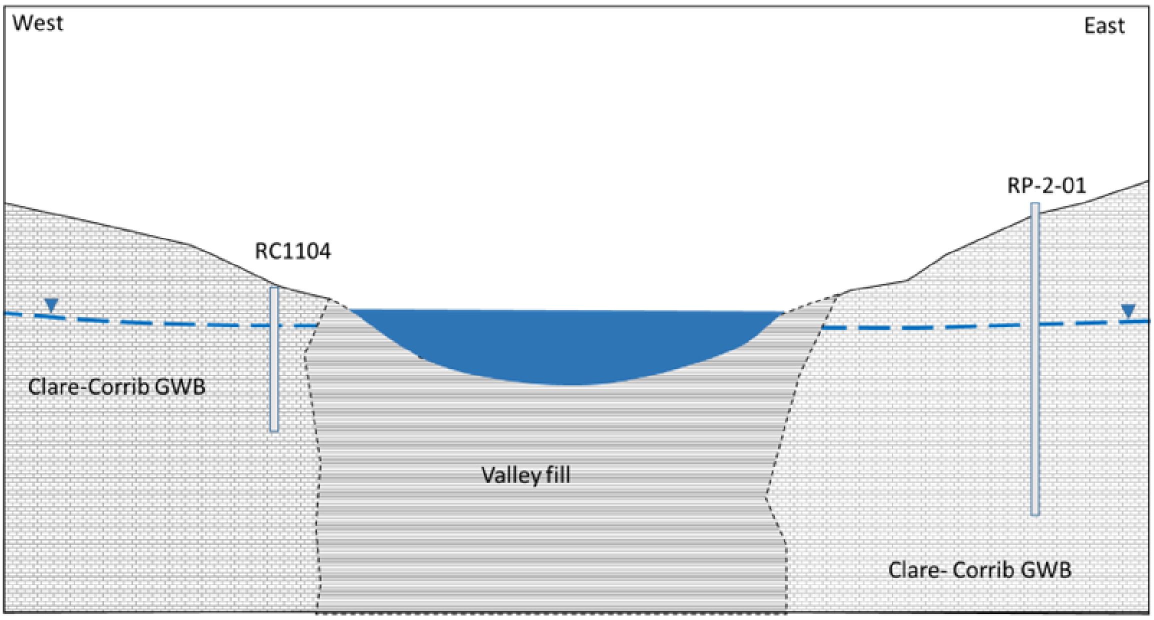

Plate 10.8 Schematic east west Cross-section through Ballindooley Lough showing the Interaction of Groundwater with the Lake during Low Groundwater Levels

During the winter, the lake level in Ballindooley Lough and the groundwater level in the limestone aquifer are in continuity. On this basis, Ballindooley Lough only receives groundwater during high groundwater levels.

Bathymetry of Ballindooley Lough shows that the lake has a max depth of 10m (-2.5m OD). Based on the geophysics data and the analyses that the summer lake water level is distinct from groundwater, then the base of summer water level in Ballindooley Lough lies on low permeability subsoil and not limestone.

The hydrographs for the GWB below in Plate 10.9 show that the groundwater level in wells surrounding Ballindooley Lough are continuous with the level of Ballindooley Lough during the winter. However, in the summer the groundwater level lowers below the permanent water level of the lough perching it.

Also notable are the groundwater levels in monitoring well RP-2-03 located 300m south of Ballindooley Lough (Figure 10.6.009) are significantly lower than other groundwater levels in the area and the surface water level at Ballindooley Lough. The lower water table in RP-2-03 indicates the direction of flow southwards within the groundwater body.

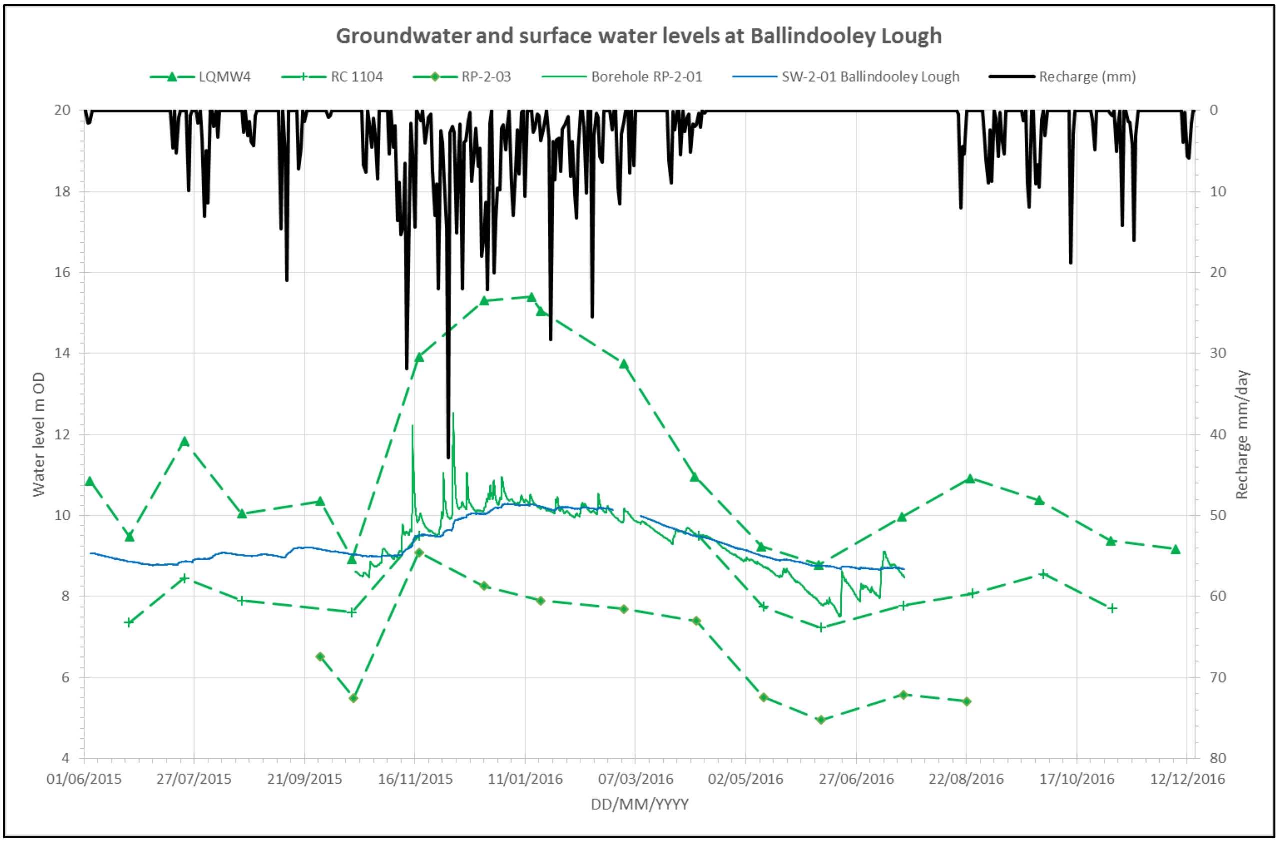

Plate 10.9 Groundwater and Surface Water Levels at Ballindooley Lough

<u>Enclosed depression (Doline) K97</u>

Doline K97 was identified by the karst survey. It is a 40m circular enclosed depression, with soft clay in the base, that is located near Castlegar (Figure 10.1.002). This doline is included in this assessment as it was originally highlighted as potentially being a turlough, however as outlined below and in Chapter 8, Biodiversity it has since been confirmed as not meeting either the ecological or hydrogeological criteria for a turlough.

Based on the above groundwater levels there is a distinct difference in groundwater level to the west (Monitoring well BH3/34) and to the east (monitoring well RC-2-01 & RC-2-03) (Refer to Plate 10.10 and Plate 10.11).

The ground investigation data shows that the feature K97 is located within thick subsoil. BH3/32 shows silt and clay subsoil to 23m below ground level (bgl) and geophysics GP3/32 (ERT) (Appendix A.9.1) shows low resistivity material to a depth of greater than 20m. However, to the east of the site BH3/33 (no piezometer) and geophysics GP3/13 show bedrock to be with 3m of the surface.

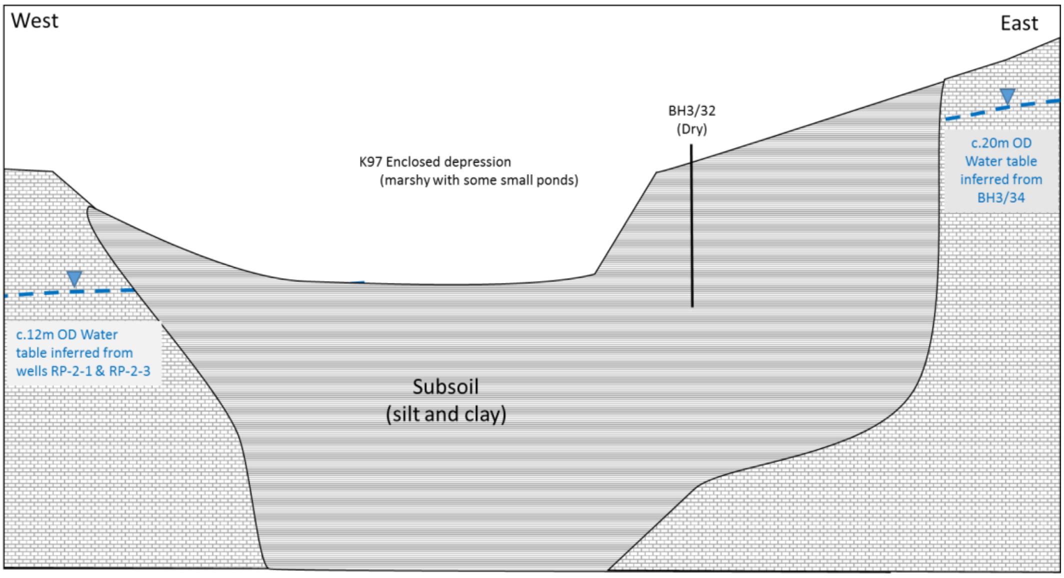

Plate 10.10 Schematic east west Cross-section through Enclosed Depression K97 showing the Interaction of Groundwater with the Feature during High Groundwater Levels

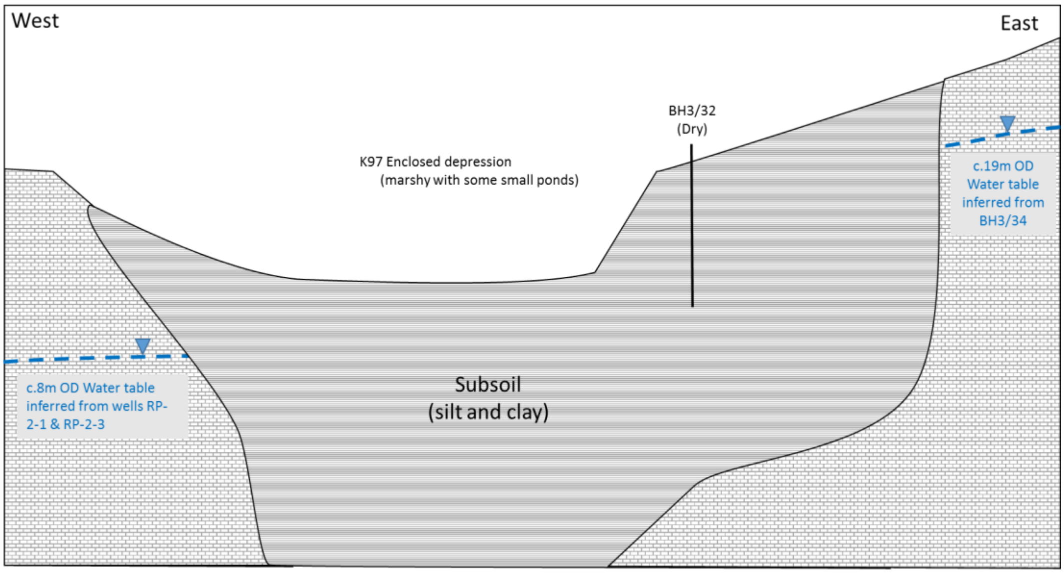

Plate 10.11 Schematic east west Cross-section through Enclosed Depression K97 showing the Interaction of Groundwater with the Feature during Low Groundwater Levels

Due to the low permeability nature of the subsoils, it is very unlikely that there is a groundwater contribution to the base of the depression. Water ponding in the base is likely to be entirely due to incident rainfall, captured by the depression. The hydrogeological descriptions provided strongly indicate that the feature does not receive groundwater.

Surface water at Ballinfoyle

The surface water feature (reference K74) is located at Ballinfoyle where it is located in the valley floor approximately 600m southwest of Ballindooley Lough (Figure 10.1.002). It lies immediately east of the N84 Headford Road and is square in shape with sides 80m long. It is lies upon silt/clay subsoils, which are seen in the margins and banks.

The feature is a seasonal lake that fills during the autumn and drains during spring. Groundwater levels on the north-western side (monitoring wells LQMW1-4) rise above the feature’s floor and cause it to flood during the winter. Notably the groundwater level on the south-eastern side always remains below the feature’s floor (monitoring well RP-2-03). The disparity in groundwater levels across the feature (refer to Plate 10.12 and Plate 10.13) indicates a barrier to groundwater flow and based on the location along the trend of the valley at Ballindooley it is likely that this feature is located on thick clay subsoil.

Based on the groundwater level data, this feature receives groundwater from the bedrock aquifer to the northwest during the winter. As the feature itself is not located on limestone the feature does not have the hydrogeological characteristics of a turlough and instead is surface water ponding.

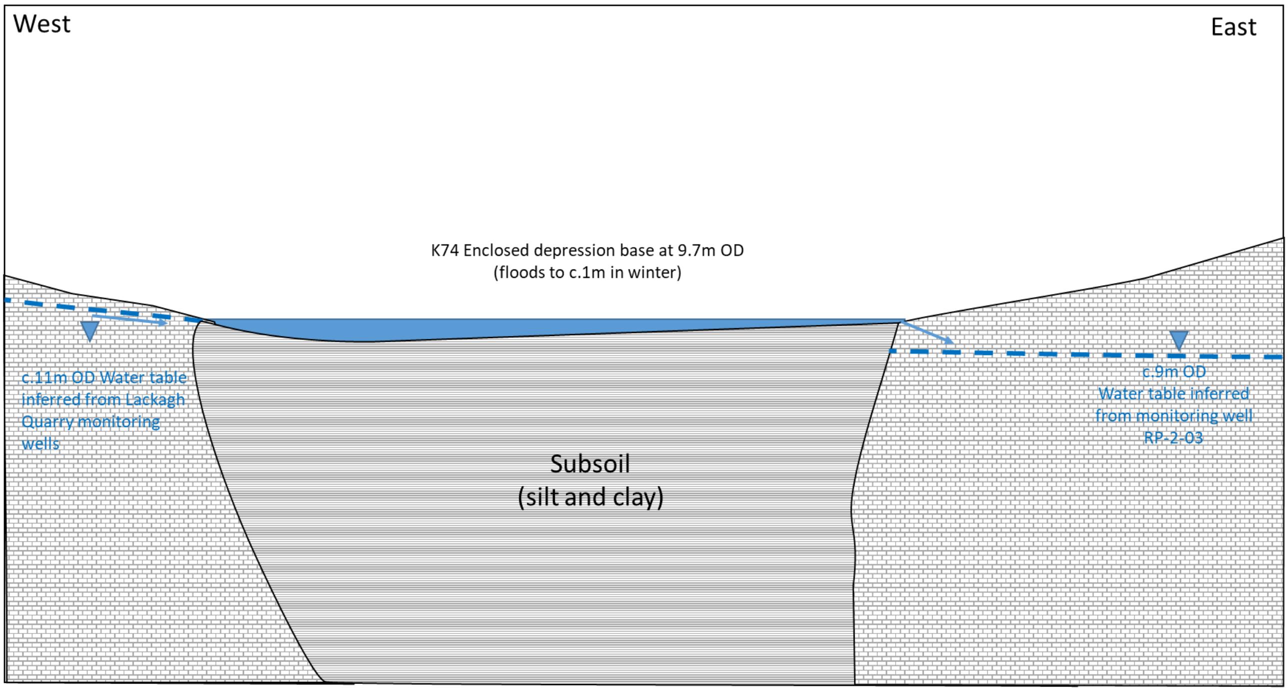

Plate 10.12 Schematic east west Cross-section through Feature showing the Interaction of Groundwater with the Feature during High Groundwater Levels

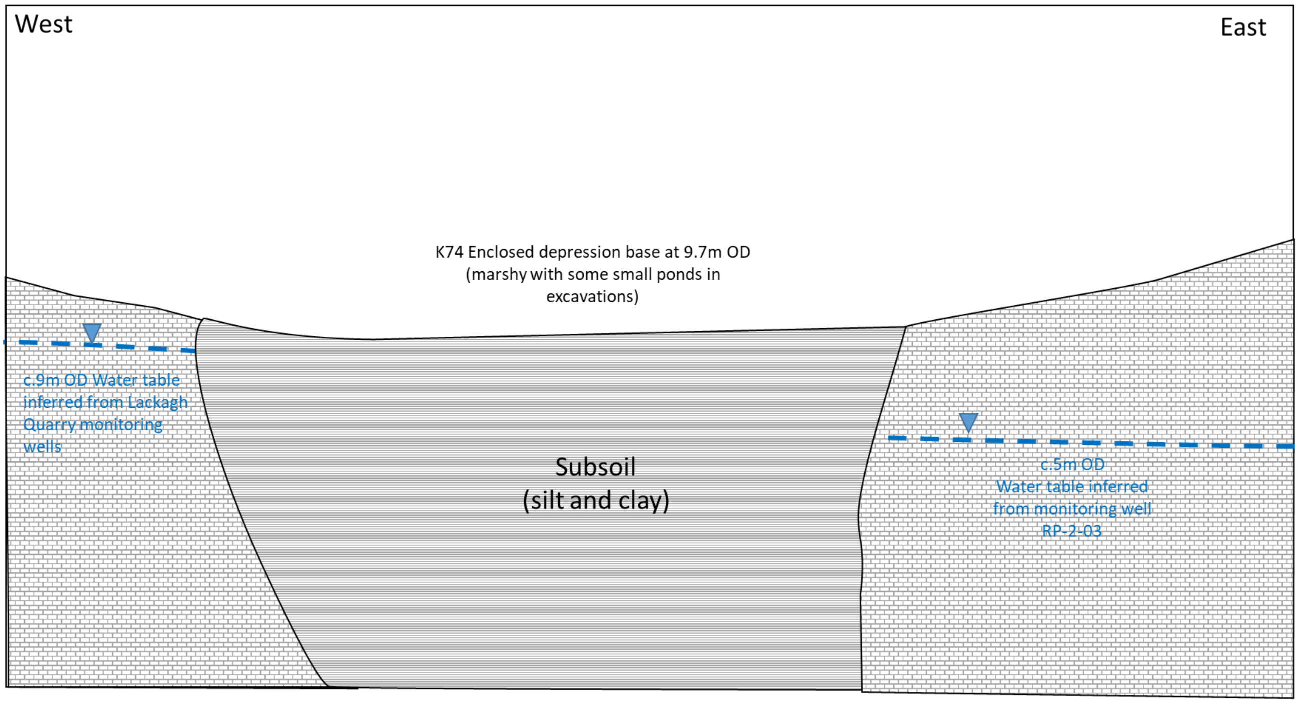

Plate 10.13 Schematic east west Cross-section through Feature showing the Interaction of Groundwater with the Feature during Low Groundwater Levels

Terryland River

Under normal conditions the Terryland River sinks at two stream sinks, named Pollavurleen West and East (K87 and K96) near Glenanail (Refer to karst study in Appendix A.10.2) (Plate 10.14) (Figure 10.1.001). However, during high groundwater levels, the Terryland sinks become resurgences and discharge groundwater into the Terryland River. OPW data shows that whilst water levels in the Terryland River do backup, rise and cause local flooding when the sinks turn to resurgences, the Terryland River levels have remained significantly lower than the River Corrib for the OPW data record (2021-2024) and there have been no incidences on record of water backing up to the River Corrib (Plate 10.15). OPW data for the Terryland River, River Corrib and Galway Bay tidal levels are presented and discussed in Appendix A.10.3.

The switching between sink to resurgence means these features should be considered 'estavelles'. Whilst the sinks are located near limestone outcrop, the Terryland River flows for its length along a low-lying area that has thick overburden. The low permeability of the subsoil here carries the surface water across the valley until the limestone is met at the southern side of the valley.

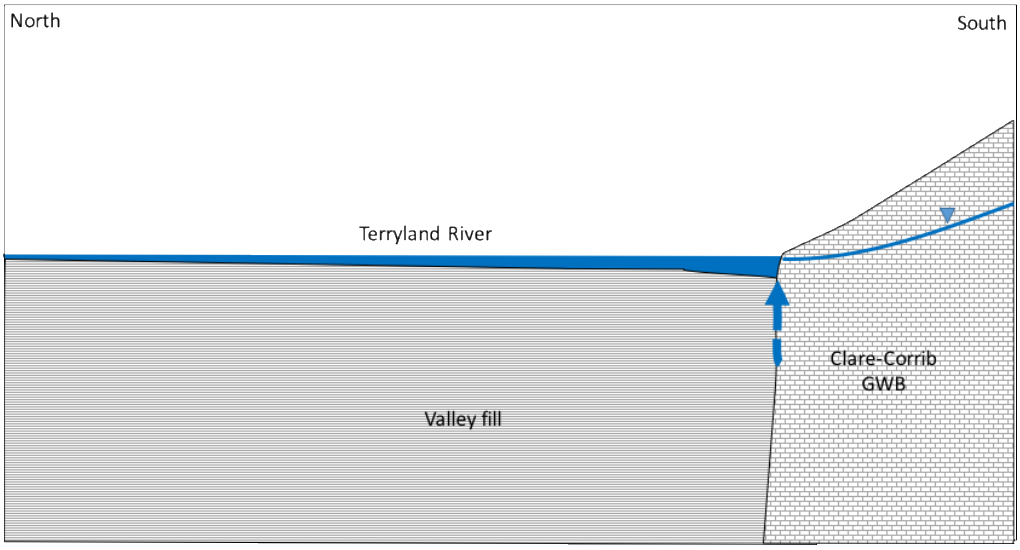

Plate 10.14 Schematic north south Cross-section through Terryland River showing the Operation of the Estavelles at Pollavurleen West and East during High Groundwater Levels

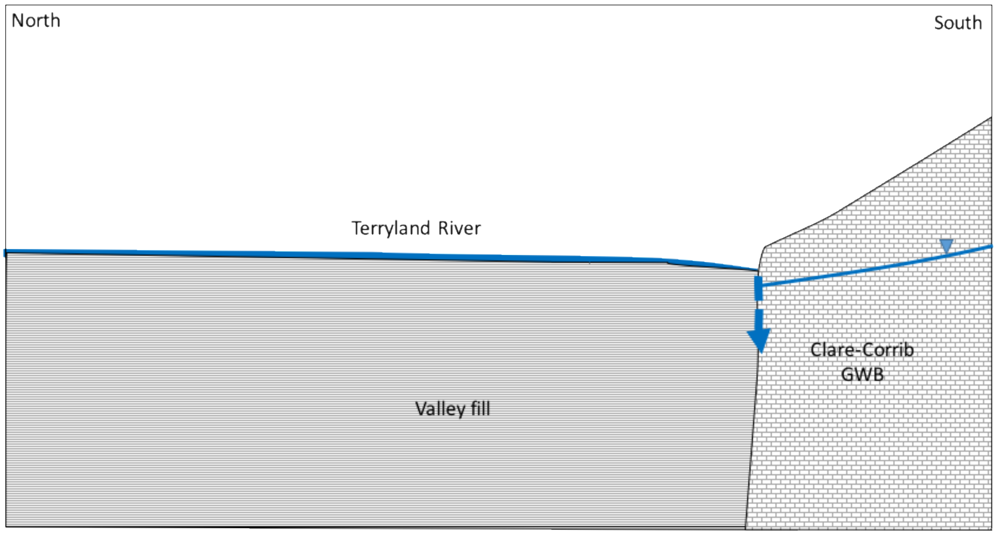

Plate 10.15 Schematic north south Cross-section through Terryland River showing the Operation of the Estavelles at Pollavurleen West and East during Low Groundwater Levels

There are a number of Annex I habitats that occur in the valley of the Terryland River on the thick subsoil deposits. As these features are not located on bedrock but on the thick subsoil, these features are dependent on pluvial flooding and are not groundwater dependent.

Clarinbridge Groundwater Body

The Clarinbridge GWB as delineated by the GSI is a large groundwater body that extends from Galway City eastwards past Galway Airport to Athenry and then south from Athenry to Clarinbridge and as far south as Ardrahan. As the Clarinbridge GWB extends over a number of rivers and streams it can be subdivided into several smaller groundwater bodies that are distinct and isolated from each other. One of these smaller sub-catchments of the Clarinbridge GWB is the area of the higher ground between Galway Airport and Ballybrit.

The divide between the Clarinbridge GWB and the Clare-Corrib GWB is marked by the thick overburden deposits along the line of the N83 Tuam Road. These thick low permeability superficial deposits have been proven to a minimum depth of 30m. Conceptually these thick low permeability deposits form a hydraulic barrier between the Clare-Corrib and Clarinbridge groundwater bodies.

The groundwater level monitoring data collected in the Clarinbridge GWB for the Project has a shallow water table relative to the rest of the hydrogeology study area. The shallow groundwater table is generally within 4m of the surface and follows topography, lowering gradually southwards towards Galway Bay. The seasonal fluctuation in the aquifer is of the order of 2m.

The characteristics of the Visean Limestone Undifferentiated in the GWB indicate lower aquifer properties, with fracture flow and only small scale surface karst landforms present.

10.3.5 Hydrogeological Features of Importance

There are a number of receptors within the hydrogeology study area which are connected to or dependent upon groundwater to maintain their hydrogeology. The types of receptors that could be affected by the Project are:

- Groundwater resources and abstractions
- Groundwater dependent habitats
- Groundwater dependent surface water features

The individual receptors identified under these headings are described below and an outline of the receiving environment for each is provided. Based on the conceptual model outlined in Section 10.3.3.4, a number of these will not be affected by the Project and a full impact assessment will not be required. These are clearly identified and those which do require an impact assessment are assessed in full in Section 10.5.

As mentioned earlier in this updated chapter, during the 2020 Oral Hearing several queries were raised regarding potential groundwater related settlement impacts to buildings and potential impacts to wastewater treatment systems and their percolation areas. The risk of impact may arise from change in groundwater levels and, depending on the setting, may cause settlement of building foundations or alter the thickness of an unsaturated zone on wastewater percolation areas. Changes to groundwater levels were presented in the 2018 EIAR. Further details of the groundwater assessment specific to buildings and wastewater treatment systems are included in this update to ensure that all potential impacts to groundwater level are presented.

The potential for building subsidence is considered for all areas where groundwater levels are expected to change, this includes where groundwater levels are expected to be drawn down for example from a road cutting or where there may be localised groundwater rise for example, from an infiltration basin.

The importance of these groundwater receptors is ranked according to TII Guidelines on the attribute classification criteria presented in Table 10.1. Potential hydrogeological impacts are defined as any negative changes to the baseline groundwater quantity and/or groundwater quality.

10.3.5.1 Groundwater Resources

As outlined in Section 10.3.1 and presented on Figures 10.1.001 and 10.1.002, the western part of the hydrogeology study area, is classified by GSI as a Pl aquifer and in the eastern part of the hydrogeology study area is classified by GSI as a Rkc aquifer. These aquifers have an importance ranking of Low and Very High respectively in line with TII importance ranking criteria presented in Table 10.1.

10.3.5.2 Groundwater Supplies

Water Supplies refer to any large springs, groundwater abstractions for local authorities, commercial/industrial, holy wells, Group Water Schemes or private well supplies within the hydrogeology study area. All groundwater supplies in the hydrogeology study area are shown in Figures 10.5.001 and 10.5.002.

Source Protection Plans have been published by the GSI/EPA to define the groundwater catchment for some large public water supplies and state appropriate land use practices within the catchment. The Source Protection Areas include Inner and Outer Protection areas. There are no Source Protection Areas within the hydrogeology study area for the Project.

Records of abstractions, wells and springs are kept by the GSI, the National Federation of Group Water Schemes (NFGWS), the Environmental Protection Agency (EPA) and the National Monuments Service. Where wells are recorded in the national databases these are included in Figures 10.5.001 and 10.5.002 for completeness. Abstractions identified from submissions made by third on the Section 51 Application and dealt with during the oral hearing are also considered within this assessment. All wells within the hydrogeology study area for the hydrogeological assessment are listed below in Table 10.11. As per TII guidelines the hydrogeology study area is dependent on the hydrogeological characteristics of the bedrock aquifers. On this basis the hydrogeology study area for the limestone aquifer extends beyond the Assessment Boundary and it includes all groundwater sub catchments that the Project crosses.

The reference numbering used in this assessment is based on the GSI data, where the prefix is based on the confidence in well location and where the number after the W refers to the radius (in meters) within which these wells lie. Therefore, the W50 codes have been located or have a national grid reference as confidence in the location of these wells is high as they are very close at only 50m from their reference point. W1000 codes are locations provided by GSI that are within 1000m of a central point.

The data presented on supply wells in the 2018 EIAR is tabulated for ease of reference in this updated chapter. There are seven additional wells noted since 2018 which are W50-16, W50-17, W50-18, W50-19, W50-20, W50-21 and W50-22. Information on the additional wells is sourced either from consultation that occurred as part of the 2020 Oral Hearing or from the EPA Water Abstractions Register (greater than 25m^3/d), which has become publicly available since the 2020 Oral Hearing.

All wells in the hydrogeology study area are presented below in Table 10.11, which presents information on the well use, the source of the information and the feature importance ranking.

There is some duplication across the sources of groundwater supply information. Where such duplication occurs, then each of the information sources are listed below in Table 10.11. Well W1000-02 has been removed from the 2018 list of groundwater supplies, which was a duplication of W50-10.

Table 10.11 List of all Supply Wells in the Hydrogeology Study Area

Feature reference	Geology	Use	Source data	Ranking
W50-01	Granite	Knocknacarra group scheme supplying up to 50 houses	GSI Database	Medium
W50-02	Limestone	Agricultural / Domestic supply (Shallow well <10m deep)	GSI Database	Low
W50-03	Limestone	Agricultural / Domestic supply	GSI Database	Low
W50-04	Limestone	Agricultural / Domestic supply	GSI Database	Low
W50-05	Limestone	Agricultural / Domestic supply	GSI Database	Low

Feature reference	Geology	Use	Source data	Ranking
W50-06	Limestone	Agricultural / Domestic supply	GSI Database	Low
W50-07	Limestone	Agricultural / Domestic supply	GSI Database	Low
W50-08	Limestone	Agricultural / Domestic supply (Shallow well <10m deep)	GSI Database	Low
W50-09	Granite	Agricultural / Domestic supply	GSI Database	Low
W50-10	Limestone	Agricultural / Domestic supply (76.2m deep)	GSI Database	Low
W50-11	Limestone	Agricultural / Domestic supply	EPA Abstraction Register / GSI Database	Low
W50-12	Limestone	Commercial supply 250m^3/d	GSI Database / consultation	Medium
W50-13 and 14	Limestone	Commercial supply 2,000m^3/d	EPA Abstraction Register / GSI database	Very High
W50-15	Limestone	Commercial supply 380m^3/d	EPA Abstraction Register	High
W50-16	Granite	Historic Domestic / Agricultural supply spring	Consultation	Low
W50-17	Granite	Agricultural / Domestic supply	Consultation	Low
W50-18	Granite	Agricultural / Domestic supply	Consultation	Low
W50-19	Granite	Agricultural / Domestic supply	Consultation	Low
W50-20	Limestone	Commercial potable supply 50m^3/day	EPA Abstraction Register / Consultation / GSI database	Medium
W50-21	Limestone	Commercial: quarry 400m3/d	EPA Abstraction Register	High
W50-22	Granite	Commercial: golf course irrigation 250m3/d	EPA Abstraction Register	Medium
W100-01	Limestone	Agricultural / Domestic supply (shallow well <10m deep)	GSI Database	Low
W100-02	Limestone	Agricultural / Domestic supply	GSI Database	Low

Feature reference	Geology	Use	Source data	Ranking
		(shallow well <10m deep)		
W100-03	Limestone	Agricultural / Domestic supply	GSI Database	Low
W100-04	Limestone	Agricultural / Domestic supply	GSI Database	Low
W100-05	Limestone	Agricultural / Domestic supply	GSI Database	Low
W100-06	Limestone	Agricultural / Domestic supply	GSI Database	Low
W500-01	Limestone	Agricultural / Domestic supply	GSI Database	Low
W1000-01	Granite	Agricultural / Domestic supply	GSI Database	Low
W1000-03	Limestone	Agricultural / Domestic supply (Shallow well <3m deep)	GSI Database	Low
W1000-04	Limestone	Agricultural / Domestic supply	GSI Database	Low
G50-01	Limestone	Agricultural / Domestic supply	Consultation	Low

TII importance criteria for groundwater supplies is categorised based on the number of homes supplied (refer to Table 10.1).

Landowners were consulted regarding private well supply and where these were identified they have been incorporated into this assessment (refer to Section 10.2.3). Where information on the construction or abstraction details of these private well supplies is not available from GSI, EPA or NFGWS records, a conservative approach has been undertaken (i.e. the assumption has been made that they are shallow wells so more vulnerable to pollution). Based on TII importance ranking criteria, single house domestic abstraction wells have an importance ranking of 'Low'.

In order to categorise commercial supplies, the equivalent supply rate is based on the average metered (residence) water consumption of 357 litres per day for 2022 (Central Statistics Office, 2023). On this basis:

- W50-12 has an abstraction rate of approximately 250m^3/day which is equivalent supply of approximately 700 houses and is ranked as having an importance ranking of 'Medium'
- The cumulative abstraction of W50-13 and W50-14 is 2,000m^3/day which is a combined equivalence of >2,500 houses and a 'Very High' importance
- Galway Racecourse well W50-15 abstracts 380m^3/day for potable use. Based on TII criteria for domestic wells W50-15 has an equivalence of 1,064 houses and is ranked as having a 'High' importance
- W50-20 is a commercial potable supply which abstracts 50m^3/day for potable use. Based on TII criteria for domestic wells, W50-20 has an equivalence of 140 houses, it is ranked as having a 'Medium importance'
- W50-21 extracts 400m^3/day for quarry use (wash down and dust suppression). Based on TII criteria for domestic wells W50-21 has an equivalent of 1,120 houses and is ranked as having a 'High importance'

- W50-22 extracts 250m^3/day for golf course irrigation. Based on TII criteria for domestic wells W50-22 has an equivalent of 700 houses and is ranked as having a 'Medium importance'

One geothermal well has been identified (G50-01), which located on Ballybrit Crescent. The geothermal well is of a closed loop design developed within the Visean Undifferentiated Limestone. Consultation with the landowner identified that the well relies on an open borehole design, which uses the thermal conductance of the groundwater from the bedrock to heat the closed loop piping. Domestic closed loop geothermal wells are assessed as being comparable to domestic abstraction wells and have an importance ranking of 'Low'.

10.3.5.3 Groundwater Dependant Habitats

A full review of ecological features and designated ecological sites in the hydrogeology study area are detailed in Chapter 8, Biodiversity. The habitats listed in this section are those identified in Chapter 8, Biodiversity as being water dependant. Those habitats dependent on hydrogeological characteristics include groundwater dependant terrestrial ecosystems (GWTDE) receptors that are dependent on emergent groundwater but also features such as limestone pavement and associated ecosystems, which are dependent on well drained karst bedrock.

European sites comprise of Special Areas of Conservation (SAC) and Special Protection Areas (SPA), whilst National sites comprise of National Heritage Areas (NHA) and potential Heritage Areas (pNHA). As detailed in TII Guidelines, those sites that are designated as European sites status are ranked of international importance whilst those designated as National sites are ranked of national importance.

Habitats outside of European and National sites are ranked dependent on hydrogeological characteristics. Annex I habitats are attributed as 'Very High' owing to their national importance.

European sites

This section identifies those European sites that have the potential to be impacted from a hydrogeological perspective. All European sites within 30km of the Project have been considered based on the potential for hydraulic connectivity or interaction. Based on assessment of each European site those beyond 15km to the 30km boundary do not have groundwater connectivity or interaction from the Project. On this basis those European Sites more than 15km from the Project are not considered further. All European sites within 15km of the Project have been considered using the precautionary principle.

The screening of all European sites within 15km of the Project is presented below in Table 10.12. Those European sites that are located in separate and distinct groundwater bodies or sub catchments are not considered further as there is no groundwater connection from the Project.

Table 10.12 Screening of European sites by Proximity to the Project

Site Name	Proximity to Project	Screening	Result
Black Head-Poulsallagh Complex SAC	11km	Site lies in separate groundwater body	Not considered further
Moneen Mountain SAC	13km	Site lies in separate groundwater body	Not considered further
Castletaylor Complex SAC	14km	Site lies in separate groundwater body	Not considered further
Galway Bay Complex SAC	0.2km	Site lies adjacent to groundwater body that the Project traverses	Impact assessment required
Lough Corrib SAC	0km	Site lies adjacent to groundwater body that the Project traverse	Impact assessment required
Rahasane Turlough SAC	13km	Site lies in separate groundwater body sub catchment	Not considered further
Lough Fingall Complex SAC	11km	Site lies in separate groundwater body sub catchment	Not considered further

Site Name	Proximity to Project	Screening	Result
Gortnandarragh Limestone Pavement SAC	14km	Site lies in separate groundwater body sub catchment	Not considered further
Kiltiernan Turlough SAC	14km	Site lies in separate groundwater body sub catchment	Not considered further
Ross Lake and Woods SAC	10km	Site lies in separate groundwater body sub catchment	Not considered further
East Burren Complex SAC	13km	Site lies in separate groundwater body	Not considered further
Connemara Bog Complex SAC	6km	Site lies in separate groundwater body	Not considered further
Ardrahan Grassland SAC	15km	Site lies in separate groundwater body sub catchment	Not considered further
Inner Galway Bay SPA	1km	Site lies adjacent to groundwater body that the Project traverses	Impact assessment required
Lough Corrib SPA	0.1km	Site lies adjacent to groundwater body that the Project traverses	Impact assessment required
Rahasane Turlough SPA	13km	Site lies in separate groundwater body sub catchment	Not considered further
Cregganna Marsh SPA	4km	Site lies in separate groundwater body sub catchment	Not considered further
Connemara Bog Complex SPA	9km	Site lies in separate groundwater body	Not considered further

Based on the above regional screening there are four European sites that are either located within or receiving groundwater from catchments that the Project traverses which is unchanged since the 2018 EIAR. These are:

- Lough Corrib SAC
- Lough Corrib SPA
- Galway Bay Complex SAC
- Inner Galway Bay SPA

The locations of the above SAC and SPA are presented on Figure 10.5.001 and Figure 10.5.002.

Ballindooley Lough is identified in Chapter 8, Biodiversity as supporting the wintering birds of the Lough Corrib SPA and Inner Galway Bay SPA. On this basis Ballindooley Lough is included in the assessment under the heading of European sites.

Lough Corrib SAC, Lough Corrib SPA, Galway Bay Complex SAC and Inner Galway Bay SPA receive groundwater from the Galway Granite Batholith and the Visean Undifferentiated Limestone that the Project traverses. The supporting site, Ballindooley Lough, only receives groundwater from the Visean Undifferentiated Limestone. A breakdown of the contributions from groundwater bodies traversed by the Project to these European sites (including supporting sites) are summarised below in Table 10.13.

Table 10.13 Groundwater Bodies Traversed by the Project and the European sites they Potentially Contribute to

Groundwater Body	Lough Corrib SAC	Lough Corrib SPA	Galway Bay Complex SAC	Inner Galway Bay SPA	Ballindooley Lough
Spiddal GWB	-	-	Contributes	Contributes	-
Maam Clonbur GWB	Contributes	Contributes	Contributes	Contributes	-
Ross Lake GWB	Contributes	Contributes	Contributes	Contributes	-
Lough Corrib Fen 1 (Menlough) GWB and Lough Corrib Fen 1 (Lackagh) GWB	Contributes	-	Contributes	Contributes	-
GWDTE Lough Corrib Fen 2	Contributes	Contributes	Contributes	Contributes	-
Clare-Corrib	Contributes	Contributes	Contributes	Contributes	Contributes
Clarinbridge	-	-	Contributes	Contributes	-

Based on the hydrogeological characterisation along the alignment as presented in Section 10.3.3 the Visean Undifferentiated Limestone contributes a greater component of groundwater to the River Corrib than the Galway Granite Batholith.

The Visean Undifferentiated Limestone includes a number of karst point discharges to the Lough Corrib SAC, which include the Western Coolagh Spring and Terryland River (during high groundwater flow). These karst point discharges contribute to the water environment supporting habitat in the Lough Corrib SAC.

Each of these European sites has a ranking of 'Extremely High' importance in line with TII Guidelines. Potential impacts to these European sites from the characteristics of the Project are evaluated in Section 10.5.

National Heritage Area (NHA)

This section identifies those National sites (both National Heritage Areas and proposed National Heritage Areas) that have the potential to be impacted from a hydrological perspective. All National sites within 30km of the Project have been considered using the precautionary principle. However, the National sites beyond 15km do not have a groundwater connection from the Project and are not considered further. The number of sites remain unchanged since 2018.

The screening of all National sites within 15km of the Project is presented below in Table 10.14. Those National sites that are located in separate and distinct groundwater bodies or sub catchments are not considered further as there is no groundwater connection from the Project.

Table 10.14 Screening of National Heritage Areas (NHA) and proposed National Heritage Areas (pNHA) by Proximity to the Project

Site Name	Proximity to the Project	Screening	Result
Ross Lake and Woods pNHA	11km	Site lies in separate groundwater body sub catchment	Not considered further
Moycullen Bogs NHA (Lough Inch / Na Foraí Maola Thair, Tonabrocky and Letteragh)	0km	Lough Inch / Na Foraí Maola Thair lies within 250m Tonabrocky lies at 250m Letteragh lies adjacent	Impact assessment required for all three locations
Furbogh Woods pNHA	2km	Site lies beyond 250m but within groundwater body traversed by Project	Impact assessment required
Gortnandarragh Limestone Pavement pNHA	14km	Site lies in separate groundwater body	Not considered further
Drimcong Wood pNHA	8km	Site lie in separate groundwater body	Not considered further
Killarainy Lodge, Moycullen pNHA	8km	Site lies in separate groundwater body	Not considered further
Ballycuirke Lough pNHA	5km	Site lies in separate groundwater body	Not considered further
Lough Corrib pNHA	0km	Site lies adjacent at the Corrib crossing	Impact assessment required
Kiltullagh Turlough pNHA	2km	Site lies within same groundwater body sub catchment	Impact assessment required
Cregganna Marsh NHA	4km	Site lies in separate groundwater body sub catchment	Not considered further
Galway Bay Complex pNHA	0.2km	Site lies adjacent to groundwater body traversed by Project	Impact assessment required
East Burren Complex pNHA	14km	Site lies in separate groundwater body	Not considered further
Rahasane Turlough pNHA	14km	Site lies in separate groundwater body sub catchment	Not considered further
Lough Fingal Complex pNHA	11km	Site lies in separate groundwater body	Not considered further
Castletaylor Complex pNHA	14km	Site lies in separate groundwater body sub catchment	Not considered further
Kiltiernan Turlough pNHA	14km	Site lies in separate groundwater body sub catchment	Not considered further
Ballyvaughn Turlough pNHA	15km	Site lies in separate groundwater body	Not considered further
Blackhead Poulsallagh Complex pNHA	11km	Site lies in separate groundwater body	Not considered further

Based on the above regional screening there is one NHA site and four pNHA sites that have the potential to be impacted by the Project as per the 2018 EIAR. These are:

- Moycullen Bogs NHA
- Furbogh Woods pNHA
- Kiltullagh Turlough pNHA

- Galway Bay Complex pNHA
- Lough Corrib pNHA

The locations of the above NHA and pNHA are presented on Figure 10.5.001 and Figure 10.5.002, and in more detail Figures 8.17.1 and 8.17.2.

The Moycullen Bogs NHA, which are located on the Galway Granite Batholith, occur as one main site encompassing west of Lough Inch and two isolated sites one at Letteragh and one at Tonabrocky. The southern corner of the main site lies within 250m of the Project, whilst the site at Letteragh lies adjacent to the Project. The site at Tonabrocky lies 250m away from the footprint of Project.

The Moycullen Bogs include areas of surface water ponding, which is present at all sites. Based on the conceptual site model for the Galway Granite Batholith (Section 10.3.4.1) the surface water ponding is caused by the low aquifer properties (permeability and storage) of the underlying granite, which causes water infiltrating through the subsoil to perch above the undulating rock head.

These surface ponds are not dependant on groundwater per se but they are dependent on the site specific hydrogeology, specifically the low aquifer properties, the undulating nature of the rockhead and also rainfall. The Moycullen Bogs are ranked as having a ‘Very High’ importance based on the TII guidance and are assessed in the evaluation of impacts (Section 10.5).

Furbogh Woods pNHA area located at the coast within the Spiddal GWB approximately 2km west of the Project. Groundwater flow within the Spiddal GWB follows surface water patterns and may be divided into sub catchments on the basis of surface water streams. On this basis the Furbogh Woods pNHA lies in a separate sub catchment to the Project and is not considered further in this assessment.

Kiltullagh Turlough pNHA lies near Galway Airport, 2.5km east of the Project. The turlough lies within the Clarinbridge GWB at an elevation of approximately 10m OD. Based on the groundwater levels recorded within the Clarinbridge GWB for the Project (refer to Section 10.3.3.4) the groundwater flow within the GWB is southwards towards Galway Bay. On this basis, although Kiltullagh Turlough pNHA is topographically low, it is located 2.5km upgradient of the Project and is not considered further.

Lough Corrib pNHA and Galway Bay Complex pNHA receive groundwater from the Galway Granite Batholith and the Visean Undifferentiated Limestone that the Project traverse. Both the Lough Corrib pNHA and Galway Bay Complex pNHA has a ranking of ‘Very High’ importance in line with TII Guidelines.

In summary, the following National sites are considered receptors for the Project:

- Moycullen Bogs NHA (Lough Inch/Na Foraí Maola Thair, Tonabrocky and Letteragh)
- Galway Bay Complex pNHA
- Lough Corrib pNHA

A breakdown of the groundwater bodies that contribute to those NHA identified above to be included in the evaluation of impacts are summarised below in Table 10.15 and are unchanged since the 2018 EIAR.

Table 10.15 Summary of Groundwater Bodies traversed by the Project that contribute to National Heritage Areas (NHA) and proposed National Heritage Areas (pNHA)

Groundwater Body	Lough Corrib pNHA	Galway Bay Complex pNHA	Moycullen Bogs NHA	Moycullen Bogs NHA at Tonabrocky	Moycullen Bogs NHA at Letteragh
Spiddal GWB	-	Contributes	Contributes	Contributes	Contributes
Maam Clonbur GWB	Contributes	Contributes	-	-	Contributes
Ross Lake GWB	Contributes	Contributes	-	-	-
Lough Corrib Fen 1 GWB	Contributes	Contributes	-	-	-
Lough Corrib Fen 2 GWB	Contributes	Contributes	-	-	-
Lough Corrib Fen 3 & 4 GWB	Contributes	Contributes			
Clare-Corrib GWB	Contributes	Contributes	-	-	-
Clarinbridge GWB	-	Contributes	-	-	-

Annex I habitats

In addition to the European sites, Chapter 8, Biodiversity details Annex I water dependant habitat that are outside of the European site boundaries. These habitat names are listed in Table 10.16 below (refer to Chapter 8, Biodiversity for further details on the habitat).

Table 10.16 Annex I Water Dependant Habitat

Annex I habitat code	Habitat name
4010	Wet heath
6410	Molinia meadows
6430	Hydrophilous tall herb
*7130/7130	Blanket bog (active*)
7140	Transition mires
7150	Rhynchosporion depressions
*7210	Cladium fen*
*7220	Petrifying Springs*
7230	Alkaline fens
*8240	Limestone pavement*
*91E0	Residual alluvial forests*
*3180	Turloughs*

Notes:* Denotes a priority habitat

On the Galway Granite Batholith, the Annex I habitats outside of European and National sites include wet heath, blanket bog and Molinia Meadows. On the Visean Undifferentiated Limestone the Annex I habitats outside of European and National sites include Turloughs, Limestone pavement, Petrifying springs. Annex I habitats are ranked as having a 'Very High' importance, and unless shown to be beyond the hydrogeology study area, are considered in the evaluation of impacts assessment.

Like the Moycullen Bogs, as described in the section on NHA, the surface water ponding within wetland sites on the Galway Granite Batholith are not derived from groundwater, rather that they are caused by ponding above rockhead where the rainfall and runoff is perched and trapped by basins in the bedrock topography. These include Annex I wetland habitats that are present along, or adjacent to, the route of the road alignment within the hydrogeological study area. The habitat features do not have names as such but are described in relation to place names and the chainage along the alignment that they occur.

The Annex I habitat locations and extents are detailed in Chapter 8 Biodiversity and are presented on Figure 10.5.001 and Figure 10.5.002 to show the location of these habitats relative to GWBs (note that the chainages for the road alignment are shown on Figures 10.6.001 to 10.6.012).

- Wetland habitats (Spiddal GWB) at Na Foraí Maola Thiar (Ch. 0+650 to Ch. 0+750), Na Foraí Maola Thoir (Ch. 1+250 to Ch. 1+500), Troscaigh Thiar (Ch. 1+850 to Ch. 2+400), Bearna (Ch. 2+600 to Ch. 3+100), Aille (Ch. 3+600 to Ch. 3+850) and Ballyburke (Ch. 4+650 to Ch. 4+800)
- Wetland habitats (Maam-Clonbur GWB) at Knocknabrona (Ch. 7+700 to Ch. 7+750)
- Wetland habitats (Ross Lake GWB) at University of Galway (N) (Ch. 8+800 to Ch. 8+950 and University of Galway (S) (Ch. 9+150 to Ch. 9+250)

All the Annex I habits had been identified in the 2018 EIAR except for Knocknabrona (Ch. 7+700 to Ch. 7+750), which was identified following 2023 habitat surveys. The extent of Annex I habitats at three locations namely Na Foraí Maola Thiar (Ch. 0+650 to Ch. 0+750), Aille (Ch. 3+600 to Ch. 3+850) and Ballyburke (Ch. 4+650 to Ch. 4+800) has changed since the 2018 EIAR.

Karst features are considered in this section of the assessment based on the water dependent ecology that they support. Three Turloughs (referenced as K20, K31 K72 in the karst database) were identified during the field surveys and their locations are presented in Figure 10.1.002. The Turloughs are all located in different groundwater bodies as follows:

- K31 is in the Lough Corrib Fen 1 (Menlough) GWB
- K20 is in the Lough Corrib Fen 2 GWB
- K72 is in the Clare-Corrib (Ballindooley East) GWB

Turlough K31 is crossed by the proposed N6 GCRR by a bridge structure. It is included as a receptor in the evaluation of impacts.

Turlough K20 is located 425m north of the Project in an adjacent GWB. Although in a separate GWB, the feature lies within 250m of the groundwater divide between Lough Corrib Fen 1 (Menlough) and Lough Corrib Fen 2, and as such is included as a receptor in the evaluation of impacts.

Turlough K72 is located in the same groundwater body as the Project albeit 500m up-gradient of it. Turlough K72 is included as a receptor in the evaluation of impacts.

Limestone pavement is also considered in this section as it is present in the region between Lackagh Quarry and Menlough (Chapter 8, Biodiversity). Whilst Limestone pavement habitat is not dependent on groundwater it does require the development of a free draining upper zone in the limestone (referred to as epikarst) that rapidly drains rainfall into the aquifer so as not to cause ponding.

Limestone pavement is considered as a hydrogeological receptor as it is susceptible to groundwater level rise and could be impacted if groundwater were to flood the habitat. Limestone pavement is also described as a receptor in both Chapter 8, Biodiversity and Chapter 9, Soils and Geology. Limestone pavement ecosystems are included as potential hydrogeological receptors.

Lackagh Quarry includes 29 (No.) seepages points (2023 survey, refer to Chapter 8 Biodiversity), which are mainly located on the western and northern quarry faces. Chapter 8, Biodiversity, classifies six of these seepages as petrifying springs, which have tufa (calcium carbonate) deposition. Of the six petrifying springs classified in 2018 EIAR, three have been declassified as petrifying and three non-petrifying springs have now been classified as petrifying, giving a total of six petrifying springs in this updated EIAR.

Hydrogeological observation of all the seepages concludes that all are seasonal and are generally only active between September and May, but they can also activate following prolonged or heavy summer rainfall. All the seepages including the six identified as petrifying springs occur higher than the regional water table. All the seepages occur where karst flow paths through the unsaturated limestone bedrock have been intercepted by the quarry void.

As the six petrifying springs are Annex I habitats dependant on recharge along karst pathways they ranked as 'Very High' in terms hydrogeology.

Non-Annex I habitat

Several locally important ecological habitats, which are dependent on water or hydrogeological characteristics, have been identified and these are included in the Chapter 8, Biodiversity. These include wetland sites on the Galway Granite Batholith and calcareous springs in Lackagh Quarry. These features are described in Chapter 8, Biodiversity.

Non-Annex I wetland sites at the below locations are similar in hydrogeological character to the Moycullen Bogs discussed earlier in this section on NHA. Often the Galway Granite Batholith forms basins in the rock topography and in these hollows surface water ponds and is slow to drain away. These wetland sites are fens that are generally located in topographic hollows in the local granite topography. The sites identified in the hydrogeological study are comprised of habitat in the following locations (note that some are individual features and some a grouped together when multiple features are close):

- An Baile Nua (Ch. 0+150), Na Forai Maola Thoir (Ch. 1+150), Barna (Ch. 3+100 and Ch. 3+400), Knocknabrona (Ch. 7+850 to Ch. 8+150)

There are an additional four non-Annex I sites identified since the 2020 Oral Hearing.

Of the 29 (No.) seepages identified in Lackagh Quarry a total of 23 (No.) are classified in Chapter 8, Biodiversity as being calcareous springs/seepages, which are a non-Annex I habitat type (2023 survey, refer to Chapter 8, Biodiversity). There are two new seepages in the 2023 survey, and these are non-Annex I habitat. Like the petrifying springs, identified above, the calcareous springs/seepages have developed where shallow karst pathways have been intercepted by the quarry void. Like the petrifying springs these features are seasonal in nature and typically flow between September and May but can activate following prolonged or heavy summer rainfall. From a hydrogeological standpoint, petrifying springs and calcareous springs/seepages are the same but the naming depends on the habitat present and as such the naming is an ecological differentiation.

10.3.5.4 Groundwater Dependent Surface Water Features

As presented in the conceptual site model, the hydrogeology study area includes surface water features that are dependent on groundwater. These include the River Corrib, Ballindooley Lough, Coolagh Lakes, Turlough K20, Turlough K31, Turlough K72 and Terryland River.

Of these features, the River Corrib, Ballindooley Lough, Coolagh Lakes, Turlough K20, Turlough K31 and Turlough K72 are either part of a European site or are Annex I habitat outside of designated sites and have already been described in detail in Section 10.3.5.3 Groundwater Dependent Habitats.

The Terryland River is not presented in the Section 10.3.5.3 as it is not designated within a context of groundwater dependant habitat, and it is included here as a surface water feature that has groundwater interaction. During times of high water table in the surrounding limestone aquifer, groundwater contributes to the Terryland River. During extreme events it may be possible for the Terryland River to contribute to the River Corrib. The complex interaction between groundwater and the Terryland River is presented in detail in Appendix A.10.3. On the basis that groundwater has the potential to contribute to the River Corrib (which is part of the Lough Corrib SAC) the Terryland River is considered to have an 'extremely high' importance rating but only during extreme flood events when flow in the Terryland River has reversed its normal flow and flooded back to the River Corrib.

10.3.5.5 Groundwater Flooding

After the publication of the 2018 EIAR and after the close of the 2020 oral hearing in November 2020 the GSI has initiated guidance on groundwater flooding. The GSI data on groundwater flooding for the hydrogeology study area has been considered in this updated assessment and is included below.

The GSI provides mapping of groundwater flood probability with categories of high (annual exceedance probability (AEP) of 10%), moderate (AEP of 1%), and low (AEP of 0.1%). The GSI also provide a map showing the Maximum Historical Groundwater Flood which present the observed peak flood extents caused by groundwater. Reference is made by GSI to the winter of 2015/16, which is recognised as having significant flooding in Galway, which is largely considered to be the most extensive witnessed in the region.

An area of historical groundwater flooding which also coincides with mapped areas of low to high probability flooding is mapped approximately 3km northeast of the Assessment Boundary within the Clarinbridge GWB. This area is associated with the Kiltullagh Turlough and as discussed in Section 10.3.5.3 there is unlikely to be a connection from the Project site to the turlough is therefore it is not considered further.

Another area of historical groundwater flooding is located 2km north of the Assessment Boundary. This area is within the Clare-Corrib GWB and has no hydrogeological connection to the Project site.

10.3.5.6 Summary

This section has identified all hydrogeological features of importance which are the receptors of relevance within the hydrogeology study area that have the potential of being impacted by the Project. Hydrogeological receptors are divided in subcategories of resources and supplies, surface water and ecosystems. Those sites and features from each of these subcategories within the hydrogeology study area are summarised below in Table 10.17.

Since the 2018 EIAR, this summary table has been updated with an additional seven groundwater supply wells (W50-16, W50-17, W50-18, W50-19, W50-20, W50-21 and W50-22) and has also been updated with Annex I habitat and non-Annex I habitat.

Table 10.17 Ranking of Importance of all Hydrogeological Features within the Hydrogeology Study Area

Feature	Location relative to Project	Importance Ranking	Justification
Groundwater resources			
Poor Bedrock Aquifer (Pl)	Section 1 of Project	Low	Poor Bedrock Aquifer
Regionally Important Aquifer (Rkc)	Sections 2, 3 and 4 of the Project	Very High	Regionally Important Aquifer (Rkc)
Groundwater supplies (wells and springs)			
Knocknacarra GWS (W50-01)	1km	Medium	Group water scheme supplying up to 50 houses
W50-02	2km	Low	Agricultural / Domestic supply
W50-03 04, 05, 06 and 07	2km	Low	Agricultural / Domestic supply
W50-08	1.4km	Low	Agricultural / Domestic supply
W50-09	0.5km	Low	Agricultural / Domestic supply
W50-10	0km	Low	Agricultural / Domestic supply
W50-11	0.5km	Low	Agricultural / Domestic supply

Feature	Location relative to Project	Importance Ranking	Justification
W50-12	0km	Medium	Commercial supply 250m^3/d
W50-13 and W50-14	0km	Very High	Commercial supply 2,000m^3/d
W50-15	0km	High	Commercial supply 380m^3/d
W50-16	0km	Low	Historic domestic / agricultural supply spring
W50-17	0.1km	Low	Agricultural / Domestic supply
W50-18	0.4km	Low	Agricultural / Domestic supply
W50-19	0km	Low	Agricultural / Domestic supply
W50-20	2.5km	Medium	Commercial potable supply 50m^3/day
W50-21	1km	High	Commercial: quarry 400m^3/d
W50-22	2.5km	Medium	Commercial: golf course irrigation 250m^3/d
W100-01 & 02	0.6km	Low	Agricultural / Domestic supply
W100-03, 04, 05 and 06	0.3km	Low	Agricultural / Domestic supply
W500-01	0.8km	Low	Agricultural / Domestic supply
W1000-01	0.5km	Low	Agricultural / Domestic supply
W1000-03	1.1km	Low	Agricultural / Domestic supply
W1000-04	0.5km	Low	Agricultural / Domestic supply
G50-01	0.1km	Low	Geothermal well
Surface water features			
Terryland River	0.6km	Extremely High	Contributes to River Corrib during but only during extreme peak groundwater levels
Habitat conservation areas			
Galway Bay Complex SAC	0.8km	Extremely High	European site
Inner Galway Bay SPA	1km	Extremely High	European site
Lough Corrib SPA	0km	Extremely High	European site
Lough Corrib SAC	0km	Extremely High	European site
Ballindooley Lough	0.1km	Extremely High	Supporting feature for Lough Corrib SPA
Moycullen Bogs	0.2km	Very High	National site
Moycullen Bogs (Tonabrocky)	0.3km	Very High	National site
Moycullen Bogs (Letteragh)	0km	Very High	National site
Lough Corrib pNHA	0km	Very High	National site

Feature	Location relative to Project	Importance Ranking	Justification
Galway Bay Complex pNHA	0.2km	Very High	National site
Turlough K20	0.4km	Very High	Annex I habitat
Turlough K31	0km	Very High	Annex I habitat
Turlough K72	0.5km	Very High	Annex I habitat
Annex I wetlands (9 No.) • Na Foraí Maola Thiar • Na Foraí Maola Thoir • Troscaigh Thiar • Bearna • Aille • Ballyburke • Knocknabrona • UoG (N) • UoG (S)	0.0km	Very High	Annex I habitat
Petrifying springs (6 No.) (Lackagh Quarry)	0km	Very High	Annex I habitat
Non-Annex I wetlands (4 No.) • An Baile Nua • Na Forai Maola Thoir • Barna • Knocknabrona	0km	Low	Locally important habitat
Calcareous springs (23 No.) (Lackagh Quarry)	0km	Low	Locally important habitat

10.4 Characteristics of the Project

A detailed description of the Project and construction work is provided in Chapter 5, Description of Project and Chapter 7, Construction Activities. There are five phases in the Project as set out below. The inclusion of the temporary stables but relocated to the infield at Galway Racecourse and ancillary works in the assessment of the Project for this updated EIAR has resulted in the increased area of the Assessment Boundary in the vicinity of Galway Racecourse. This section outlines the characteristics and activities of the Project which will interact with hydrogeology and hydrogeological receptors noting that Phase 2 is the most significant characteristic of the Project.

10.4.1 Phase 1

Phase 1 includes the construction of a temporary stableyard including horsebox parking, machinery shed, maintenance shed, ESB substation, two wells, new pre-parade ring and pavilion on Galway Racecourse lands. (Approval for which was granted by Galway City Council in December 2024 Planning Ref. No.:24/60279).

10.4.2 Phase 2

Phase 2 comprises the construction and operation of the proposed N6 GCRR.

10.4.3 Phase 3

Phase 3 comprises the construction of the new permanent stableyard including horsebox parking post-handover of the proposed N6 GCRR. (Approval for which was granted by Galway City Council in December 2024 Planning Ref. No.:24/60279).

10.4.4 Phase 4

Phase 4 comprises the demolition of the temporary stables constructed in Phase 1. (Approval for which was granted by Galway City Council in December 2024 Planning Ref. No.:24/60279).

10.4.5

10.4.6 Phase 5

Phase 5 is the operational phase of the Project.

10.4.7 Construction and Operation Activities of the Project of Importance

The elements of the Project that will interact with the hydrogeological environment are those activities that have the capacity to change the groundwater regime in terms of recharge groundwater levels and water quality. These activities could be:

- Construction: dewatering of the bedrock aquifer for cuts or structures, accidental spillages of potentially polluting materials etc.
- Operation: discharge due to road drainage from the proposed N6 GCRR leading to a change in recharge patterns; reduced recharge due to surface sealing by road pavement, road cuts intercepting groundwater flow, structures (tunnels, sealed cuttings) acting as a barrier to groundwater flow

The profile of the proposed N6 GCRR is presented in Figure 10.6.001 to Figure 10.6.012 shows the locations where the Project is in cutting, fill and at grade as well as showing the location of minimum and maximum groundwater levels for comparison. Assessment of potential drawdown is presented in Appendix A.10.6 and remains unchanged since the 2018 EIAR.

Impacts are assessed depending on changes to catchment boundaries and uses the TII HD45 assessment to determine potential impacts (HD45 assessment is undertaken in Appendix A.10.7).

Lowering of groundwater levels is referred to as water table 'drawdown'. Table 10.18 summarises the excavations along each section of the Project and identifies those sections of the Project that will incur drawdown. Based on properties for the aquifers (Table 10.10) the maximum zone of influence radius from the cutting is calculated, which is included in Table 10.18, as a measurement from the footprint of the Project. The radius of influence is the area within which groundwater levels are affected by drawdown. Outside the radius of influence, there will be no effect on groundwater levels. The radius of influence was calculated using the Sichardt empirical formula as follows:

$$Ro = \frac{\mathrm{C(H - hw)}}{\sqrt{(k)}}$$

Where, Ro = radius of influence

C = empirical calibration factor

(H-hw) = drawdown (amount the water table would be lowered)

K = hydraulic conductivity (the rate at which groundwater can flow through the material)

This analysis was undertaken on a highly conservative basis to ensure that the calculated zone of influence would be as large as possible. Some of the conservative assumptions used included:

1. Using the maximum recorded winter groundwater level so that maximum drawdown was used in the calculation, which accordingly increases the ZoI
2. The hydraulic conductivity used is the highest recorded for the section of aquifer along the Project. Details of the range of hydraulic conductivity for both granite and limestone are presented in Plate 10.1 of Chapter 10 of this updated EIAR
3. The drawdown calculation was applied at 100m chainage points in each cutting to ensure that the ZoI accommodates changes in cutting length such as depth of cut and hydraulic gradient

It is assumed that the dewatering of the groundwater level is 1m deeper than the drainage invert depth to allow for sumps or excavations that may be required during construction. During operation the dewatering of the groundwater level is assumed to be the drainage invert level.

On this basis construction dewatering of the groundwater is deeper than that required for operation and drawdown may be presented where the Project is at grade or on embankment. This is particularly the case in the granite area, where the groundwater level is assumed to be at surface.

It should be noted that drawdown at cuttings is in an elongated inverted cone shape: within the zone of influence, the highest level of drawdown will be in the cutting (i.e. the location where the water table is being drawn down) and the water levels will get higher until they return to normal at the edge of the radius of influence.

With respect to the aquifer types discussed in Section 10.3.3 the location and extent of excavations on the proposed N6 GCRR are as per the 2018 EIAR and can be summarised as:

- Galway Granite Batholith: there are seven road cuttings (Table 10.18) namely, EW01, EW02 (three cuttings), EW04, EW07 and EW11. There are bridge structures at Troscaigh (S01/01), Aille (S03/01), Rahoon (S06/01), Letteragh (S07/01), N59 Link Road North and South (S07/02) and the N59 Moycullen Road (S08/02).
- Visean Undifferentiated Limestone: includes EW22, EW25, EW27, EW28 and EW34-35 (combined) (five cuttings) (Table 10.18). There are two tunnels, Lackagh Tunnel (S11/01) and Galway Racecourse Tunnel (S14/02) both of which have approaches. Bridge structures comprise of one crossing of the River Corrib (S08/04), one viaduct at Menlough (S10/01) to cross limestone pavement and road bridges for Menlo Castle Boithrin (S09/01), Coolagh Road (S10/02), the N84 Headford Road (S12/01), Wildlife Overpass Castlegar (S12/02), School Road (S13/01), N83 Tuam Road (S13/02), Park Road Link (S14/01), Monivea Road (S15/01) and Coolagh Junction (S16/01 and S16/02).

In addition to the excavations for tunnel construction in Galway Racecourse, works will be undertaken for temporary stables, new stables area and replacement of the existing groundwater supply. The works associated with the stables include shallow excavations and are not of significance from a hydrogeological perspective as they will not intersect either the shallow or the deep water table that has been identified in the southern part of Galway Racecourse. Furthermore, as the existing supply wells on the Galway Racecourse site will be replaced with new wells close to the location of the existing wells, drawing an equivalent volume of water from the new locations. As the same volume of water will be abstracted from the same aquifer as the original abstraction wells, the new wells are not of significance.

The maximum depth of the proposed finished proposed N6 GCRR road level below ground level for each cut section is presented in Table 10.18. The excavation depths for foundations and drainage have a maximum cut depth elevation of 3m below the finished road elevation, which is applied to the full length of the proposed N6 GCRR. This is an over estimation on the maximum potential cut depth for drainage and foundations.

The construction schedules for Lackagh Tunnel and the Menlough Viaduct shall accommodate the seasonal groundwater fluctuation so that construction works always occurs above the water table and dewatering in the bedrock aquifer is not required. For this reason, there will be no lowering in groundwater levels at these locations and accordingly the drawdown is represented as ‘0m’ in Table 10.18. For clarity, it is noted that the construction schedule is an embedded feature of the design and not mitigation.

Galway Racecourse Tunnel will be constructed and fully operational at the end of Phase 2 of the Project. The maximum construction excavation depth of the Galway Racecourse Tunnel is 12.2m and the finished road level is proposed to be at a maximum of 9.4m below ground level (bgl). Along the western approach to the Galway Racecourse Tunnel the excavation extends to a maximum depth of 11.4mbgl.

The main construction characteristics of the Project with relevance to hydrogeology are detailed below in Table 10.18, which shows the maximum vertical drawdown (road centreline) and maximum zone of influence (from top of cutting and considering both sides of the cutting). Calculation of the vertical drawdown and lateral zone of influence are presented in Appendix A.10.6. Lateral extent of the cutting ZoI is presented in Figure 10.7.101 - 115 (Construction) and Figure 10.8.101 - 115 (Operation).

Table 10.18 Summary of Main Earthwork (EW) Locations for the Project

Feature Type	Earth-works Ref. No.	Approx. Chainage	Length (m)	Max depth of finished road level (m BGL)	Max depth of construction excavation (m BGL)	Depth to peak winter ground water level (m BGL)	Max ground water draw down (m)	Max Zone of influence radius (m) from footprint of the Project
Section 1 Galway Granite Batholith – R336 to N59 Moycullen Road								
Road Cutting	EW01	0+000 – 0+500	500	1.3	4.3	1.1	3	15
Road Cutting	EW02	1+150 – 1+350	200	0.9	3.9	1.9	2	9
Road Cutting	EW02	1+600 – 1+950	350	1.0	4.0	1.1	3	14
Road Cutting	EW02	2+230 – 2+640	410	3.1	6.1	3.6	2	12
Road Cutting	EW04	3+100 – 4+080	980	5.9	8.9	1.5	8	35
Road Cutting	EW07	5+250 – 5+580	330	5.3	8.3	3.4	5	23
Road Cutting Letteragh Junction	EW11	7+600 – 8+280	690	14.4	17.4	5.7	12	54
Section 2 & 3 Visean Limestone Undifferentiated - River Corrib to N83 Tuam Road								
River Corrib Structure (S06/04)	EW15	9+300 – 9+500	200	(Above ground)	(Above ground)	(Above ground)	0	0
Menlough Viaduct (S10/01)	EW17	9+500 – 10+100	600	(Above ground)	(Above ground)	(Above ground)	0	0
Western Approach to Lackagh Tunnel	EW19	10+810 – 11+140	350	13.5	16.5	12.2	0	0
Lackagh Tunnel (S11/01)	EW20	11+140 – 11+420	270	Bored tunnel	Bored tunnel	Bored tunnel	0	0

Feature Type	Earth-works Ref. No.	Approx. Chainage	Length (m)	Max depth of finished road level (m BGL)	Max depth of construction excavation (m BGL)	Depth to peak winter ground water level (m BGL)	Max ground water draw down (m)	Max Zone of influence radius (m) from footprint of the Project
Road Cutting	EW22	11+720 – 11+920	200	24.6	27.6	35.5	0	0
Road Cutting	EW25	12+500 – 12+920	370	7.6	10.6	15.6	0	0
Road Cutting	EW27	13+050 – 13+650	600	12.0	15.0	12.1	3	70
Section 4 N83 Visean Limestone Undifferentiated Tuam Road to existing N6								
Road Cutting	EW28	14+150 – 14+450	300	12.3	15.3	18.6	0	0
Western Approach to Galway Racecourse Tunnel	EW30	14+450 – 14+950	500	11.4	14.4	18.5*5	2	14
Galway Racecourse Tunnel (S14/02)	EW31	14+950 – 15+190	240	9.2	12.2	8.9	4	35
Eastern Approach to Galway Racecourse Tunnel	EW32	15+190 – 15+500	310	8.7	11.7	7.8	4	35
Road Cutting	EW34-35	16+200 – 17+500	740	6.8	9.8	11.9*6	2	12

Notes:

Structure depths are presented to 10cm. Predicted drawdown and radius are rounded up to nearest 1m.

The maximum depth of proposed road level refers to the finished road level.

Max drawdown depth = Max baseline groundwater level - (max finished road level - 3m over excavation for drains)

Maximum groundwater level uses maximum groundwater levels measured during the project monitoring period 2015 - 2017 (**Section 10.3.2**) for the chainage with the maximum excavation depth

Winter water table at eastern end of cutting (Ch. 14+950) has seasonal peak 1.6m higher than max excavation depth

Winter water table at western end of cutting (Ch. 16+200) has seasonal peak 1.3m higher than max excavation depth

Phase 5 is the operational phase of the Project and the design features which are put in place during the construction will manage groundwater without any further impacts to the hydrogeological features of importance.

The drainage design of the Project is presented in Chapter 5, Description of the Project and is summarised below for the four hydrogeological sections. The operational drainage features of the Project comprise of:

- Section 1 – R336 to N59 Moycullen Road: Ch. 0+000 to Ch. 8+850
  - Permeable drains where possible on mainline, side roads and service roads
  - Treated road runoff discharged to surface watercourse (refer to Chapter 11, Hydrology) or public sewers

- Permeable sub-surface groundwater interception drains in road cuttings

- Section 2 - N59 Moycullen Road to River Corrib Ch. 8+850 to Ch. 9+400
  - Sealed drains on mainline, side roads and service roads
  - Discharge of road runoff to River Corrib (refer to Chapter 11, Hydrology)
- Section 3 - River Corrib to N83 Tuam Road Ch. 9+400 to Ch. 14+000
  - Sealed drains on mainline, side roads and service roads
  - Discharge of treated road runoff to ground via infiltration basins in the absence of surface water (refer to Chapter 11, Hydrology) or public sewers
  - Permeable sub-surface groundwater drains in all cuttings
- Section 4 – N83 Tuam Road to existing N6
  - Sealed drains on mainline, side roads and service roads
  - Discharge of treated road runoff to ground via infiltration basins in the absence of surface water features or public sewers
  - Permeable sub-surface drains in all cuttings

The drainage at Galway Racecourse will revert to the pre-development regime at Phase 5 (operation). The catchment of swallow hole (K328), near Ballybrit castle, which lies in the southern part of Galway Racecourse will remain unchanged as part of the racecourse runoff management.

The assessment of the potential impacts that these design elements may have on the hydrogeological environment is presented in Section 10.5.

10.5 Evaluation of Effects

The potential impacts on hydrogeology receptors from the Project are presented in this section. The Do-Nothing scenario is presented in Section 10.5.1. An assessment of potential impacts for the construction phase is presented in Section 10.5.2 and during the operation phase in Section 10.5.3.

Hydrogeological receptors within the hydrogeology study area are listed and ranked for importance in Section 10.3.5 for each of the four hydrogeological sections. A summary of these rankings is presented in Table 10.17. This section has been updated to include all additional receptors that are identified since 2018 in Section 10.3, including swallow hole K328 south of Galway Racecourse and seven additional groundwater supply wells. No additional GWDTE features have been identified since the 2018 EIAR.

The inclusion of the temporary stables as relocated in the infield at Galway Racecourse and ancillary works in the assessment of the Project has provided further information for the assessment of hydrogeological Section 4. This includes an update to the conceptual model of the limestone aquifer in this area as having a distinct shallow and deep aquifer. This has led to revision of the evaluation of impacts. In particular the presence of swallow hole K328 has required assessment of the groundwater resources and the receptors that lie down gradient.

Several appendices provide supporting data to this section on evaluation of impacts. The following are referred to throughout the section:

- Appendix A.10.6 Hydraulic calculations
- Appendix A.10.7 HD45 assessments
- Appendix A.10.8 Eco Hydrogeology reports

Appendix A.10.6 provides the details on the calculation used to determine the drawdown at road cuttings. Drawdown is provided in terms of the vertical lowering of the groundwater level and the lateral extent that the drawdown reaches perpendicular to the road. Drawdown data are provided in the appendix for every

100m chainage of the proposed N6 GCRR. The data presented in the appendix are reported from the road centreline and these datapoints are then used to determine the drawdown extents in Figures 10.7.101 - 115 and Figure 10.8.101 - 115. Note that for hydrogeology, the drawdown extents are presented as distance from the cutting (not distance from centreline) as it is standard convention to present drawdown from the cutting face.

Appendix A.10.7 HD45 assessments compiles all hydrogeological assessments for the drainage networks of the proposed N6 GCRR. These assessments are unchanged from the 2018 EIAR as the maximum groundwater level used in the assessment is based on the winter of 2015/16, which is still recognised in Galway as having the highest water levels on record.

Appendix A.10.8 Eco Hydrogeology Reports. Two GWDTE formed the focus of the hydrogeology presentations in the 2020 Oral Hearing, namely Moycullen Bogs NHA (Letteragh) and Coolagh Lakes SAC. Two standalone responses were compiled to present the proposed N6 GCRR study of these two GWDTE. These two reports are included in this updated EIAR in Appendix A.10.8 to provide a summary of the main discussion points and include a collection of cross-sections and hydrographs specifically looking at each GWDTE. The Eco-hydrogeology reports provide a comprehensive assessment of the hydrogeology at Moycullen Bogs and Lough Corrib SAC. The conclusion of both reports is that the hydrogeology assessment for both Moycullen Bogs and Lough Corrib SAC provides a reliable conceptual model, and this has enabled the project to incorporate design considerations to rule out potential hydrogeology impacts.

On conclusion of the 2020 Oral Hearing the following summary was provided in ABP’s Inspectors’ Report dated 22 June 2021 in Section 11.9.111.

In conclusion, based on the conceptual model, the differences between the granite and limestone areas, and the design considerations of the PRD included to protect Natura 2000 sites, Mr Dodds’ professional opinion is that the applicant has provided sufficient analysis to rule out any potential impacts derived from changes in groundwater quantity and quality on the integrity/conservation objectives of Natura 2000 sites, including the River Corrib, GWDTE and including consideration of any supporting aquatic habitats outside the Natura 2000 sites, such as Coolagh Lakes, beyond all reasonable scientific doubt. I agree with Mr Dodds conclusion on this matter in terms of hydrogeology, noting that these issues are also addressed in the Appropriate Assessment section of this report.

This section ranks the Magnitude and Significance of any potential hydrogeological impacts in line with TII Guidelines. Where hydrogeological impacts are predicted then these are also assessed for interaction with other aspects of the environment, most notably Biodiversity, Soils and Geology, Hydrology and Material Assets.

10.5.1 Do-Nothing Effects

In the absence of the Project then the baseline hydrogeological environment will remain as presented in Section 10.3.

10.5.2 Construction Phase

Construction activities can interact with hydrogeological receptors by changing the groundwater regime that a receptor is dependent upon. The potential impacts outlined in this section are pre-mitigation. Mitigation measures are described in Section 10.1 and residual impacts post mitigation are outlined in Section 10.7.

There are a number of ways the hydrogeological environment may potentially be impacted during the construction phase and these include:

- the removal of the aquifer during excavations
- changes in recharge characteristics
- changes in groundwater levels
- changes in water quality

These potential changes to the groundwater regime are considered here and the interaction of these changes on receptors are considered below for groundwater resources (Section 10.5.2.1), groundwater supplies

(Section 10.5.2.2), groundwater dependant habitats (Section 10.5.2.3) and groundwater contributions to surface water (Section 10.5.2.4).

Removal of part of the groundwater resource (aquifer) occurs in cut sections where saturated rock is removed. Those cuttings that intercept groundwater will lead to a reduction in groundwater level, the aquifer saturated thickness and the aquifer unsaturated thickness for the cutting footprint. If groundwater is not intercepted, then there will only be a reduction in the unsaturated thickness.

The concept of recharge is explained in Section 10.3.2, with data both for the granite and limestone areas presented. During construction where vegetation is removed then there will be an increase in the quantity of effective rainfall available to recharge to ground or runoff as surface water. Where vegetation is removed then there typically is an increase in the quantity of runoff. Any potential impacts of this on the identified receptors are discussed further below where relevant.

Groundwater levels will be lowered by dewatering of the bedrock aquifer during the construction phase of the proposed development for those elements of the road being constructed below the water table. These include road cuttings and construction phase excavations for drainage (attenuation ponds, infiltration ponds, stream realignment) as well as excavations for structures including bridges, viaducts, tunnels and underpasses. This section of the report outlines how the groundwater levels will change during the construction phase. The potential impacts on specific receptors are discussed below, which also includes potential impact on groundwater levels from the interception of karst pathways during construction.

The drawdown extents are presented in Figure 10.7.101 to Figure 10.7.115 for the construction phase for the full dataset (road cuttings and drainage excavations combined). A summary extract of the drawdown extents at individual road cuttings (road cuttings and drainage excavations combined) are presented below in Table 10.18. The Zone of Influence (ZoI) of the cutting/dewatering location is the area within which groundwater levels are affected by dewatering of the bedrock aquifer – outside of this area groundwater levels will remain at their natural level. The ZoI is presented as a radius on either side of the Project, which is calculated using the upper range of aquifer properties and the hydraulic gradient of the water table. The detailed calculations are presented in Appendix A.10.6 and summarised in Table 10.18. The assessment of drawdown is conservative as it assumes that drainage excavation extends across the full width of the footprint of the Project, when the drainage excavations will be significantly narrower.

In summary, Table 10.18 identifies that groundwater levels will be lowered during the construction phases at the following sections:

- Section 1 (Galway Granite Batholith): EW01, EW02 (three cuttings), EW04, EW07, EW09 and EW11. EW11 includes cuttings associated with the N59 Link Road North and N59 Link Road South
- Sections 2 - 4 (Visean Undifferentiated Limestone): cutting EW27, Galway Racecourse Tunnel and its approaches and the cutting EW34-35. Groundwater lowering in cutting EW27 will only be required during the winter when groundwater levels are at their seasonal high. Note as part of the design no dewatering will be required at Lackagh Tunnel

Where groundwater drawdown occurs at road cuttings then there is potential in certain circumstances for this to lead to soil settlement and subsidence. The potential for subsidence depends on the geotechnical characteristics and depth of the soil and sub soil cover over bedrock, the nature of the bedrock itself. During the 2020 Oral Hearing it was identified that one property lies on the margin of drawdown ZoI extent at cutting EW02 on the Galway Granite Batholith and that this property has risk of soil settlement and subsidence. There is potential subsidence caused by drawdown in the Visean Undifferentiated limestone at cutting EW27 (Castlegar), the Galway Racecourse Tunnel and EW34-35. There are three buildings within the EW27 drawdown ZoI and these properties have risk of soil settlement and subsidence. There are no buildings within the drawdown ZoI of Galway Racecourse (including its approaches). Furthermore, there are no identified buildings within the drawdown ZoI of cutting EW34-35.

As part of the groundwater assessment potential changes in groundwater level have been considered in terms of wastewater treatment systems. On-site domestic wastewater treatment systems typically discharge to ground via a percolation area. For this percolation area to work effectively and provide treatment to the waste, there must be a dry zone between the base of the discharge point and the groundwater level (this is referred to an ‘unsaturated zone’). This unsaturated zone provides treatment through attenuation, dispersion and dilution so that the contamination is reduced substantially by the time it moves vertically downwards and reaches groundwater.

If groundwater levels were to rise beneath the base of the percolation area (i.e. the ‘unsaturated zone’ was to reduce), the treatment provided by the system would reduce and the groundwater quality would deteriorate. The areas where groundwater rise may occur due to the Project are limited to those areas either where infiltration basins are located (which is limited to the limestone area) or where the foundation of structures could divert flow paths. At these locations (infiltration basins and structures) there is a risk that groundwater levels may become slightly elevated during the winter when groundwater levels peak. Based on the assessment undertaken, no buildings have been identified where there is potential impact to wastewater treatment infiltration systems.

The quality of groundwater is potentially at-risk during construction and activities on site are managed in accordance with guidelines to ensure that this potential risk managed appropriately. Risk to groundwater quality derives from the following main sources:

- Storm runoff, which can have high turbidity
- Occurrence of karst, which can lead to point recharge input to the aquifer
- Accidental spillages of polluting materials on site
- Vandalism

The above risks are assessed for receptors in Section 10.5.2.1to Section 10.5.2.4. Management of the above risks are dealt with by mitigation measures, which are detailed in Section 10.1.

10.5.2.1 Potential Impact to Groundwater Resources

The potential impact assessment on the groundwater resources during the construction phase considers the impact that the changes in the groundwater quantity and groundwater quality have on the granite and limestone aquifers. The assessment considers all potential impacts that could impact on groundwater resources first by considering those impacts on groundwater quantity, such as loss of aquifer, groundwater lowering and changes to recharge, and then by considering those impacts that could change the overall groundwater quality, such as contamination impacts from pollution. The impact assessment in the 2018 EIAR considered groundwater resources to primarily based on groundwater quantity but this assessment for this updated EIAR has been updated so that the assessment is a combination of groundwater quantity and groundwater quality.

Both aquifers are relatively large and cover many thousands of square kilometres. The assessment considers how the Project could potentially impact on the groundwater resources of each aquifer in terms of future resources. The potential impact on each of these aquifers is assessed below.

In the sections below, those receptors that receive water from the aquifer, such as wells, springs, streams and GWDTE are considered separately.

10.5.2.1.1 Galway Granite Batholith (Section 1)

Based on TII guidelines the Galway Granite Batholith is assessed as a receptor of Low importance in terms of its attributes, which is based on its aquifer classification by the GSI as a Poor Aquifer. The GSI classification indicates that the aquifer has limited groundwater resources. The impacts are assessed under impacts on groundwater quantity firstly and groundwater quality secondly below.

Groundwater Quantity

In line with TII guidance, the magnitude of the impact on the aquifers within the hydrogeology study area is based on the portion of the aquifer that will be removed. The Pl Galway Granite Batholith is 2,378km^2 (2,378,000,000m^2) in size (GSI Groundwater data viewer) and 1,000m thick (Pracht, 2015). If only the upper 100m has groundwater flow (i.e. is the aquifer) then this gives a volume of 237,800,000,000m^3. The volume of granite to be excavated for the construction of the Project is 905,345m^3, which is very small percentage of the aquifer volume. The volume of granite removed remains unchanged since the 2018 EIAR and the oral hearing in 2020.

Changing the recharge characteristics has the potential to impact the aquifer. GSI data indicates that the recharge rate to the Galway Granite Batholith is 100mm/yr (Table 10.7) and this will not change during construction.

Changing groundwater levels during construction activities may affect the groundwater regime. Seven locations have been highlighted in Table 10.18 for where groundwater levels will be lowered locally during construction in the Galway Granite Batholith.

Table 10.18 presents the Zone of Influence (ZoI) of drawdown for each of these locations, which is the area on either side of the carriageway where groundwater levels will be lowered during construction. The largest drawdown ZoI occurs at the N59 Letteragh Junction (EW11). Based upon the assessment undertaken (Appendix A.10.6) the drawdown at this junction will extend for up to 54m beyond the cutting extent (refer to Figure 10.7.106).

Owing to the low aquifer properties of the Galway Granite Batholith the expected inflows from the construction are expected to be low. During construction the quantities of water intersected will initially be higher as the groundwater storage in the bedrock is tapped into, when the storage has been drained then the quantities that are intercepted will relate to recharge within the ZoI. Groundwater intercepted during construction will remain within the surface water catchment that they would naturally have been received by.

Based on the above assessment of potential impacts to groundwater resource quantity then the risk to groundwater resources in the granite may be summarised as:

- A very small portion of the aquifer will be removed
- Minimal changes to recharge
- Minor localised changes to aquifer groundwater level

On this basis, the magnitude of impact to the quantity of groundwater resources in the aquifer is Negligible and accordingly based on the Low importance of the aquifer, the Significance is Imperceptible.

Groundwater Quality

Suspended solids in site runoff is the prime concern with pollution from accidental spillages or vandalism also being a risk. Based on the recharge cap of 100mm/yr more than 90% of the effective rainfall during construction will remain overland flow and will not recharge to ground. Spillages, accidental or by vandalism, will generally runoff rather than infiltration.

Pollutants that do infiltrate to ground will have very limited mobility and will only be limited to the construction footprint. Where fractures or faulting are encountered then it is possible contaminants may travel downgradient by up to 100m. As much of the granite surface is rounded, or undulating, the downgradient direction varies along the Project. On this basis, in the worst-case scenario of spillage occurring at the edge of the development boundary, then contaminants could in theory travel 100m offsite if the contaminants entered a flow path in the granite bedrock. The distance of 100m is considered the maximum likely flow path length in the Galway Granite Batholith for the GWB in the hydrogeology study area. On this basis the risk to the groundwater in the Galway Granite Batholith is generally limited to the construction footprint but in certain cases may be able to travel 100m off site. Based on the above description, water quality impacts from the construction project are deemed to be of a small scale and as such the magnitude of impact for groundwater quality is Negligible and the Significance is imperceptible. The ZoI for construction phase pollution risk (in the worst case and pre-mitigation) is presented for the Galway Granite Batholith in Figure 10.7.101 to Figure 10.7.106.

The balance of rock excavated in cuttings and used for embankments and fill calculates a surplus of granite but a deficit of limestone. Due to the chemically inert nature of granite, if it is transported and used on embankments in limestone areas then there are no water quality concerns in terms of hydrogeology.

If unplanned activities which have the potential to impact water quality occur, these have the potential to contaminate groundwater. Owing to the poor aquifer properties of the Galway Granite Batholith, the dispersal of pollutants in the bedrock will be very limited. In line with TII guidance, the magnitude of potential impacts to groundwater resources is deemed to be Small Adverse. Based on the low importance ranking of the aquifer the significance is Imperceptible. Note that in the 2018 EIAR the potential impact was classified as being Moderate Adverse, but a review of the aquifer properties in the Project highlighted the Moderate Adverse impact assessment as being an overestimate of the potential effects from pollutants infiltrating a poor aquifer.

Summary

In order to maintain a precautionary approach, the overall ranking is based on the greatest impact of the quantity and quality assessment combined. On this basis, the combined quantity and quality hydrogeological impact for the groundwater resources of the granite aquifer, is Small Adverse. Given the importance of the receptor is Low then the significant environmental impact is ranked as Imperceptible.

10.5.2.1.2 Visean Undifferentiated Limestone (Sections 2, 3 & 4)

Based on TII guidelines the Visean Undifferentiated Limestone is assessed as a receptor of Very High importance in terms of its attributes, which is based on its aquifer classification by the GSI as a Regionally Important Aquifer with karst conduits (Rkc). As per TII guidelines, a regionally important aquifer may be classified as very high or high. The conservative assessment of the aquifer as being very high is applied owing to the record of high yielding wells in the region. However, it is noted from the baseline water quality assessment that the groundwater quality in the aquifer is impacted from urban and agricultural sources of pollution.

Groundwater quantity

The Rkc Visean Undifferentiated Limestone aquifer is 7,062km^2 (7,062,000,000m^2) in size (GSI Groundwater data viewer) and 400m thick (Pracht, 2015). Assuming that pathways in the limestone aquifer are small below 100m depth then the volume of limestone rock with storage is estimated to be 706,200,000,000m^3. A total of 2,096,175m^3 limestone will be removed in cuttings and tunnels, which is a very small percentage of the aquifer volume as computed in this updated EIAR. The total removal of limestone is unchanged since the 2018 EIAR and the oral hearing in 2020.

Based on an assessment of the road cuttings and tunnels relative to groundwater table, then only the Galway Racecourse Tunnel and approaches will intersect the groundwater table all year-round whilst cutting EW27 may encounter the water table but only during peak winter groundwater levels. It is noted that the design of Lackagh Tunnel does not require dewatering. Details of the assessment of Lackagh Tunnel and its approaches are presented in Appendix A.7.3. Due to the very small loss in saturated thickness of limestone, which is limited to the saturated thickness at the Galway Racecourse Tunnel and the seasonal peak groundwater table at cutting EW27, then the volume of saturated thickness of the limestone aquifer is very small.

The effect of an increased recharge in areas where vegetation has been removed may cause a groundwater rise below the footprint of the Project due to an increase in recharge. Based on the baseline recharge quantities listed in Table 10.9, and the increase in recharge/runoff being equal then recharge is estimated to rise to 705- 803mm/yr and runoff to 447-545 mm/yr. Using these estimations there will be a temporary increase in winter groundwater levels of up to 0.1m during the construction period (Appendix A.10.6).

Where infiltration basins are used to discharge runoff during the construction period then there will be modest temporary rises in groundwater level at these locations, of up to approximately 0.4m. Calculations for the estimated groundwater level rise are presented in Appendix A.10.6.

The removal of vegetation will increase effective rainfall and lead to increases in recharge and runoff in the Visean Undifferentiated Limestone. It is estimated that there will be a temporary rise of up to 0.1m in peak groundwater levels below the construction site.

If karst is intercepted in any of these earthworks or infiltration basin excavations, then there is a risk of point recharge from construction site runoff directly to the aquifer.

Changing groundwater levels during construction activities may affect the aquifer characteristics. Three locations have been highlighted in Table 10.18 where groundwater levels will be lowered locally during construction in the limestone aquifer: EW27, Galway Racecourse Tunnel and EW34-35.

Table 10.18 presents the ZoI for each of these, and this is the area away from the Project within with groundwater levels will be lowered during construction. However, it should be noted that due to the design of the Project, where dewatering of the bedrock aquifer will not be undertaken in the most sensitive areas, the drawdown and zones of influence associated with the construction impacts are small.

For example, the largest ZoI in the Visean Undifferentiated Limestone will be observed in EW27 which lies west of the N83 Tuam Road. The groundwater levels recorded in this part of the Clare-Corrib GWB show a seasonal variation of 9m (ref BH3/34) and based on the design elevations for the cutting (refer to Figure 10.6.108) then groundwater has the potential to enter the cutting only during peak winter water levels. The impact from the dewatering of the bedrock aquifer is localised around the cutting and calculated to have a maximum lateral extent of 70m (Table 10.18), which is calculated using the upper range of permeabilities measured from testing.

Regarding cutting EW27, the assessment has also taken into account any likely recovery of groundwater due to dewatering at the nearby Twomileditch quarry. The groundwater levels below the Project will not change because of the implementation of the quarry restoration plan because cutting EW27 (22.84m AOD) is significantly higher than the maximum rebounded groundwater level specified for Twomileditch quarry (11m AOD).

Based on the assessment for groundwater quantity that a very small volume of limestone aquifer would be removed, most of which is unsaturated, and considering the minimal impact on groundwater level and minimal impact on recharge, it is assessed that the is a Negligible impact on groundwater resources. Given the very high importance of the receptor, then the significance of the environmental impact is Imperceptible.

Groundwater quality

For a number of the structure excavations concrete is required as part of the foundation construction, which may need to be poured into excavations. There is a risk that poured concrete may enter the aquifer if karst is present in the foundation excavations. If karst is present, then the concrete could migrate into the aquifer and cause pollution. Of the GWB with karst there are three structures that have a risk to groundwater quality, namely the Corrib Bridge, Menlough Viaduct and Lackagh Tunnel.

The overburden across the hydrogeology study area consists of glacial till derived from the underlying bedrock. The bedrock changes in Section 2 at the N59 Moycullen Road, from a granite to a limestone bedrock which have different chemical compositions.

If limestone derived material is placed over granite bedrock, surface water run-off or groundwater movements through the material have the potential to impact local areas of peatland habitats by changing the pH of the local groundwater. In line with TII rating, the Magnitude of the impact on the aquifer from placing non-native rock is small and the impact imperceptible. Due to the chemically inert nature of granite, if it is transported and used on embankments on limestone then there are no water quality concerns in terms of hydrogeology.

Unplanned discharges such as site runoff with a high proportion of fines/sediment or accidental spillages of fuel, lubricants have the potential to cause groundwater quality to deteriorate.

Unlike the low aquifer properties encountered in the granite, the limestone has a wide range of aquifer properties with zones where conduit flow can occur. Similarly, the Visean Undifferentiated Limestone has a high recharge coefficient when karst is present and in these areas, runoff generally recharges to ground rather than becoming overland flow.

These features mean that if potential pollutants enter karst pathways then they can travel significant distances relatively quickly. The groundwater bodies (GWB) that have karst are Ross Lake GWB, Lough Corrib Fen 1 (Menlough) GWB, Lough Corrib Fen 1 (Lackagh) GWB, Lough Corrib Fen 2 GWB, Clare-Corrib GWB and the southern part of Clarinbridge GWB. The southern part of Clarinbridge GWB includes a karst swallow hole (K328) which receives surface water from Galway Racecourse, this feature allows surface water to directly enter the aquifer, via karst conduit pathways and is part of the karst drainage of the aquifer that includes stream sinks of the Terryland River. Such features mean that karst groundwater is vulnerable to contamination from pollution incidents downgradient of the Project. Figure 10.7.106 to Figure 10.7.115 show the limestone aquifer downgradient of the Project at risk from groundwater contamination from accidental pollution. Note that Figure 10.7.10 and Figure 10.7. 14 have been updated for this updated EIAR to include the area of the deep aquifer downgradient of swallow hole K328.

In the northern Clarinbridge GWB there are no recorded significant karst features and surface water ponding as well as overland flow occurs during storm events, which is due to the lower recharge rates that are present in this area. Infiltration to ground will diffuse and provide slow pathways to the groundwater table that will naturally promote settlement of fines. In the groundwater there will be significant dilution and some attenuation of any fines.

Earthworks along the Project include areas where the subsoil is removed leaving a reduced thickness of subsoil or exposing the underlying limestone. The removal of subsoil will reduce the natural protection for groundwater and increases the groundwater vulnerability (Table 10.6). During construction the excavation of subsoil will increase the risk to groundwater from accidental pollution. Those areas most susceptible to pollution are the locations where the subsoil is already thin, which are the high and extreme areas presented in Figure 10.7.106 to Figure 10.7.115.

Conversely, in the natural environment, recharge to limestone where there is no karst relies in part on storage in the overlying subsoil which provides superficial storage to the fracture flow network in the underlying limestone. In the situation where the subsoil is removed there is an increase in overland flow with recharge significantly reduced. As such, where the limestone bedrock is shallow or exposed, there can be an increase in runoff, such as in the Clarinbridge GWB of the hydrogeology study area.

For the Ross Lake GWB, Lough Corrib Fen 1 (Menlough) GWB, Lough Corrib Fen 1 (Lackagh) GWB, Lough Corrib Fen 2 GWB, the Clare-Corrib GWB and the southern part of the Clarinbridge GWB where there is a potential for karst and point input of runoff the areas at higher risk of pollution is extended over the full extent downstream of the Project. For the northern part the Clarinbridge GWB where aquifer properties are relatively low and groundwater level near surface, this area encompass the full extent of the construction footprint. In the limestone aquifer the downgradient direction of flow is consistently towards the River Corrib and the coast. Given the clear flow direction, the aquifer upgradient of the Project is deemed not to be at risk for water quality impacts.

Infiltration from construction runoff on the Visean Undifferentiated Limestone will occur on the construction footprint, including from infiltration basins. The infiltration basins will be excavated at the construction stage to allow their use during construction. These may act as a source of point contamination to the karst.

The presence of features such as the swallow hole at Galway Racecourse, highlight the vulnerability of the karst aquifer to contamination from pollution incidents. In the 2018 EIAR assessment whilst the vulnerability of the aquifer was recognised there were no point inputs such as the K328 shallow hole down gradient of the construction site and as such the groundwater resource assessment has been updated. In line with TII rating, the magnitude of the potential impact on the water quality of the aquifer has conservatively been assessed as being Moderate Adverse and the significance of the impact is Profound/Significant. This is owing to the high connectivity of the aquifer from the risk of unplanned contamination, specifically from accidental spillage. These risks require mitigation which is presented in Section 10.6. Hydrogeological mitigation measures are required to control runoff to limit the potential impacts of accidental discharges to groundwater quality during construction.

Summary

In order to maintain a precautionary approach, the overall ranking is based on the greatest impact of the quantity and quality assessment combined. On this basis, the combined quantity and quality hydrogeological impact for the groundwater resources of the limestone aquifer, is Moderate Adverse. Given the importance of the receptor is Very High then the significant environmental impact is ranked as Profound/Significant.

10.5.2.2 Potential Impacts to Groundwater supplies

A number of groundwater abstractions which may be impacted by the Project were identified in Section 10.3.5.2. If groundwater levels at supply wells were lowered due to construction dewatering of the bedrock aquifer, or the groundwater quality at these wells was impacted, it could render the wells unusable. For the case of geothermal wells, a reduction in groundwater level can reduce the heat supply if the well relies on groundwater for thermal conductance.

The potential impact of construction dewatering of the bedrock aquifer on the wells can be assessed by comparing the well locations to the drawdown zone of influence. If the wells are located within the zone of influence, then by the precautionary principle it is assumed that they will be impacted by dewatering of the bedrock aquifer.

The risks to the water quality of a well were assessed based on a number of factors including:

- The likelihood of contaminated runoff entering groundwater. There are a number of factors that determine if any potentially contaminated water at the surface will enter groundwater. Areas with thick soil or subsoil, with low permeability (i.e. water flows through it slowly) are more likely to cause water to stay on the surface and runoff to drains or watercourses than to enter groundwater, or areas with a low ‘recharge cap’ (the amount of water the rock comprising the aquifer can accept) are unlikely to be vulnerable to surface spills. Areas with thinner subsoil or a higher recharge cap are more vulnerable to contamination. These locations of highest vulnerability for both the granite and limestone areas in the hydrogeology study area are reported by GSI and shown in detail on Figures 10.3.001 and 10.3.002.

- The position of a feature of interest relative to any potential source of contamination: if a feature such as a well is ‘up-gradient’ of the potential source then the groundwater will flow away from the feature and towards the source of contamination, but if the feature is ‘down-gradient’ of the potential source, then any potential contamination that enters groundwater would flow towards the it. Features up-gradient of any locations where spillages may occur (e.g. storage compounds etc) are not at risk. If a well is down-gradient, then the travel time of any contamination to that well should be considered. The GSI determine the Inner Source Protection Area as the area within which human activities may have an immediate effect on the source and it is defined by the 100-day time of travel (TOT) from any point below the water table to the source.

- The permeability of the rock that groundwater flows through: The higher the permeability of a rock, the faster water can travel through it. This can also be referred to as the hydraulic conductivity of the rock. As outlined in Section 10.3.4 extensive testing was undertaken to fully understand this and how it varied across the length of the Project.

The 100-day TOT distance have been calculated for each aquifer. For the Visean Undifferentiated Limestone distinction is made between the limestone with karst pathways and those without. On this basis for the karst limestone the 100-day TOT distance is set to be the full aquifer downgradient of the site from the Project to the receiving water (River Corrib, Terryland River or Galway Bay). The calculated 100-day TOT calculations for Granite and non-karst limestone are presented below:

- Based on maximum locally measured permeability of $4.6x10^{-7}$m/s[3], the distance which indicates the 100-day TOT in granite is 80m

- Based on the maximum locally measured permeability of $1.7x10^{-6}$m/s[3] for shallow limestone aquifer in the Ballybrit to Briarhill area, indicates the 100-day TOT to be 500m

For completeness, the maximum locally measured non-karst limestone permeability in the Menlough and Ballindooley area is $3.1x10^{-5}$m/s[3]. Based on this calculation the non karst maximum permeability for limestone has a 100-day TOT distance of 1,500m.

It should be noted that this is a highly conservative assessment as the 100-day TOT was derived based on the likelihood of microbial contamination. These contaminants are more mobile than those associated with road runoff, however, the resultant distance indicates the maximum travel distance in 100 days and allows an informed decision on whether there is any potential for the well to be impacted.

This updated EIAR takes account of the proposed development at Galway Racecourse. In the area of the racecourse, the limestone aquifer is part of the Clarinbridge GWB and has two units, an upper shallow aquifer and a lower deep aquifer. Based on the characterisation of these aquifers, the deep aquifer has karst pathways, but the shallow aquifer does not. Receptors located in the shallow aquifer are assessed based on a 100-day TOT being 500m. However, as the deep aquifer includes karst pathways, the 100-day TOT comprises of the deep aquifer downgradient of the swallow hole K328.

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[3] This has been calculated based on the hydraulic conductivity rather than the average linear velocity. Using hydraulic conductivity to determine 100-TOT is more conservative.

Based upon the regional south westwards flow of groundwater towards Galway Bay, the 100-day TOT area for the deep aquifer comprises of the area to the west and south of swallow hole K328. This downgradient area includes seven supply wells, namely W50-02, W50-08, W50-20, W100-01, W100-02, W500-01 and W1000-03 (Refer to Figure 5.002). Note that the supply wells near Lough Atalia, namely W50-03, W50-04, W50-05, W50-20 and W50-07, lie in a separate sub catchment of the GWB with no connection to K328.

The downgradient supply wells are assessed as:

- Supply wells W50-08, W100-01 and W100-02 are in the shallow aquifer and set more than 500m from swallow hole K328. As such, these wells are outside of the 100-day TOT and there is no impact
- Supply wells W50-02, W50-20, W500-01 and W1000-03 are in the deep karst aquifer. On the basis that a karst pathway has the potential to connect from K328 to these supply wells, the hydrogeological impact is assessed as Moderate Adverse

The assessment of potential impact on each well has been summarised in Table 10.19 and have been updated since the 2018 EIAR.

Table 10.19 Impact Assessment of Supply Wells within the Hydrogeology Study Area (Pre-mitigation)

Feature	Location relative to radius of influence	Position relative to Project	Within 100-day TOT of the well?	Potential impact	Magnitude of impact	Significance of impact
Knocknacarra GWS (W50-01)	Outside the zone of influence	Down-gradient	No	None	No Impact	N/A
W50-02	Outside the zone of influence	Down gradient	Yes	Downgradient of K328 in the deep aquifer	Moderate Adverse	Slight
W50-03 04, 05, 06 and 07	Outside the zone of influence	Down gradient	No	None	No Impact	N/A
W50-08	Outside the zone of influence	Down gradient	No	None	No Impact	N/A
W50-09	Outside the zone of influence	Up gradient	N/A	None	No Impact	N/A
W50-10	Inside the zone of influence	Below footprint of Project	Yes	Well will be lost	Large adverse	Slight / moderate
W50-11	Outside the zone of influence	Down gradient	No	None	No Impact	N/A
W50-12	Inside the zone of influence	Below footprint of Project	Yes	Well will be lost	Large adverse	Significant
W50-13 & W50-14 (Racecourse)	Inside the zone of influence	Below footprint of Project	Yes	Both wells will be lost	Large adverse	Profound
W50-15 (Racecourse)	Inside the zone of influence	Below footprint of Project	Yes	Well will be lost	Large adverse	Profound / Significant

Feature	Location relative to radius of influence	Position relative to Project	Within 100-day TOT of the well?	Potential impact	Magnitude of impact	Significance of impact
W50-16	Inside the zone of influence	Below footprint of Project	Yes	Well will be lost	Large adverse	Slight / moderate
W50-17	Inside the zone of influence	Below footprint of Project	Yes	Well will be lost	Large adverse	Slight / Moderate
W50-18	Down gradient	Below footprint of Project	Yes	Well will be lost	Large adverse	Slight / Moderate
W50-19	Down gradient	Below footprint of Project	Yes	Well will be lost	Large adverse	Slight / moderate
W50-20	Outside the zone of influence	Down gradient	Yes	Downgradient of K328 in the deep aquifer	Moderate Adverse	Moderate
W50-21	Outside of zone of influence	Up gradient	No	None	No Impact	N/A
W50-22	Outside of zone of influence	Down gradient	No	None	No Impact	N/A
W100-01 & 02	Outside the zone of influence for shallow aquifer	Down gradient	No	None	No Impact	N/A
W100-03, 04, 05 and 06	Outside the zone of influence	Up gradient	N/A	None	No Impact	N/A
W500-01	Outside the zone of influence	Down gradient	Yes	Downgradient of K328 in the deep aquifer	Moderate Adverse	Slight
W1000-01	Outside the zone of influence	Up gradient	N/A	None	No Impact	N/A
W1000-03	Outside the zone of influence	Down gradient	Yes	Downgradient of K328 in the deep aquifer	Moderate Adverse	Slight
W1000-04	Outside the radius of influence	Down gradient	No	None	No Impact	N/A
G50-01 (Geothermal well)	Outside the radius of influence	Up gradient	N/A	None	No impact	N/A

This assessment highlights that nine wells (W50-10, W50-12, W50-13, W50-14, W50-15, W50-16, W50-17, W50-18 and W50-19) will be permanently impacted. Accordingly, these will be removed as part of the Project and decommissioned based on IGI (2007) and EPA (2013) guidelines. Furthermore, there are four wells that have the potential of groundwater quality impact. All four wells (W50-02, W50-20 W500-01 and W1000-03) are in the deep karst aquifer located downgradient of swallow hole K328, which is present on land in the southern part of Galway Racecourse.

Decommissioning the existing Galway Racecourse wells will change the groundwater flow regime on a local scale. As these wells are proposed to be replaced by new wells in different locations to the existing wells (100m to the south) the impact of moving the zone of contribution will be Negligible in relation to the overall integrity of the aquifer. The significance of the impact is Imperceptible and will not be considered further.

10.5.2.3 Potential Impacts to Groundwater Dependent Terrestrial Ecosystems (GWDTE)

This section assesses potential impact to groundwater dependent habitats and limestone pavement habitat from the construction phase of the Project. Ecosystems may be potentially impacted through accidental contamination of the groundwater which supports them, the alteration of groundwater levels and/or the reduction in the groundwater contribution to the ecosystem. The characteristics which determine the potential impact are:

- The proximity to the feature
- The level of hydraulic connection between the feature and the section of aquifer at the Project i.e. is the feature in the same aquifer unit as the Project, or is there a hydraulic divide between the feature and the Project
- The groundwater flow direction in the vicinity
- The level of cut of the Project, which may determine the degree of variation in the groundwater level and also the extent of dewatering which may occur
- The water quality of the feature and the groundwater from which it receives its baseflow

Habitat receptors comprise of European sites (SAC and SPA) and National sites (NHAs and pNHAs) as well as Annex I habitats and non-Annex I that lie outside of designated sites.

It should be noted that this chapter identifies the potential impacts to the hydrogeology that supports these ecological features and does not assess the magnitude or impact significance of the habitats themselves, which is presented in Chapter 8, Biodiversity based on the information provided here.

European Sites

Four European sites have been identified as receiving groundwater from groundwater bodies that are traversed by the Project as per the 2018 EIAR. These include:

- Lough Corrib SAC
- Lough Corrib SPA
- Galway Bay Complex SAC
- Inner Galway Bay SPA

Ballindooley Lough is also included in this assessment as it supports the wintering birds of the Lough Corrib SPA and Galway Bay SPA but also includes Annex I habitat on the fringe of the lough.

The discussion of the characteristics of the Galway Granite Batholith in Section 10.3.4.1 outlines the zones of influence for dewatering of the bedrock aquifer and the areas vulnerable to contamination. Based on these there will be no impact either from drawdown or water quality impacts from the Project to European sites.

The discussion of the characteristics of the Visean Undifferentiated Limestone in Section 10.5.2.1.2 outlines the zones of influence for dewatering of the bedrock aquifer and interception of karst pathways as well as the areas vulnerable to contamination.

For the Visean Undifferentiated Limestone, the drawdown zones of influence do not impact on any European sites or Ballindooley Lough. However, this section of the report provides additional detail on the construction in order to relate the conceptual model to any potential impacts that may arise during construction.

Lough Corrib SAC

The Lough Corrib SAC potentially receives groundwater from three sources (1) groundwater contribution to Coolagh Lakes, (2) groundwater contribution directly to the River Corrib and (3) groundwater contribution from Terryland River (in flood). All three groundwater contributions have been assessed separately and appear as separate rows in Table 10.20, which summarises and ranks all potential GWTDE impacts.

Coolagh Lakes receives groundwater from Lough Corrib Fen 1 (Menlough) GWB via groundwater flowing westwards to Western Coolagh Spring. Water emergent from Western Coolagh Spring is the main contribution to Coolagh Lakes.

The hydrogeological setting of the Western Approach to Lackagh Tunnel (EW19) and Lackagh Tunnel (EW20) are located at the groundwater divide between Lough Corrib Fen 1 (Menlough) and Clare-Corrib GWBs. Details of the Western Approach to Lackagh Tunnel (EW19) and Lackagh Tunnel (EW20) are discussed in the Lackagh Tunnel Appraisal Report, which is included in Chapter 7, Construction Activities.

Due to the dependency of Coolagh Lake (part of the Lough Corrib SAC) on groundwater from the limestone aquifer the tunnel design excludes dewatering of the bedrock aquifer. Assessment of groundwater levels (refer to Figure 10.6.008) in the limestone aquifer, together with consideration of buried valleys in the area, is undertaken in an eco-hydrogeology report for Lough Corrib SAC, which is presented in Appendix A.10.8. Appendix A.10.8 provides a detailed assessment of interaction between eco-hydrogeology that was presented at the 2020 Oral Hearing. It covers all aspects of groundwater contributions to Coolagh Lake. Based on this assessment the limestone catchment that contributes to Lough Corrib SAC encompasses the area Ch. 9+700 and Ch. 11+500. This is the catchment area for Coolagh Western Spring and seepages from the limestone aquifer that can contribute to Coolagh Lakes.

Dewatering of the bedrock aquifer will not be permitted during construction so there is no reduction in groundwater flow transmitted by these pathways through the aquifer to the Western Coolagh Spring. By not dewatering, the boundary between Clare-Corrib GWB and Lough Corrib Fen 1 (Menlough) will not be impacted. All construction works will remain above the groundwater table for the duration of the works to ensure the groundwater table is not intercepted and dewatering of the bedrock aquifer is not required.

On this basis there will be no drawdown in the Western Approach to Lackagh Tunnel (EW19) and Lackagh Tunnel (EW20) and therefore no impact to the groundwater divide between the Lough Corrib Fen 1 (Menlough) GWB and the Clare-Corrib GWB or to the Lough Corrib SAC.

In addition, as detailed in the Karst Protocol (refer to CEMP Appendix A.7.5), if karst conduits are encountered during the excavation of structure foundations, concrete poured in these may contaminate the conduits. This may affect the hydrogeological regime of the groundwater body feeding the ecological receptors. Mitigation measures for this are presented in Section 10.1.

Regarding potential impacts on groundwater contribution directly to the River Corrib, the main feature that has the potential to impact is the bridge over the River Corrib (EW15), which requires excavations on the east and west shore to install piers. These excavations will extend below the groundwater table and will require dewatering to enable dry working conditions. As the eastern excavations occur on the margins of the Lough Corrib Fen 1 (Menlough) GWB with the River Corrib, there is no potential for impact to Western Coolagh Spring, which is up-gradient of the location.

In normal flow, the Terryland River receives groundwater from River Corrib and the Clare Corrib GWB, which then sinks underground at the Terryland estavelles (K87 and K96) and flows southwards to Galway Bay. During times of high flow flooding occurs in the Terryland River and although unlikely, it is possible that the Terryland River could contribute to the River Corrib. If such an instance were to occur then groundwater from the Clare Corrib GWB and water emergent from the Terryland estavelles could potentially drain to the River Corrib (Lough Corrib SAC). It is noted that these potential contributions from Terryland River would form an extremely small component of flow to the River Corrib.

Since the 2018 EIAR and the 2020 Oral Hearing the OPW have installed a gauging station on the Terryland River. The below section provides a summary of this dataset, which is used to provide further assessment of the Terryland River. Assessment of river levels in the Terryland River is presented in Appendix A.10.3 using water level data publicly available from the OPW. In summary, under normal conditions the Clarinbridge GWB, which includes design elements at Galway Racecourse, is hydraulically separate from the River Corrib SAC. However, during high groundwater levels the Terryland sinks ("estavelles"[4].) switch to become resurgences and discharge groundwater into the Terryland River and cause flooding in the Terryland River. Taking the precautionary principle, it is assumed that groundwater contribution from the Clarinbridge GWB to the Lough Corrib SAC can occur but that it only occurs temporarily during times of high-water table in the Clarinbridge GWB, combined with storm events and high tide.

Given the nature of the limestone aquifer within the Lough Corrib Fen 1 GWB, Clare Corrib GWB and the southern part of the Clarinbridge GWB there is potential for rapid groundwater transfer via karst pathways. On this basis, unplanned construction contamination from accidents, spill and vandalism could present a risk to the groundwater flow paths and the water quality received by GWDTE. This assessment has been updated to include the hydrogeological assessment at Galway Racecourse, which identified that swallow hole K328 in the southern part of the Clarinbridge GWB contributes to the conduit system that the Terryland estavelles drain to. On this basis swallow hole K328 may also contribute to flooding in the Terryland River and in extreme flooding, drain to the Corrib River and Lough Corrib SAC.

Mitigation has been developed to accommodate potential pollution via karst pathways and these are detailed in Section 10.6.

Galway Bay

The groundwater flow direction beneath the Project is towards the coast. On this basis all groundwater for the Project area eventually flows into Galway Bay. During construction there is potential for the pathways that groundwater flows to the coast to be temporarily altered, for example, due to dewatering at the Galway Racecourse Tunnel, however, any changes in the quantity of groundwater will be immeasurable compared to the volume of the receiving water in Galway Bay. Similarly, any deterioration in groundwater quality from temporary construction activities will not be measurable owing to the dilution rates on entering the receiving water. On this basis, the magnitude of any hydrogeological impacts on the receiving water at Galway Bay is negligible.

Ballindooley

Ballindooley Lough is up gradient of the Project and as such not considered to be at risk from pollution.

National Heritage Areas

Three National Heritage Areas have been identified as receiving groundwater from groundwater bodies that are traversed by the Project. These include:

- Moycullen Bogs NHA (including Tonabrocky and Letteragh)
- Galway Bay Complex pNHA
- Lough Corrib pNHA

The hydrogeological assessment undertaken in Section 10.4.6 has identified zones of influence for drawdown and also identified those parts of the aquifer that have the potential groundwater pollution.

Based on the zones of influence for the Galway Granite Batholith, there will be no impact either from drawdown or water quality impacts from the Project to NHA receptors. The Moycullen Bog at Letteragh is close to the Project however, the calculated drawdown does not extend as far as the habitat. Moycullen Bog at Letteragh lies upgradient of the Project and as such there is no risk of pollution. Assessment of groundwater levels (refer to Figure 10.6.008) in the granite is undertaken in an eco-hydrogeology report for Moycullen Bog which is presented in Appendix A.10.8. The detailed assessment provided in Appendix A.10.8 was provided to the 2020 Oral Hearing for assessment of the groundwater regime at Moycullen Bog.

[4] Estavelle – A karst feature that can function as a spring or as a swallow hole depending on underground water levels. Karst Working Ground (2000) Karst of Ireland. Limestone Landscapes, Caves and Groundwater Drainage Systems.

For the Visean Undifferentiated Limestone the drawdown zones of influence do not impact on any NHA receptors. The zone of influence for water quality at the Clarinbridge GWB shows no impact to NHA receptors. However, the areas which may be prone to potential pollution shows a potential groundwater impact for:

- Lough Corrib Fen 1 (Menlough) westwards to Western Coolagh Spring and the River Corrib (Lough Corrib pNHA)
- Clare Corrib GWB southwards to Terryland River, which flows to the River Corrib (Lough Corrib pNHA) during times of high groundwater levels

The extent of the area where contamination may extend to is caused by the potential presence of karst which could allow pathways to carry pollutants from the construction site to receptors. Mitigation has been developed to accommodate potential karst and these are detailed in Section 10.1.

The River Corrib pNHA receives groundwater from three sources (1) groundwater contribution to Coolagh Lakes, (2) groundwater contribution to the River Corrib and (3) groundwater contribution from Terryland River (in flood). The pNHA assessment has been updated to include swallow hole K328, which was identified as part of the hydrogeological assessment for the Project at Galway Racecourse. All three groundwater contributions to the Lough Corrib pNHA have been assessed separately and appear as separate rows in Table 10.20, which summarises and ranks all potential GWTDE impacts.

Annex I habitats

A number of Annex I habitats have been identified as water dependant and are located on groundwater bodies that are traversed by the Project and are listed below:

- Wetland habitats (Spiddal GWB) at Na Foraí Maola Thiar (Ch. 0+650 to Ch. 0+750), Na Foraí Maola Thoir (Ch. 1+250 to Ch. 1+500), Troscaigh Thiar (Ch. 1+850 to Ch. 2+400), Bearna (Ch. 2+600 to Ch. 3+100), Aille (Ch. 3+600 to Ch. 3+850) and Ballyburke (Ch. 4+650 to Ch. 4+800)
- Wetland habitats (Maam-Clonbur GWB) at Knocknabrona (Ch. 7+700 to Ch. 7+750)
- Wetland habitats (Ross Lake GWB) at University of Galway (N) (Ch. 8+800 to Ch. 8+950 and University of Galway (S) (Ch. 9+150 to Ch. 9+250)
- Turlough K31 (Lough Corrib Fen 1 (Menlough) GWB)
- Turlough K20 (Lough Corrib Fen 2 GWB)
- Turlough K72 (Clare-Corrib (Ballindooley West) GWB)
- Lackagh Quarry petrifying springs (Clare-Corrib (Ballindooley West) GWB)

It is noted that proposed road alignment will remove part of the following Annex I habitats within the townlands of Troscaigh Thiar (Ch. 1+850 to Ch. 2+400) and Aille (Ch. 3+600 to Ch. 3+850). It is also noted that the proposed road alignment will remove all of the Annex I habitat within Ballyburke (Ch. 4+650 to Ch. 4+800) and Knocknabrona (Ch. 7+700 to Ch. 7+750). As a result of the change of extents of habitat, the drawdown zone of influence will not affect the habitat in Na Foraí Maola Thiar (Ch. 0+650 to Ch. 0+750). These impacts are detailed in Chapter 8 Biodiversity.

- Drawdown impacts have the potential to partially lower the groundwater table at Na Foraí Maola Thoir (Ch. 1+250 to Ch. 1+500) and Troscaigh Thiar (Ch. 1+850 to Ch. 2+400) and Aille (Ch. 3+600 to Ch. 3+850)
- There is potential for reduction in groundwater quality from contamination at part of Na Foraí Maola Thiar (Ch. 0+650 to Ch. 0+750) albeit the area has significantly reduced, Na Foraí Maola Thoir (Ch. 1+250 to Ch. 1+500), Troscaigh Thiar (Ch. 1+850 to Ch. 2+400) and Aille (Ch. 3+600 to Ch. 3+850)
- There are hydrogeological impacts to Annex I habitat at Barna (Ch. 2+600 to Ch. 3+100)

Wetland habitats at University of Galway (UoG) Sporting Campus lie north and south of the Project. Neither habitat at UoG Sporting Campus lies within the drawdown ZOI, however, the habitat to the south, which lies downgradient, has the potential to be impacted from pollution.

Turlough K31 also lies within the footprint of the Project but as it is traversed as part of the Menlough Viaduct. As the viaduct can be constructed without dewatering of the bedrock aquifer there will be no impact from groundwater lowering at turlough K31.

The extent of the area identified as being prone to potential pollution shows that Turlough K31 lies within this area but that Turloughs K20 and K72 lie beyond it. The potential impacts to Turlough K31 derive from the potential of karst being encountered during construction and as such pollution from the site draining to ground, and the turlough.

Petrifying springs (with tufa formation) have been included in Chapter 8, Biodiversity as occurring on the western and northern faces of the inactive Lackagh Quarry. The Petrifying springs occur as seepages that are located above the regional groundwater table, which occur from small pathways in the limestone bedrock that are fed by recharge. The source area for the seepages is the limestone pavement immediately north and west of Lackagh Quarry. These seepages have developed from the excavation of the quarry. Rock bolting is proposed to stabilise the quarry face at the eastern portal of Lackagh Tunnel in Lackagh Quarry. Rock bolting will have an insignificant impact on recharge pathways through the unsaturated zone. Concreting will not be part of the face stabilisation works.

Some of the newly classified petrifying springs will be covered as part of the material deposition areas (MDA) in Lackagh Quarry. Whilst the MDA will not change the nature of the flow paths through the limestone aquifer, the water emerging at the quarry face will be collected by drainage and routed to the quarry floor. On this basis, the quantity and quality of the emergent water will not change but the springs will be lost in the sense that whilst they remain present and responding as normal, they will no longer be viewable. On this basis the MDA areas will not change the hydrogeology of the aquifer.

Where the MDA covers petrifying springs then collection and drainage systems for petrifying springs will route water from the quarry face to the quarry floor. This will alter the flow of water that had flowed down the surface of the quarry walls to areas where tufa had precipitated. On this basis, the quality and quantity of emergent water from the aquifer will not change but the way the water flows down the quarry wall surface will. The hydrogeology of the springs is not impacted in Lackagh Quarry other than no longer being visible. However, the capture of surface flows will mean that existing areas of tufa precipitation will cease. For assessment of MDA impacts on the petrifying springs, including tufa precipitation, refer to Chapter 8 Biodiversity.

Non-Annex I Habitat

A number of local ecosystems are identified in the Chapter 8, Biodiversity that are water dependant and these include An Baile Nua (Ch. 0+150), Na Forai Maola Thoir (Ch. 1+150), Barna (Ch. 3+100 and Ch. 3+400), Knocknabrona (Ch. 7+850 to Ch. 8+150) and calcareous springs in the Visean Undifferentiated Limestone in Lackagh Quarry.

It is noted that the proposed road alignment will remove all four non-Annex I habitat. Details of these impacts are presented in Chapter 8, Biodiversity.

The calcareous spring locations identified in Lackagh Quarry are all located above the groundwater table and mainly in the western quarry face. All seepages occur above the water table and occur from recharge within the unsaturated zone. Impacts presented above for the petrifying springs also apply to the calcareous springs/seepages.

Summary

The hydrogeology of ecological receptors with dependence on groundwater have been assessed (in the absence of mitigation measures) for the construction phase of the Project. The assessment considers receptors within the hydrogeology study area for both the drawdown zone of influence and areas which are potentially vulnerable to pollution.

Table 10.20 below provides a summary of the ecological receptors and identifies those that lie within the drawdown zone of influence and those areas that lie down gradient of the Project and are at risk from pollution. There are no additional receptors to those presented in the 2018 EIAR.

The magnitude and significance of hydrogeological impacts refer to potential changes in groundwater quality at springs or seepages that supply European or National site or groundwater dependent Annex I habitat. The assessment is in accordance with TII Guidelines. For assessment on ecological impacts because of the potential hydrogeological impacts, please refer to Chapter 8, Biodiversity.

Table 10.20 Summary of Potential Hydrogeological Impacts at GWDTE during Construction Phase (Pre-mitigation)

Feature	Potential Impact to Groundwater Level	Potential Impact to Groundwater Quality	Magnitude of Hydrogeology Impact	Significance of Hydrogeology Impact
European sites				
Galway Bay Complex SAC	Potential temporary quantity deterioration of groundwater in karst pathways to Galway Bay. The groundwater contribution from GWB is of insufficient magnitude to affect integrity	Potential temporary quality deterioration of groundwater in karst pathways to Galway Bay. The groundwater contribution from GWB is of insufficient magnitude to affect integrity	Negligible	Imperceptible
Inner Galway Bay SPA	Potential temporary quantity deterioration of groundwater in karst pathways to Galway Bay. The groundwater contribution from GWB is of insufficient magnitude to affect integrity	Potential temporary quality deterioration of groundwater in karst pathways to Galway Bay. The groundwater contribution from GWB is of insufficient magnitude to affect integrity	Negligible	Imperceptible
Lough Corrib SAC (Groundwater contribution to Coolagh Lakes)	Potential temporary quantity deterioration of groundwater in karst pathways within contributing GWB could impact on groundwater contribution to Coolagh Lakes	Potential temporary quality deterioration of groundwater in karst pathways within contributing GWB could lead to water quality impact at Coolagh Lakes	Large Adverse	Profound
Lough Corrib SAC (Groundwater contribution to River Corrib)	The groundwater contribution from GWB to River Corrib is of insufficient magnitude to affect integrity	The groundwater contribution from GWB to River Corrib is of insufficient magnitude to affect integrity	Negligible	Imperceptible
Lough Corrib SAC (Groundwater contribution to Terryland River when K87 and K96 active)	No potential groundwater level impacts	Potential temporary quality deterioration of groundwater in karst pathways within contributing GWB could lead to water quality impact at Terryland River (within catchment of karst feature K328)	Small adverse	Significant
Lough Corrib SPA	No	No	N/A	N/A

Feature	Potential Impact to Groundwater Level	Potential Impact to Groundwater Quality	Magnitude of Hydrogeology Impact	Significance of Hydrogeology Impact
	(upgradient of the Project)	(upgradient of the Project)		
Ballindooley Lough	No (upgradient of the Project)	No (upgradient of the Project)	N/A	N/A
National Heritage Sites				
Moycullen Bogs (Lough Inch/Na Foraí Maola Thair)	No (upgradient of the Project)	No (upgradient of the Project)	N/A	N/A
Moycullen Bogs (Tonabrocky)	No (upgradient of the Project)	No (upgradient of the Project)	N/A	N/A
Moycullen Bogs (Letteragh)	No (upgradient of the Project)	No (upgradient of the Project)	N/A	N/A
Lough Corrib pNHA (Groundwater contribution to Coolagh Lakes)	Potential temporary quantity deterioration of groundwater in karst pathways within contributing GWB would lead to impact at Western Coolagh Spring, which is the main water contribution for Coolagh Lakes	Potential temporary quality deterioration of groundwater in karst pathways within contributing GWB would lead to impact at Western Coolagh Spring, which is the main water contribution for Coolagh Lakes	Large Adverse Deterioration of groundwater level and/or groundwater quality	Profound
Lough Corrib pNHA (Groundwater contribution to River Corrib)	The groundwater contribution from GWB to River Corrib is of insufficient magnitude to affect integrity	The groundwater contribution from GWB to River Corrib is of insufficient magnitude to affect integrity	Negligible	Imperceptible
Lough Corrib pNHA (Groundwater contribution to Terryland River when K87 and K96 active)	No potential groundwater level impacts.	Potential impact to groundwater dependant habitat due to deterioration of water quantity or quality from accidental spills from construction works at Galway Racecourse (within catchment of karst feature K328)	Small adverse Deterioration of groundwater quality	Significant / Moderate
Galway Bay Complex pNHA	Potential temporary quantity deterioration of groundwater in karst pathways to Galway Bay. The groundwater contribution from GWB is of insufficient	Potential temporary quality deterioration of groundwater in karst pathways to Galway Bay. The groundwater contribution from GWB is of insufficient	Negligible	Imperceptible

Feature	Potential Impact to Groundwater Level	Potential Impact to Groundwater Quality	Magnitude of Hydrogeology Impact	Significance of Hydrogeology Impact
	magnitude to affect integrity	magnitude to affect integrity		
Annex I habitats (outside of designated sites)				
Na Foraí Maola Thiar (Ch. 0+650 to Ch. 0+750)	Outside of drawdown zone of influence	Within area liable to contamination	Large Adverse	Profound
Na Foraí Maola Thoir (Ch. 1+250 to Ch. 1+500)	Partially within drawdown zone of influence	Partially within area liable to contamination	Large Adverse	Profound
Troscaigh Thiar (Ch. 1+850 to Ch. 2+400)	Partially removed by road alignment and part within drawdown zone	Removed by road alignment and part liable to contamination	Large Adverse	Profound
Bearna (Ch. 2+600 to Ch. 3+100)	Outside of drawdown zone of influence	Outside of area liable to contamination	N/A	N/A
Aille (Ch. 3+600 to Ch. 3+850)	Partially removed by road alignment and part within drawdown zone	Removed by road alignment and part liable to contamination	Large Adverse	Profound
Ballyburke (Ch. 4+650 to Ch. 4+800)	Removed by road alignment	Removed by road alignment	Large Adverse	Profound
Knocknabrona (Ch. 7+700 to Ch. 7+750)	Removed by road alignment	Removed by road alignment	Large Adverse	Profound
University of Galway (N) (Ch. 8+800 to Ch. 8+950	No (upgradient of the Project)	No (upgradient of the Project)	N/A	N/A
University of Galway (S) (Ch. 9+150 to Ch. 9+250	No Outside of drawdown zone of influence	Within area liable to contamination	Moderate Adverse	Profound / Significant
Turlough K20 (Menlough Northeast)	No Outside of drawdown zone of influence	No (upgradient of proposed road)	N/A	N/A
Turlough K31 (Menlough East)	No Outside of drawdown zone of influence	Within area liable to contamination	Large Adverse	Profound
Turlough K72 (Coolagh North)	No Outside of drawdown zone of influence	No (upgradient of proposed road)	N/A	N/A
Petrifying Springs (Lackagh Quarry)	Rock bolts may intersect recharge pathways	No Located above the groundwater table	Negligible	Imperceptible

Feature	Potential Impact to Groundwater Level	Potential Impact to Groundwater Quality	Magnitude of Hydrogeology Impact	Significance of Hydrogeology Impact
Local habitats				
An Baile Nua (Ch. 0+150)	Removed by road alignment	Removed by road alignment	Large Adverse	Slight / Moderate
Na Forai Maola Thoir (Ch. 1+150)	Removed by road alignment	Removed by road alignment	Large Adverse	Slight / Moderate
Barna (Ch. 3+100 and Ch. 3+400)	Removed by road alignment	Removed by road alignment	Large Adverse	Slight / Moderate
Knocknabrona (Ch. 7+850 to Ch. 8+150)	Removed by road alignment	Removed by road alignment	Large Adverse	Slight / Moderate
Calcareous springs (Lackagh Quarry)	Rock bolts may intersect recharge pathways	No Located above the groundwater table	Negligible	Imperceptible

On the basis of the above assessment impacts to groundwater dependant habitat are assessed based on the importance of the hydrogeology attribute and the magnitude of impact. Those features that lie beyond the zone of influence to hydrogeological impacts and away from the area vulnerable to contamination are assessed to have no impact.

10.5.2.4 Hydrogeological Impacts to Groundwater Dependent Surface Water Features

Groundwater contributes to surface water across the hydrogeology study area. In the area of the Galway Granite Batholith, the groundwater contribution is minimal, as evidenced by low baseflow. However, groundwater provides more significant contribution to baseflow in the area of the Visean Undifferentiated Limestone (refer to Chapter 11, Hydrology). Whilst the River Corrib receives most of its contribution from upstream of the hydrogeology study area, features such as Ballindooley Lough, Coolagh Lakes, turlough K20, Turlough K31, Turlough K72 and the Terryland River (during high groundwater levels), all contribute to the flow of the Corrib.

Owing to the GWDTE in the vicinity of the River Corrib most surface water features have already been described in Section 10.5.2.3. The only surface water feature not yet discussed is the Terryland River, which is presented below.

The hydrogeology of the Terryland River is described in Section 10.3.3, which explains the importance of two estavelles at the eastern end of the river. Although the Terryland River sinks at the estavelles for most of the year, these reverse during peak groundwater levels and become resurgences. On the occasion of peak winter groundwater storms events groundwater from the Clare-Corrib GWB may contribute to the River Corrib and the Lough Corrib SAC due to flooding and backup in the Terryland River. On this basis the Clare-Corrib GWB contributes to Galway Bay during normal conditions but to Galway Bay and the River Corrib during high groundwater levels.

The potential impact magnitude to the Terryland River during high groundwater is quantified as ‘Small Adverse’. As during these times, the Terryland River is entirely groundwater fed, then the rating significance is ‘Significant’. The hydrological impacts are described in Chapter 11, Hydrology.

The magnitude and significance of hydrogeological impacts refer to potential changes in groundwater quantity and/or quality at receiving surface water from the Project. The assessment is made in accordance with TII Guidelines. For assessment on surface water impacts as a consequence of these potential hydrogeological impacts, please refer to Chapter 11, Hydrology.

10.5.2.5 Summary

This section has provided a detailed assessment of the potential impacts to receptors for the Project prior to implementation of mitigation measures. Based on the conceptual site model (Section 10.3.4) a zone of impact has been delineated for groundwater level drawdown. Areas that lie downgradient of the Project have also been identified as being at risk from pollution, with the extent downgradient being dependant on the aquifer properties. Where the source and receptor are located in a limestone aquifer with karst pathways then the receptors are assessed using the precautionary principle and all receptors downgradient are considered to be within the 100-day TOT.

The design of the Project is cognisant of the hydrogeological existing environment and specifically groundwater receptors. Below is a summary of the design measures incorporated into the design of the Project for the construction phase:

- The design of the construction minimises areas of land stripping so as to reduce the increase in runoff from where vegetation (and evapotranspiration) is removed
- In the area of the Galway Granite Batholith the aquifer properties (permeability and storage) are low and recharge is very low. In these areas runoff is managed on site and discharged to surface water (refer to Chapter 11, Hydrology). There is no reliance on groundwater infiltration where the road traverses the Galway Granite Batholith
- Groundwater inflows will occur in road cuttings due to the high-water table in the Galway Granite Batholith. Where groundwater inflows occur, these are likely to be minimal owing to the low aquifer properties. In the case of local zones of higher inflow, for example at a fault zone, then mitigation measures will be employed to control the inflow and isolate the pathway from the construction site
- The assessment has identified a risk specific to the Visean Undifferentiated Limestone where karst is present within the groundwater bodies that the Project traverses. Karst has been identified in Lough Corrib Fen 1 GWB, Lough Corrib Fen 2 GWB and the Clare-Corrib GWB. If karst was encountered in these groundwater bodies then there is a risk that runoff and accidental spills could impact on groundwater quantity and quality. These potential impacts require mitigation using the karst protocol, which is detailed in Section 10.6 mitigation measures
- During construction of the proposed tunnel at Lackagh Quarry there is a risk of groundwater impacts if dewatering of the bedrock aquifer occurs, which could have hydrogeological impacts at Coolagh Lakes which are part of Lough Corrib SAC. Detail of the assessment of Lackagh Tunnel and its approaches are presented in Appendix A.7.3
- For the tunnel section the eastern section of the western portal and approach the construction works will be restricted to above the groundwater table at all times
- At the eastern approach to Lackagh Tunnel support system of rock bolts will be used to stabilise the quarry face rather than concrete. Rock bolts will prevent impact to the petrifying springs and calcareous identified in the faces of Lackagh Quarry
- To facilitate groundwater flow around the fully watertight Lackagh Tunnel the construction design includes a drainage blanket. It is envisaged that the drainage blanket will take the form of a drainage layer below the tunnel, with drainage pipes or similar placed outside the permanent cast in-situ reinforced concrete tunnel lining and waterproof membrane. The drainage layer will include baffles to prevent flow in the drainage layer along the line of the tunnel
- The proposed finished level of the Project at Lackagh Quarry will lie above the groundwater table, however, the embankment starter layer at the eastern approach would, in part, be submerged during peak winter groundwater high. In this regard the starter layer will be constructed so as not to dam groundwater in parts of the quarry floor. Similarly, the drainage network will not be installed during the seasonal groundwater high so as to avoid the need for dewatering of the bedrock aquifer and groundwater lowering
- A watertight seal will be installed on the road base of Lackagh Tunnel and its western approach and the cutting sides to protect against groundwater inflow. This area will be sealed during construction (and permanently) to +17.7mOD; which is derived from the groundwater high (+15.7mOD) plus 2m free board. Slope or retaining structures will be utilised from +17.7mOD to existing ground level where required

Based on the design measures above, each of the hydrogeology receptors have been assessed. Table 10.21 below provides a summary of impact magnitude and impact significance for those hydrogeological receptors considered to have risk during the construction phase. Where the assessment phase has determined that the receptor has no impact (for example because it is outside of a zone of contribution or upgradient of contamination) and that the significance is not applicable, in that case then that receptor is not included in the summary table.

The assessment of ecological and surface water receptors refers only to the hydrogeology of each location (refer to Chapter 8, Biodiversity and Chapter 11, Hydrology).

Table 10.21 Summary of Impact Magnitude and Significance for Hydrogeological Aspects of Receptors at Risk during the Construction Phase of the Project

Feature	Importance of Hydrogeology Attribute	Hydrogeology Impact Summary	Hydrogeology Impact Magnitude	Hydrogeology Impact Significance
Groundwater Resources				
Galway Granite Batholith (Pl)	Low	Small loss of resource Minor change to aquifer / unsaturated zone Low risk of pollution	Negligible impact to resource quantity Small adverse risk to resource quality	Combined assessment is Imperceptible
Visean Undifferentiated Limestone (Rkc)	Very High	Small loss of resource No significant change to groundwater table High risk of pollution	Negligible impact to groundwater quantity Moderate adverse impact to quality due to potential unplanned contamination	Combined assessment is Profound / Significant based on potential impact to groundwater quality
Groundwater Supplies (note where a receptor assessment has no impact then the hydrogeology significance is N/A and the receptor is not listed in summary)				
W50-02	Low	Downgradient of K328 in the deep aquifer	Moderate adverse	Slight
W50-10	Low	Well will be lost	Large adverse	Slight / moderate
W50-12	Medium	Well will be lost	Large adverse	Significant
W50-13 & W50-14	Very High	Well will be lost	Large adverse	Profound
W50-15	High	Well will be lost	Large adverse	Profound / significant
W50-20	Medium	Downgradient of K328 in the deep aquifer	Moderate adverse	Moderate adverse
W50-17	Low	Well will be lost	Large adverse	Slight / moderate
W50-18	Low	Well will be lost	Large adverse	Slight / moderate
W50-19	Low	Well will be lost	Large adverse	Slight / moderate

Feature	Importance of Hydrogeology Attribute	Hydrogeology Impact Summary	Hydrogeology Impact Magnitude	Hydrogeology Impact Significance
W50-16	Low	Well will be lost	Large adverse	Slight / moderate
W500-01	Low	Downgradient of K328 in the deep aquifer	Moderate adverse	Slight
W1000-03	Low	Downgradient of K328 in the deep aquifer	Moderate adverse	Slight
Ecological Receptors within Designated Sites (European and National) (note where a receptor assessment has no impact then the hydrogeology significance is N/A and the receptor is not listed in summary)				
Galway Bay Complex SAC	Extremely High	Potential temporary quantity and quality deterioration of groundwater in karst pathways to Galway Bay. The groundwater contribution from GWB is of insufficient magnitude to affect integrity	Negligible	Imperceptible
Inner Galway Bay SPA	Extremely High	Potential temporary quantity and quality deterioration of groundwater in karst pathways to Galway Bay. The groundwater contribution from GWB is of insufficient magnitude to affect integrity	Negligible	Imperceptible
Lough Corrib SAC (Groundwater contribution to Coolagh Lakes)	Extremely High	Potential temporary quantity and quality deterioration of groundwater in karst pathways within contributing GWB would lead to impacts at Western Coolagh Spring, which is the main water contribution for Coolagh Lakes	Large adverse	Profound

Feature	Importance of Hydrogeology Attribute	Hydrogeology Impact Summary	Hydrogeology Impact Magnitude	Hydrogeology Impact Significance
Lough Corrib SAC (Groundwater contribution to River Corrib)	Extremely High	The groundwater contribution from GWB to River Corrib is of insufficient magnitude to affect integrity	Negligible	Imperceptible
Lough Corrib SAC (Groundwater contribution to Terryland River when K87 and K96 active)	Extremely High	Potential temporary quality deterioration of groundwater in karst pathways within contributing GWB could lead to water quality impact at Terryland River (within catchment of karst feature K328)	Small adverse	Significant
Lough Corrib pNHA (Groundwater contribution to Coolagh Lakes)	Very High	Potential temporary quantity and quality deterioration of groundwater in karst pathways within contributing GWB would lead to impacts at Western Coolagh Spring, which is the main water contribution for Coolagh Lakes	Large adverse	Profound
Lough Corrib pNHA (Groundwater contribution to River Corrib)	Very High	The groundwater contribution from GWB to River Corrib is of insufficient magnitude to affect integrity	Negligible	Imperceptible
Lough Corrib pNHA (Groundwater contribution to Terryland River when K87 and K96 active)	Very High	Potential impact to groundwater dependant habitat due to deterioration of water quantity or quality from accidental spills from construction works at Galway Racecourse (within catchment of karst feature K328)	Small adverse	Significant / Moderate
Galway Bay Complex pNHA	Very High	Potential temporary quantity deterioration of groundwater in karst pathways to Galway Bay. The groundwater contribution from GWB is of	Negligible	Imperceptible

Feature	Importance of Hydrogeology Attribute	Hydrogeology Impact Summary	Hydrogeology Impact Magnitude	Hydrogeology Impact Significance
		insufficient magnitude to affect integrity		
Habitats outside of designated sites				
Na Foraí Maola Thiar (Annex I) (Ch. 0+650 to Ch. 0+750)	Very High	Within area liable to contamination	Large adverse	Profound
Na Foraí Maola Thoir (Annex I) (Ch. 1+250 to Ch. 1+500)	Very High	Within drawdown zone of influence Within area liable to contamination	Large adverse	Profound
Troscaigh Thiar (Annex I) (Ch. 1+850 to Ch. 2+400)	Very High	Partially removed by road alignment and part within drawdown zone Part liable to contamination	Large adverse	Profound
Aille (Annex I) (Ch. 3+600 to Ch. 3+850)	Very High	Partially removed by road alignment and part within drawdown zone Part liable to contamination	Large adverse	Profound
Ballyburke (Annex I) (Ch. 4+650 to Ch. 4+800)	Very High	Removed by road alignment	Large adverse	Profound
Knocknabrona (Annex I) (Ch. 7+700 to Ch. 7+750)	Very High	Removed by road alignment	Large adverse	Profound
University of Galway (S) (Annex I) (Ch. 9+150 to Ch. 9+250	Very High	Potential contamination impact	Moderate adverse	Profound
Turlough K31 (Annex I) Menlough East	Very High	Project traverses the habitat Potential temporary groundwater contamination impact	Large adverse	Profound
Petrifying springs (Annex I)	Very High	Rock bolting to stabilise eastern portal of Lackagh Tunnel	Negligible	Imperceptible
An Baile Nua(non-Annex I) (Ch. 0+150)	Low	Removed by road alignment	Large adverse	Slight / moderate
Na Forai Maola Thoir (non-Annex I) (Ch. 1+150)	Low	Removed by road alignment	Large adverse	Slight / moderate

Feature	Importance of Hydrogeology Attribute	Hydrogeology Impact Summary	Hydrogeology Impact Magnitude	Hydrogeology Impact Significance
Barna (non-Annex I) (Ch. 3+100 and Ch. 3+400)	Low	Removed by road alignment	Large adverse	Slight / moderate
Knocknabrona (non-Annex I) (Ch. 7+850 to Ch. 8+150)	Low	Removed by road alignment	Large adverse	Slight / moderate
Calcareous springs (non-Annex I)	Low	Rock bolting to stabilise eastern portal of Lackagh Tunnel	Negligible	Imperceptible
Surface water				
Terryland River	Extremely High	Potential temporary water quality impact to Terryland estavelles (K87 & K96) during high groundwater levels when these outflows contribute to the River Corrib	Small adverse	Significant

10.5.3 Operational Phase

There are a number of operation phase activities or features of the Project that have the potential to cause hydrogeological impacts. The potential impacts of operation activities on the hydrogeological receptors, identified in Section 10.3.5, are discussed in this section of the chapter. The potential impact outlined in this section are pre-mitigation. Mitigation measures are presented in 10.1, whilst residual impacts are presented in Section 10.7.

As with construction activities, the main impacts to groundwater from operation arises from the potential to impact on groundwater level and groundwater quality. Operation can alter the groundwater regime by:

- Lowering of groundwater level from operational dewatering
- Raising groundwater levels by impeding or impounding groundwater
- Discharge of road runoff to ground

The quantification of these potential operational impacts are presented in this section of the chapter.

There will be no active dewatering of the bedrock aquifer required during the operation phase but passive dewatering will occur at a number of cutting locations and the drainage associated with the Project will cause the groundwater levels to adjust locally.

The drawdown and ZoI for road cuttings is presented in Table 10.18 of the construction impacts and should also be referred to when considering the impacts from the operation phase. It should be noted that all tunnels and associated approaches will be sealed as part of their construction where below the winter water table and so, for example, the Galway Racecourse Tunnel and approaches will require dewatering of the bedrock aquifer during construction, but they will not require dewatering during operation. Dewatering of the bedrock aquifer either during construction or operation at Lackagh Tunnel and its approaches is not permitted.

The potential impacts from interception of karst conduits was highlighted during the construction phase as having a potential impact on the hydrogeological regime by either modifying pathways (reactivating sediment filled karst or blocking active karst) or from point input recharge for contaminants. Mitigation measures to prevent these impacts from occurring are presented in Section 10.1. If implemented during the construction phase, these impacts will not occur during the operation phase.

During operation, potential groundwater quality impacts occur from the discharge of road runoff or from accidental spillages. Potential impacts of the discharge of routine road runoff is assessed in line with HD45/15 ‘Road Drainage and the water Environment’ Method C, while the assessment of accidental spillages is undertaken in Chapter 10, Hydrology line with HD45/15 ‘Road Drainage and the water Environment’ Method D. Based upon the traffic assessment for the proposed N6 GCRR the calculated risk of serious pollution incident during operation is less than 0.5% annually.

Within HD45/15, a Groundwater Protection Response (GPR) is presented which is a risk assessment methodology based on the vulnerability and aquifer classification of the aquifer where the discharge will occur. A matrix of these elements, presented below in Table 10.22, is used to determine the potential risk and sets out a series of ‘Responses’ that the drainage design of the Project should comply with to minimise the risk to the groundwater environment. The assessment is considered a screening tool which can be superseded by a site specific hydrogeological risk assessment.

Table 10.22 Groundwater Response Matrix for the use of Permeable Drains in Road Schemes (TII, HD45/15, 2015)

Vulnerability Rating	Source Protection Area	Resource Protection Area (Aquifer Category)							
		Regionally Important Aquifer			Locally Important Aquifer			Poor Aquifer	
		Rk*	Rf	Rg	Lg	Lm	Ll	Pl	Pu
Extreme: Rock near Surface or karst (X)	R4	R4	R4	R3(2)	R3(2)	R3(1)	R3(1)	R3(1)	R3(1)
Extreme (E)	R4	R2(3)	R2(2)	R3(2)	R3(2)	R2(2)	R2(2)	R2(1)	R2(1)
High (H)	R3(2)	R2(2)	R2(2)	R2(2)	R2(2)	R2(2)	R2(2)	R2(1)	R2(1)
Moderate (M)	R3(1)	R2(1)	R2(1)			R2(1)	R2(1)	R1	R1
Low (L)	R3(1)	R1	R1			R1	R1	R1	R1

*A small proportion of the country (~0.6%) is underlain by locally important karstic aquifers (Lk); in these areas, the groundwater protection responses for the Rk groundwater protection zone shall apply.

The GSI provides mapped classifications of the aquifer and vulnerability criteria across the country, however it is recommended that the vulnerability criteria is updated based on site specific information.

Groundwater vulnerability assesses the geological and hydrogeological characteristics of the subsoil overlying the aquifer and provides a rating response using the TII HD45/15 GPR (Table 10.22). The GSI make a distinction between extreme vulnerability with bedrock at surface (X) and extreme vulnerability with subsoil being 0-3m thick (E). Where extreme (X) vulnerability refers to rock outcrop at surface or the location of a karst feature.

The groundwater protection response for the Project is presented in Appendix A.10.7 and concludes the following:

- Significant areas of the Galway Granite Batholith are identified by the GSI as being rock at or near surface. However, as most of the proposed N6 GCRR is on embankment the groundwater vulnerability is mainly extreme (E). Those areas where groundwater vulnerability is extreme (X) are areas where the Project is in cutting. In these areas the drainage design includes verges and swales that maintain a 1m constructed subsoil above bedrock. As the granite is of a low permeability infiltration to the bedrock is very low
- Drainage design for the Visean Undifferentiated Limestone is sealed up to the point of discharge, where to surface water or infiltration basin. Where discharge is proposed by infiltration basins then all locations have a GPR response of R2(3)

- Permeable drainage is acceptable for both R2(1) and R2(3) responses subject to subject to minimum Design Manual for Roads and Bridges (DMRB) standards and GPR Notes
- Permeable drainage is acceptable for the proposed N6 GCRR where it traverses the Galway Granite Batholith subject to minimum DMRB conditions and GPR requirements 1, 2 and 3. In the event of a vertical fault crosscutting the Project then the drainage design will locally be sealed to prevent communication between flow zone and runoff
- Permeable drainage is acceptable for the Project where it traverses the Visean Undifferentiated Limestone subject to minimum DMRB conditions and GPR requirements 1, 2, 3, 4, 5, 6 and 7. The drainage design takes into account karst primarily by avoidance but also by incorporating pre-treatment prior to discharge. Drainage design for the Visean Undifferentiated Limestone employs a sealed design with discharge either to surface water courses or infiltration basins. Where runoff discharges to surface water then there is no discharge to groundwater and a detailed hydrogeological assessment is not required. For those networks with discharge by infiltration basin then a hydrogeological assessment has been undertaken for each network to assess the potential risks to groundwater. The individual assessments are included into Appendix A.10.7

On the basis of this hydrogeological assessment the design and measures of the infiltration basins assessed meet the criteria for HD45/15 for permeable drainage.

The potential impacts from accidental spillages have been assessed in line with TII Guidelines HD45/15 Method D. The potential risk of a serious pollution incident occurring has been calculated >1% and the calculations to confirm this are presented in Chapter 10, Hydrology.

The potential zone of influence for operation drawdown and water pollution impacts are presented in Figure 10.8.101 to Figure 10.8.115.

10.5.3.1 Potential Impacts to groundwater resources

The potential impact assessment on the groundwater resources during the operation phase considers the impact that the changes in the groundwater regime and groundwater quality have on the aquifer for the operational life of the Project.

In line with TII guidance, the magnitude of the impact on the aquifers within the hydrogeology study area is based on the portion of the aquifer that will be removed, changes to the aquifer or unsaturated zone and risk of pollution from runoff. Effectively these changes occur during the construction phase (refer to Section 10.5.2) and continue through to the operational phase. This is in how the Project manages recharge, groundwater flow and groundwater quality. The assessment for the operation of the Project is the same as the assessment for the construction phase as the volume of the aquifer removed is a very small percentage of the aquifer volume. On this basis, as per the construction assessment, for the operational of the Project the Magnitude of the impact on the aquifers is ‘Negligible’ and the Significance of the impact is ‘Imperceptible’.

The presence of the Project itself can affect the aquifer by changing the recharge pattern to it as part of the drainage design. Details of the drainage design for the Project are provided in Chapter 5, Description of the Project, which includes the surface areas of the proposed N6 GCRR where rainfall will be captured by the road surface and associated drains then be managed as runoff rather than recharge. Using this data, the surface area of the proposed N6 GCRR is negligible when compared to the surface area of the land providing recharge to the aquifer. The magnitude of the impact on the aquifer is ‘Negligible’ and the significance of the impact is Imperceptible.

Other impacts that have the potential to impact on groundwater resources are permanent dewatering in cuttings and discharges from the drainage system to ground. Both cutting drainage and infiltration basins have the potential to impact on groundwater levels and groundwater quality. The magnitude and significance of impacts to groundwater resources for the two aquifer types along the Project is outlined below in Sections 10.5.3.1.1 and 10.5.3.1.2.

10.5.3.1.1 Galway Granite Batholith (Section 1)

Based on TII guidelines the Galway Granite Batholith is assessed as a receptor of Low importance in terms of its attributes, which is based on its aquifer classification by the GSI as a Poor Aquifer. The GSI classification indicates that the aquifer has limited groundwater resources.

Groundwater Quantity

There are seven cuttings in the Galway Granite Batholith which have the potential to intersect the groundwater table locally. These road cuttings are EW01, EW02 (three cuttings), EW04, EW07 and EW11. As outlined in Section 10.4, EW11 has the largest ZoI with drawdown extending up to 54m from the edge of the cutting footprint.

The installation of drainage both for the proposed N6 GCRR runoff and for pre-earthworks drainage will locally intercept drainage and for this reason, the conservative assumption is that the operational ZoI will be the same as the construction ZoI for these excavations.

Other excavations which are included in the construction ZoI such as excavation for structures and attenuation ponds are relevant for construction only and hence the ZoI for operation will locally be reduced from the ZoI for construction.

Using the reported aquifer properties, the operation ZoI within the Galway Granite aquifer will yield relatively small volumes of groundwater, which will be managed on site and discharged to those nearby watercourses that the groundwater would contribute too indicating that there will be no net change to the throughput of water into and from the aquifer. On this basis, in line with TII rating, the magnitude of the impact of lowering the groundwater level on the aquifer is Negligible and the significance of the impact is Imperceptible.

In summary, quantitative aspects of groundwater resources have been assessed including the removal of aquifer, drawdown of groundwater level and recharge. All aspects of the groundwater quantity have been assessed as being Negligible, which based on the poor classification of the aquifer has an Imperceptible rating for environmental significance.

Groundwater Quality

Potential impacts to groundwater quality during operation occur from infiltration to ground from the proposed road runoff. The assessment of the infiltration of proposed road runoff for the Galway Granite Batholith is detailed in Appendix A.10.7 and a summary is provided below.

The assessment of the operational discharges to ground is based on the TII HD45/15 GPR assessment which is uses groundwater vulnerability and the aquifer type. For the Galway Granite Batholith, the GSI Groundwater vulnerability varies between extreme (X) and high (H) and the aquifer characterisation is poor (Pl). Where the mainline of the proposed N6 GCRR is on embankment or in cutting then over the edge drainage is proposed using verges and swales. For the full length of the mainline the GPR returns a R2(1) response and meets TII HD45/15 guidelines. Due to the low hydraulic conductivity of the granite bedrock the potential impact to groundwater quality is limited to being immediately local to the Project.

If accidental spillages occur during the operation of the Project, they have the potential to impact groundwater quality immediately below the over the edge drainage. Based upon the traffic assessment for the proposed N6 GCRR the calculated risk of serious pollution incident during operation is less than 0.5% annually. In line with TII guidance, the Magnitude of this potential impact is Negligible. Based on the low importance of the granite in terms of the hydrogeology the Significance of this impact is Imperceptible.

If unplanned activities such as spillages from accidents, have the potential to contaminate groundwater at over the edge drainage. In line with TII guidance, the magnitude of potential impacts to groundwater resources is deemed to be Small Adverse. Based on the low importance ranking of the aquifer the significance is Imperceptible.

Summary

To maintain a precautionary approach, the overall ranking is based on the greatest impact of the quantity and quality assessment combined. On this basis, the combined quantity and quality hydrogeological impact for the groundwater resources of the granite aquifer, is Negligible. Given the importance of the receptor is Low then the significant environmental impact is ranked as Imperceptible.

10.5.3.1.2 Visean Undifferentiated Limestone (Section 2, 3 & 4)

Based on TII guidelines the Visean Undifferentiated Limestone is assessed as a receptor of Very High importance in terms of its attributes, which is based on its aquifer classification by the GSI as a Regionally

Important Aquifer with karst conduits (Rkc). As per TII guidelines, a regionally important aquifer may be classified as very high or high. The conservative assessment of the aquifer as being very high is applied owing to the record of high yielding wells in the region. However, it is noted from the baseline water quality assessment that the groundwater quality in the aquifer is impacted from urban and agricultural sources of pollution.

Groundwater quantity

During the operation phase of the Project, there are thirteen sections in the Visean Undifferentiated Limestone Aquifer that remain in an open cutting or tunnel (see Table 10.17). This is two less than during construction as the River Corrib Bridge and Menlough Viaduct do not have excavations during operation.

The potential for impact is assessed on the basis of the depth of the cutting, including drainage, and the maximum groundwater levels monitored during the project specific ground investigation (2015-2017). Of these thirteen cuttings, six remain above the water table at all times and will not impact on groundwater levels. Seven cuttings do have the potential to intersect and impact on the water table locally during operation.

The seven cuttings/tunnel that have the potential to intersect the water table include three cuttings (EW27, EW34 and EW35), three tunnel approaches (EW19, EW30 and EW32) and two tunnels (EW20 Lackagh Tunnel and EW31 Galway Racecourse Tunnel). Both the Lackagh Tunnel and its western approach and the Galway Racecourse Tunnel with its eastern approach will be sealed.

Based on the water level data collected for the Project and the sealed design of the tunnels and their approaches, the only excavations that have the potential to require operational dewatering of the bedrock aquifer are EW27, (Clare-Corrib GWB) EW34 and EW35 (Clarinbridge GWB).

The installation of drainage both for proposed road runoff and for pre-earthworks drainage will locally intercept drainage and for this reason, the conservative assumption is that the operational ZoI will mimic the construction ZoI for these three excavations. Based on the different aquifer properties for the various groundwater bodies outlined in the Section 10.3.4. As the aquifer properties are lower in the shallow part of the Clarinbridge GWB, the ZoI extents for drawdown are less extensive that the other limestone GWB, such as the Clare-Corrib GWB which has karst features.

EW27 lies immediately west of the N83 Tuam Road and is a cutting where the proposed finished road level lies 10m above the summer groundwater level and 0.5m above the peak recorded winter groundwater level. As part of the design permanent drains will be installed to control the groundwater level 2m below the finished road level.

All groundwater intercepted by drains during the peak groundwater rise will be carried eastwards by unlined 150mm perforated pipes either side of the Project with discharge along the pipe length and overflow to an infiltration basin. All groundwater intercepted by these drains will be discharged back into the groundwater body further east where groundwater levels are <5m below the proposed road level.

Within the Clarinbridge GWB the aquifer properties are relatively low and on this basis the volumes of groundwater to be generated during excavations are relatively small. Any groundwater lowering required will be kept within the same GWB so that groundwater volumes are maintained.

Based on the assessment for groundwater quantity that there is only limited groundwater lowering and that all intercepted groundwater is infiltrated back to ground in the sub-catchment that it was received, it is assessed that the is a Negligible impact on groundwater resources. Given the very high importance of the receptor, then the significance of the environmental impact is Imperceptible.

Groundwater quality

In the area of the Visean Undifferentiated Limestone there are few surface water features present. Where there is no option for discharge via surface water or storm water sewers the Project will discharge to ground by infiltration basins. As outlined in Section 10.4 TII HD45/15 guidelines have been followed for the drainage design of the carriageway. The full HD45 assessment is presented in Appendix A.10.7, whilst a summary is presented below.

The design of the infiltration basin includes a 2m over excavation from the invert to place a 2m thick subsoil that will meet the TII definition of being an appropriate material (TII HD45/15). All of the infiltration basins are more than 15m from surface karst mapped during the karst survey (refer to Figure 10.1.002) and will be sealed up to the point of discharge. Additionally, all infiltration basins are designed to include the following features as standard design:

- A containment area
- A hydrocarbon interceptor
- A wetland

There is also a containment area in each drainage network that can manually be activated to contain spillage on the proposed carriageway.

Groundwater levels have been monitored along the route of the Project between February 2015 and January 2017 (with reconfirmation in 2023/2024) to determine the seasonal variation in the groundwater level. Based on these measurements the minimum thicknesses of the saturated zone have been calculated for the infiltration basins and are presented in Table 10.23.

Table 10.23 Summary the Unsaturated Thicknesses below Invert Level for all Infiltration Basins

Network Ref.	S19A	S19B	S20	S21A	S21B	S22A	S22B	S22C2	S22E	S40
Minimum unsaturated zone (m)	1.4	0.3	0	2.6	9.1	2.0	3.9	15.2	9.9	1.0

The groundwater level data shows significant seasonal variation locally and whilst all infiltration basins meet the requirement of 2m unsaturated zone during the groundwater low, infiltration basins S19a, S19b, S20 and S40 have less than 2m unsaturated zone during winter peaks. On this basis, infiltration basins at networks S21A, S21B, S22A, S22B, S22C2 and S22E meet and exceed the TII HD45/15 GPR criteria for R2(3) due to the pre-treatment.

Networks S19a, S19b, S20 and S40, however, do not meet the R2(3) criteria during the winter period when groundwater levels are elevated and there is less than 2m unsaturated zone (Table 10.23). However, as the standard design for infiltration basins for the Project includes containment, a hydrocarbon interceptor and a wetland, then each infiltration basin includes significant pre-treatment of runoff prior to infiltration.

HD45/15 provides data on the event mean concentrations (EMC) of significant contaminants in routine runoff. The potential contaminants and their EMC are reproduced below in Table 10.24. The EMC data presented in TII HD45/15 is indicative of runoff water pre- treatment.

Table 10.24 Significant Pollutants and their EMC

Determinand	Routine runoff Mean EMC µg/l
Total Copper	91.22
Dissolved Copper	31.31
Total Zinc	352.63
Dissolved Zinc	111.09
Total Cadmium	0.63
Total Fluoranthene	1.02
Total Pyrene	1.03

Determinand	Routine runoff Mean EMC µg/l
Total PAHs	7.52

As the pre-treatment aspect exceeds the requirements of HD45/15 for all infiltration basins then the treated run-off at infiltration basins S19a, S19b, S20 and S40 is of a higher quality than that listed in Table 10.24.

In addition to this, as noted in Appendix A.10.3 and Section 10.3.3 the maximum water levels were recorded during a period of unusually elevated groundwater levels following sustained rainfall events in the winter 2015/2016. Outside of these events, the minimum thickness requirement for the unsaturated zone will be present.

On this basis, the use of infiltration basins is assessed as being appropriate if no karst is encountered during construction of the excavation. Mitigation measures will be employed if karst is encountered during construction (refer to Section 10.1).

The presence of karst has been accommodated in the placement of the infiltration basins and no known active surface karst is present within 15m of any infiltration basin. However, there is a potential for karst to be encountered during the construction of infiltration basins and this is dealt with in the evaluation of construction impacts in Section 10.5.2.

The potential impact of karst is recognised as a significant aspect of the infiltration basins and is included in the mitigation measures of Section 10.1, which includes inspections to ensure that the infiltration basins remain in good working order for the operational life of the Project.

Based on the TII HD45/15 Method C for groundwater protection response for routine runoff and site-specific hydrogeological assessments the drainage design for operation of the Project is considered to have an impact of negligible magnitude and imperceptible significance for all networks.

The potential accidental spillages to occur during the operation of the Project, has the potential to impact on groundwater quality and has been assessed in line with TII HD45/15 Method C risk assessment. Based on the spillage risk assessment (refer to Chapter 11, Hydrology) the risk of a serious spillage occurring has an annual probability of less than 0.5% and is considered as acceptable based on TII guidelines.

In line with TII guidance, the Magnitude of the overall potential impact on the aquifer is Negligible. The Significance of this impact on the Regionally Important Aquifer is Imperceptible.

Based upon the traffic assessment for the proposed N6 GCRR the calculated risk of serious pollution incident during operation is less than 0.5% annually. In line with TII guidance, the Magnitude of this potential impact is Negligible. Based on the very high importance of the limestone in terms of the hydrogeology, the Significance of this impact is Imperceptible.

In summary, the overall impact on groundwater quality for groundwater resources is assessed as being Negligible and based on the very high ranking of the limestone aquifer, then the environmental significance is rated as being Negligible.

Summary

To maintain a precautionary approach, the overall ranking is based on the greatest impact of the quantity and quality assessment combined. On this basis, the combined quantity and quality hydrogeological impact for the groundwater resources of the limestone aquifer, is Negligible. Given the importance of the receptor is Very High then the significant environmental impact is ranked as Imperceptible.

10.5.3.2 Potential Impacts to Groundwater supplies

An impact assessment on abstraction wells was completed for the construction phase and is presented in Section 10.5.2.1. The same assessment is valid for the operation phase.

It highlights that nine wells (W50-10, W50-12, W50-13, W50-14, W50-15, W50-16, W50-17, W50-18 and W50-19) will be removed by the Project at the construction phase.

Mitigation measures for wells impacted outside of the Assessment Boundary are proposed in Section 10.1 and the residual impacts are summarised in Section 10.7.

10.5.3.3 Potential Impacts to Groundwater Dependent Terrestrial Ecosystems (GWDTE)

Potential impacts to GWDTE during operation derive from the interception of groundwater in cuttings and the deterioration of water quality from discharges and accidental spillages. Based on the characteristics of the Project presented in Section 10.4, the zone of influence has been calculated for the operational passive dewatering of the bedrock aquifer and the area where there is potential contamination of the aquifer during operation. The zone of influence from cuttings has been considered relative to all GWDTE listed in Section 10.3.5.3. The proximity potential impacts to groundwater quantity and groundwater quality of these GWDTE are presented in Table 10.25.

The water quality assessment of discharges from the Project has been undertaken as part of TII HD45/15 groundwater protection response and individual hydrogeological assessments. The HD45/15 of road drainage assessments conclude that the magnitude of the impact is 'Negligible' and the significance 'Imperceptible' for groundwater receptors. It should be noted that operational impacts are assessed on the basis of construction with guidance of the project karst protocol. In this regard, if karst was encountered during the construction of infiltration basins then these features would have been mitigated against at the construction phase.

Table 10.25 Summary of Potential Hydrogeological Impacts at GWDTE during Operation Phase (Pre-mitigation)

Feature	Impact to Groundwater Quantity	Impact to Groundwater Quality	Magnitude of Hydrogeology Impact	Significance of Hydrogeology Impact
European sites				
Galway Bay Complex SAC	Localised rise in groundwater table below infiltration basins. Imperceptible net change to groundwater contribution	All discharges to groundwater are treated prior to infiltration	Negligible	Imperceptible
Inner Galway Bay SPA	Localised rise in groundwater table below infiltration basins. Imperceptible net change to groundwater contribution	All discharges to groundwater are treated prior to infiltration	Negligible	Imperceptible
Lough Corrib SPA	No European site lies upgradient	No European site lies upgradient	N/A	N/A
Lough Corrib SAC	Localised rise in groundwater table below infiltration basin. Imperceptible net change to groundwater contribution	All discharges to groundwater are treated prior to infiltration	Negligible	Imperceptible
Ballindooley Lough	No European site lies upgradient	No European site lies upgradient	N/A	N/A
National Heritage Sites				
Moycullen Bogs	No	No	N/A	N/A

Feature	Impact to Groundwater Quantity	Impact to Groundwater Quality	Magnitude of Hydrogeology Impact	Significance of Hydrogeology Impact
	European site lies upgradient	European site lies upgradient		
Moycullen Bogs (Tonabrocky)	No European site lies upgradient	No European site lies upgradient	N/A	N/A
Moycullen Bogs (Letteragh)	No European site lies upgradient	No European site lies upgradient	N/A	N/A
Lough Corrib pNHA	Localised rise in groundwater table below infiltration basin. Imperceptible net change to groundwater contribution	All discharges to groundwater are treated prior to infiltration	Negligible	Imperceptible
Galway Bay Complex pNHA	Localised rise in groundwater table below infiltration basin. Imperceptible net change to groundwater contribution	All discharges to groundwater are treated prior to infiltration	Negligible	Imperceptible
Annex I habitats (outside of designated sites)				
Na Foraí Maola Thiar (Ch. 0+650 to Ch. 0+750)	Outside of drawdown zone of influence	Outside of area liable to contamination	N/A	N/A
Na Foraí Maola Thoir (Ch. 1+250 to Ch. 1+500)	Partially within drawdown zone of influence	Outside of area liable to contamination	Large Adverse	Profound
Troscaigh Thiar (Ch. 1+850 to Ch. 2+400)	Partially removed by road alignment and part within drawdown zone	Partially removed by road alignment Outside of area liable to contamination	Large Adverse	Profound
Bearna (Ch. 2+600 to Ch. 3+100)	Outside of drawdown zone of influence	Outside of area liable to contamination	N/A	N/A
Aille (Ch. 3+600 to Ch. 3+850)	Partially removed by road alignment and part within drawdown zone	Partially removed by road alignment Outside of area liable to contamination	Large Adverse	Profound
Ballyburke (Ch. 4+650 to Ch. 4+800)	Removed by road alignment	Removed by road alignment	Large Adverse	Profound
Knocknabrona (Ch. 7+700 to Ch. 7+750)	Removed by road alignment	Removed by road alignment	Large Adverse	Profound

Feature	Impact to Groundwater Quantity	Impact to Groundwater Quality	Magnitude of Hydrogeology Impact	Significance of Hydrogeology Impact
University of Galway (N) (Ch. 8+800 to Ch. 8+950	No Site lies upgradient	No	N/A	N/A
University of Galway (S) (Ch. 9+150 to Ch. 9+250	No	Site is downgradient of road but the road alignment is sealed	Negligible	Imperceptible
Turlough K20 (Menlough Northeast)	No Outside of drawdown zone of influence	No (upgradient of proposed road)	N/A	N/A
Turlough K31 (Menlough East)	No Outside of drawdown zone of influence	Site is downgradient of road but the road alignment is sealed	Negligible	Imperceptible
Turlough K72 (Coolagh North)	No Outside of drawdown zone of influence	No (upgradient of proposed road)	N/A	N/A
Petrifying Springs (Lackagh Quarry)	Rock bolts may intersect recharge pathways	No likely impact. Located above the groundwater table. Rock bolts will seal in the hole	Negligible	Imperceptible
Local habitats				
An Baile Nua (Ch. 0+150)	Removed by road alignment	Removed by road alignment	Large Adverse	Slight / Moderate
Na Forai Maola Thoir (Ch. 1+150)	Removed by road alignment	Removed by road alignment	Large Adverse	Slight / Moderate
Barna (Ch. 3+100 and Ch. 3+400)	Removed by road alignment	Removed by road alignment	Large Adverse	Slight / Moderate
Knocknabrona (Ch. 7+850 to Ch. 8+150)	Removed by road alignment	Removed by road alignment	Large Adverse	Slight / Moderate
Calcareous springs (Lackagh Quarry)	Rock bolts may intersect recharge pathways	No likely impact. Located above the groundwater table. Rock bolts will seal in the hole	Negligible	Imperceptible

Operation specific mitigation measures are presented in Section 10.6.3.

10.5.3.4 Potential Impacts to Groundwater Dependent Surface Water Features

Groundwater contributes to surface water at River Corrib, Ballindooley Lough, Coolagh Lakes, Turlough K20, Turlough K31, Turlough K72, Ballinfoyle Lough and Terryland River. It is noted that whilst the Eastern Coolagh Spring has the potential for groundwater contribution, Coolagh Lakes is not dependent on this spring. Coolagh Lakes is however dependent on the Western Coolagh Spring.

A zone of influence for drawdown has been calculated for both the Galway Granite Batholith and the Visean Undifferentiated Limestone. The design of the cutting carries any groundwater intercepted in cuttings and infiltrates back to ground within the same GWB. On this basis there is no net reduction to groundwater flow in each GWB. There are no operational groundwater impacts to surface water contribution.

10.5.3.5 Summary

The design of the Project is cognisant of the hydrogeological existing environment and specifically groundwater receptors. Below is a summary of the design measures incorporated in the operation phase:

- Passive operational dewatering of the bedrock aquifer will be required within cuttings in the Galway Granite Batholith. Any intercepted groundwater will remain within its natural receiving catchment
- The drainage design in the Galway Granite Batholith is not sealed. Discharge of treated runoff will be to surface water. There will be small (<10%) losses of runoff (treated and untreated) to ground and these have no impact on groundwater quality beyond the footprint of the Project
- Dewatering of the bedrock aquifer will not be undertaken in the catchment for Coolagh Lakes. This area of the Project includes Menlough Viaduct and Lackagh Tunnel (including its approaches)
- Passive operational dewatering of the bedrock aquifer will be required in cutting EW27 but will only be operational during the seasonal groundwater peak. Any intercepted groundwater will remain within the GWB by being carried down gradient and recharged back to ground in an infiltration basin
- The design of the Galway Racecourse Tunnel and its eastern approach includes waterproofing to seal from groundwater ingress. The western approach includes groundwater interception (during peak winter only) which will drain westwards down gradient to an infiltration basin
- The drainage design of the Project in the Undifferentiated Visean Limestone includes a sealed system and uses infiltration basins (operational phase) to discharge of treated runoff

Based on the design measures above each of the receptors have been assessed.

Table 10.26 below provides a summary of impact magnitude and impact significance for those hydrogeological receptors considered to have risk during the operation phase. Where the assessment phase has determined that the receptor has no impact (for example because it is outside of a drawdown zone of contribution or upgradient of contamination) and that the significance is not applicable, in that case then that receptor is not included in the summary table.

The assessment of ecological and surface water receptors refers only to the hydrogeology of each location (refer to Chapter 8, Biodiversity and Chapter 11, Hydrology).

Table 10.26 Summary of Impact Magnitude and Significance for Hydrogeological Aspects of Receptors at risk during the Operation Phase of the Project

Feature	Importance of Hydrogeology Attribute	Hydrogeology Impact Summary	Hydrogeology Impact Magnitude	Hydrogeology Impact Significance
Groundwater resources				
Galway Granite Batholith (Pl)	Low	Small loss of resource. Minor change to aquifer/unsaturated zone Low risk of pollution	Negligible impact to resource quantity Negligible risk to resource quality	Combined assessment is Imperceptible
Visean Undifferentiated Limestone (Rkc)	Very High	Small loss of resource. Minor change to aquifer/unsaturated zone Low risk of pollution	Negligible impact to resource quantity Negligible risk to resource quality	Combined assessment is Imperceptible

Feature	Importance of Hydrogeology Attribute	Hydrogeology Impact Summary	Hydrogeology Impact Magnitude	Hydrogeology Impact Significance
Groundwater Supplies (note where a receptor is deemed to have no impact then the hydrogeology significance is N/A and the receptor is not listed in summary)				
W50-10	Low	Well will be decommissioned during construction	Large adverse	Slight / moderate
W50-12	Medium	Well will be decommissioned during construction	Large adverse	Significant
W50-13 & W50-14	Very High	Well will be decommissioned during construction	Large adverse	Profound
W50-15	High	Well will be decommissioned during construction	Large adverse	Profound / significant
W50-17	Low	Well will be decommissioned during construction	Large adverse	Slight / moderate
W50-18	Low	Well will be decommissioned during construction	Large adverse	Slight / moderate
W50-19	Low	Well will be decommissioned during construction	Large adverse	Slight / moderate
W50-16	Low	Well will be decommissioned during construction	Large adverse	Slight / moderate
Ecological Receptors (note where a receptor is deemed to have no impact then the hydrogeology significance is N/A and the receptor is not listed in summary)				
Galway Bay Complex SAC	Very High	Net change to groundwater contribution from drainage design.	Negligible	Imperceptible
Inner Galway Bay SPA	Very High	Net change to groundwater contribution from drainage design.	Negligible	Imperceptible
Lough Corrib SAC	Very High	Net change to groundwater contribution from drainage design.	Negligible	Imperceptible
Lough Corrib pNHA	Very High	Net change to groundwater contribution from drainage design.	Negligible	Imperceptible
Galway Bay Complex pNHA	Very High	Net change to groundwater contribution from drainage design.	Negligible	Imperceptible
Na Foraí Maola Thoir (Annex I habitat) Ch. 1+250 to Ch. 1+500	Very High	Partially within drawdown zone. Outside of area liable to contamination	Large Adverse	Profound
Troscaigh Thiar (Annex I habitat)	Very High	Partially removed by road alignment and partially within drawdown zone.	Large Adverse	Profound

Feature	Importance of Hydrogeology Attribute	Hydrogeology Impact Summary	Hydrogeology Impact Magnitude	Hydrogeology Impact Significance
(Ch. 1+850 to Ch. 2+400)		Outside of area liable to contamination		
Aille (Annex I habitat) (Ch. 3+600 to Ch. 3+850)	Very High	Partially removed by road alignment and partially within drawdown zone. Outside of area liable to contamination	Large Adverse	Profound
Ballyburke (Annex I habitat) (Ch. 4+650 to Ch. 4+800)	Very High	Removed by road alignment	Large Adverse	Profound
Knocknabrona (Annex I habitat) (Ch. 7+700 to Ch. 7+750)	Very High	Removed by road alignment	Large Adverse	Profound
University of Galway (S) (Ch. 9+150 to Ch. 9+250	Very High	Site is downgradient of road but the road alignment is sealed	Negligible	Imperceptible
Turlough K31 (Menlough East)	Very High	Site is downgradient of road but the road alignment is sealed	Negligible	Imperceptible
Petrifying Springs (Annex I habitat) (Lackagh Quarry)	Very High	No likely impact. Located above the groundwater table. Rock bolts will seal in the hole	Negligible	Imperceptible
An Baile Nua (non-Annex I habitat) (Ch. 0+150)	Low	Removed by road alignment	Large Adverse	Slight / Moderate
Na Forai Maola Thoir (non-Annex I habitat) (Ch. 1+150)	Low	Removed by road alignment	Large Adverse	Slight / Moderate
Bearna (non-Annex I habitat) (Ch. 3+100 and Ch. 3+400)	Low	Removed by road alignment	Large Adverse	Slight / Moderate
Knocknabrona (non-Annex I habitat) (Ch. 7+850 to Ch. 8+150)	Low	Removed by road alignment	Large Adverse	Slight / Moderate
Calcareous springs (non-Annex I habitat) (Lackagh Quarry)	Low	No likely impact. Located above the groundwater table. Rock bolts will seal in the hole	Negligible	Imperceptible
Surface water				
(No operational impacts)				

10.6 Mitigation Measures

10.6.1 Introduction

This section describes the measures to mitigate the potential impacts for both the construction (Section 10.6.2) and operational phases (Section 10.6.3) of the Project.

In order to protect receptors identified in Section 10.3.5, both in terms of groundwater resources and water quality, mitigation measures will be put in place during the construction and operational phases of the Project.

Through the evolution of the design of the Project measures were included in the design to reduce or avoid specific impacts where possible. Following the evaluation of potential impacts as a result of the design, specific mitigation measures have been developed to avoid, prevent, reduce and, if possible, remedy any significant adverse impacts on hydrogeology. These are described below and include any additional mitigation measures agreed as part of the 2019 RFI Response and agreed during the 2020 oral hearing.

On conclusion of the 2020 Oral Hearing the following summary was provided in ABP's Inspectors' Report dated 22 June 2021 regarding the construction phase.

Section 11.9.70

Mr Dodds considers that the residual risks associated with water quality are adequately mitigated by the CEMP and its associated SEPCP and Karst Protocol, as discussed above.

Section 11.9.72

Noting that risks of groundwater pollution are associated with all developments, Mr Dodds concludes that the measures proposed to mitigate the risks within the context of the PRD are concomitant with the nature and scale of the development and the level of the identified risks. Assuming that the CEMP is implemented in full and to a high standard, Mr Dodds states that it is his professional opinion that residual risk is very low and insufficient to undermine the conservation objectives for the River Corrib and associated lakes (or any other GWDTE in the SAC or surrounding area), and that, in the unlikely event that impacts occurred, they would be short-lived and insignificant. I agree with Mr Dodds' assessment and conclusion and consider that the same conclusion can be drawn in respect of the residual water quality impacts on the wider hydrogeological environment. Finally, as I am satisfied that the water quality of the GWBs will not deteriorate due to the construction or operation of the PRD, I consider the PRD to be compliant with the requirements of the European Water Framework Directive.

On conclusion of the 2020 Oral Hearing the following summary was provided in ABP's Inspectors' Report dated 22 June 2021 about the operation phase.

Section 11.9.103

As such, Mr Dodds considers that the combination of the engineered wetlands with the infiltration basins and associated features, provides an appropriate level of protection to prevent contamination of groundwater from the road run-off.

Section 11.9.111

In conclusion, based on the conceptual model, the differences between the granite and limestone areas, and the design considerations of the PRD included to protect Natura 2000 sites, Mr Dodds' professional opinion is that the applicant has provided sufficient analysis to rule out any potential impacts derived from changes in groundwater quantity and quality on the integrity/conservation objectives of Natura 2000 sites, including the River Corrib, GWDTE and including consideration of any supporting aquatic habitats outside the Natura 2000 sites, such as Coolagh Lakes, beyond all reasonable scientific doubt. I agree with Mr Dodds conclusion on this matter in terms of hydrogeology, noting that these issues are also addressed in the Appropriate Assessment section of this report.

10.6.2 Construction Phase

The measures listed below will be implemented during the construction phase of the Project. The following measures were incorporated into the design (refer to Section 10.4) of the Project:

- No dewatering of the bedrock aquifer will occur during construction at Menlough Viaduct or Lackagh Tunnel (or its approaches). Furthermore, the construction sequence will take into account the seasonal groundwater fluctuation. During the winter groundwater high, it may be necessary to limit the depth of works so that dewatering of the bedrock aquifer is not required.
- Galway Granite Batholith EW01, 02 (three cuttings), 04, 07 and 09: Groundwater intercepted will be collected and piped to the surface water receptor it would naturally have drained to.
- Limestone: Construction dewatering of the bedrock aquifer may seasonally be required in EW27 during peak groundwater levels. Any dewatering will be discharged to the same GWB.
- Construction of the Galway Racecourse Tunnel and its approaches will require dewatering of the bedrock aquifer. All groundwater intercepted will be managed and discharged within the same GWB.
- EW27: Groundwater will be controlled within the excavation by collection in drains or sumps. If groundwater is intercepted, it will be piped and discharged at an infiltration basin within the same GWB. Intercepted groundwater is controlled and infiltrates back to the same groundwater body.
- Where infiltration basins are used for discharge of site runoff during construction the runoff will be managed on site, collected and treated as per the Sediment Erosion and Pollution Control Plan (Refer to Section 8 of the CEMP in Appendix A.7.5).
- Where the zone of influence of groundwater dewatering extends below existing buildings or lies within 50m of a building then a property condition survey will be undertaken at the property prior to and during the construction period in accordance with commitment C18.23 of Chapter 23 of updated EIAR.
- Commitment that all buildings within 50m of the proposed development boundary or the zone of influence of dewatering (whichever is greater) are offered a property condition survey (as per ABP's Inspectors Report Section 11.9.120 Dated 22 June 2021).

On conclusion of the 2020 Oral Hearing the following summary was provided in ABP's Inspectors' Report dated 22 June 2021. Section 11.9.120 states that:

While I agree with Mr Dodds and the applicant that the risk of drawdown related damage to properties is very low, and that the ZoI calculations are conservative, I note that the commitment to undertake property condition surveys relates to properties within 50m of the PRD boundary, increasing to 150m in areas where blasting works are proposed (Item 17.19 in the SoEC). I recommend that this commitment be broadened to ensure that all buildings within 50m of the proposed development boundary or the zone of influence of dewatering (whichever is greater) are offered a property condition survey.

The design of the Project includes dewatering of the bedrock aquifer in cuttings in the Galway Granite Batholith and in cuttings in the Visean Undifferentiated Limestone. The drawdown from these cuttings has been assessed. Drawdown impacts are limited in extent and do not impact on European sites or National Heritage Areas. No hydrogeological mitigation is proposed with regard to the design of construction dewatering.

For the Visean Undifferentiated Limestone due to the risk of karst features being intercepted in excavations for earthworks (including viaducts, bridges and tunnels) and infiltration basins, mitigation measures have been developed to preserve the hydraulic connectivity of the feature and then seal it from the excavation. The Karst Protocol mitigation measure will ensure that there is no impact on groundwater flow paths to water dependant receptors. The Karst mitigation plan is detailed in the Construction Environmental Management Plan (CEMP) (Appendix A.7.5) and is summarised below in Section 10.6.2.2.1Aquifer Specific Mitigation Measures.

Those infiltration basins in the Lough Corrib Fen 1 (Menlough) GWB (S19a and S19b) shall have additional measures incorporated into their construction to provide further protection to the groundwater body. Infiltration basin S19a and S19b include lining the sides of the excavation to ensure vertical groundwater infiltration so that all discharges drain through the placed subsoil for the full thickness of the unsaturated zone.

10.6.2.1 Standard Mitigation Measures

Mitigation of potential construction impacts will be achieved through the stringent implementation of good construction practice procedures and environmental controls to minimise the opportunity for contaminated releases of construction runoff as set out in the CEMP (Appendix A.7.5). Such practices will include adequate bunding for oil containers, wheel washers and dust suppression on site roads, and regular plant maintenance.

The following measures included in the CEMP will be implemented to control the potential for pollution from accidental spillages on site:

- Stockpiling of contaminated material is not permitted.
- Good housekeeping (daily site clean-ups, use of disposal bins, etc.) on the site during construction, and the proper use, storage and disposal of these substances and their containers will prevent groundwater contamination.
- For all activities involving the use of potential pollutants or hazardous materials, under the CEMP, the contractor will be required to ensure that material such as concrete, fuels, lubricants and hydraulic fluids will be carefully handled and stored to avoid spillages. Potential pollutants shall also be adequately secured against vandalism and will be provided with proper containment according to codes of practice. Any spillages will be immediately contained and contaminated soil removed from the site and properly disposed of.
- The contractor will finalise the Incident Response Plan in the CEMP in Appendix A.7.5 prior to work commencing and regularly update it for pollution emergencies which will be developed by the appointed contractor. The plan identified the actions to be taken in the event of a pollution incident. As recommended in the CIRIA document, the contingency plan for pollution emergencies includes the following:
    - Containment measures
    - Emergency discharge routes
    - List of appropriate equipment and clean-up materials
    - Maintenance schedule for equipment
    - Details of trained staff, location and provision for 24-hour cover
    - Details of staff responsibilities
    - Notification procedures to inform the Environmental Protection Agency (EPA) or environmental department of the Galway County Council
    - Audit and review schedule
    - Telephone numbers of statutory water consultees
    - List of specialist pollution clean-up companies and their telephone numbers
    - No direct untreated point discharge of construction runoff to groundwater will be permitted
    - Where a pollution incident is detected, construction works will be stopped until the source of the construction pollution has been identified and remedied
    - Pollution control facilities and procedures set out in the Sediment, Erosion and Pollution Control Construction Management Plan included in the CEMP will be implemented if required
    - The pollution control and treatment facilities will be installed and the monitoring network including instrumentation and procedures established prior to construction activities taking place on the ground

in the vicinity of watercourses and sensitive surface and groundwater receptors. It is envisaged that the pollution control facilities will be monitored daily to ensure their continued function

The above mitigation measures will ensure measures are in place to reduce accidental spills of fuels and oils and mobilisation of sediment as suspended solids. By undertaking the above measures, the risk of contaminants being mobilised offsite can be safely managed. In this regard, for all aquifers those areas downgradient of the Project that were identified as being at risk to groundwater quality impacts during the construction phase (pre-mitigation) are reduced. The spatial extent of the potential impact is reduced to the construction footprint.

10.6.2.2 Receptor specific mitigation measures

A number of mitigation measures have been developed specifically for groundwater dependent receptors. These are detailed below for aquifer, supply wells and habitats.

10.6.2.2.1 Aquifer Specific Mitigation Measures

Aquifer specific mitigation measures are implemented where karst or high permeability zones are encountered during the construction programme.

In the event of karst being encountered the Karst Protocol shall be implemented, which is documented in the CEMP (Appendix A.7.5). Application of the Karst Protocol are summarised below to detail where they will be implemented:

- Where karst features are encountered during construction works these will be assessed by a hydrogeologist and an engineering geologist. These features will require their extent across the Project to be delineated. In the case of excavations (road cuttings, tunnels, bridge pier excavations) then the karst feature shall be excavated and backfilled with course fill and sealed. This will prevent runoff draining into the feature and therefore protect against accidental spillage. On this basis, construction runoff will not discharge to a karst pathway and will receive natural attenuation and dilution in the aquifer

- With regard to karst features being intercepted in excavations for earthworks (including viaducts, bridges and tunnels) and infiltration basins. The Karst Protocol preserves the hydraulic connectivity of the feature using granular material to fill but then seals the karst from the excavation using a liner (geotextile and or concrete depending on the site specifics) that will prevent linkage between excavation and the karst

- Where dewatering of the bedrock aquifer is proposed, groundwater level monitoring will be installed before construction, during the construction phase and 12 months following construction to enable potential effects from dewatering to be identified. In the shallow cuts of the Project there will be minimal dewatering of the bedrock aquifer required; nonetheless, a monitoring programme will be in place. If the monitoring indicates there is a measurable impact beyond that stated in this updated EIAR, then work with the potential to increase drawdown will be made safe and cease until the hydrogeological assessment is revised based on the site conditions and mitigation employed if appropriate

- In order to reduce potential contamination impacts, stockpiling of contaminated material and leachate generation will be prohibited. In the situation that potential contaminated material is encountered it will be tested and disposed of in an appropriate manner and in line with current water management legislation. If it is not possible to immediately remove contaminated material, then it will be stored on, and covered by, polythene sheeting to prevent rainwater infiltrating through the material. The time frame between excavation and removal will be kept to an absolute minimum.

Although the Galway Granite Batholith is a Poorly productive aquifer it is anticipated that faulting and fracturing will occasionally be encountered that may provide a flow path of up to a maximum distance of 100m. The implementation of the CEMP considers pathways in the granite like those that occur in limestone. On this basis, by implementing the CEMP contingency plan for pollution emergencies all accidental contaminant spills will be prevented from entering pathways in the granite. This will limit the extent of any fuel spill to the immediate site and limit the potential for contaminants solely to the construction footprint.

10.6.2.2.2 Mitigation measures specific for supply wells

The mitigation measures listed below will be adopted during the construction phase of the Project:

- Nine wells listed in Table 10.21 lie below the footprint of the Project and these will be decommissioned during the construction of the Project. These will each be mitigated by providing a replacement well, connecting to mains supply where available or by financial compensation. Where wells must be abandoned as part of the Project they will be sealed and abandoned in general accordance with Well Drilling Guidelines produced by the Institute of Geologists of Ireland (IGI 2007)
- Replacement wells, storage tank, associated pumping equipment and pipework for Wells W50-13 and W50-14 will be commissioned and tested to ensure adequate yield rates in advance of wells W50-13 and W50-14 being decommissioned.
- Four wells (W50-02, W50-20, W500-01 and W1000-03) are listed in Table 10.19 and Table 10.21 have potential water quality impacts. The standard mitigation measures as part of the CEMP to reduce the risk of pollution reduce the risk to these wells so that the significance of impact is reduced to insignificant.
- Wells outside of the Assessment Boundary but within the drawdown zone of influence may be impacted by reduced groundwater levels during construction. All wells within 150m of the proposed development boundary (or 50m from the calculated drawdown ZoI if greater) will be monitored for water level monthly for 12 months before construction, during construction and for 12 months after construction. If the monitoring indicates that the Project has impacted on a supply or geothermal well then mitigation will be applied
- Standard mitigation measures and aquifer specific mitigation measures are employed for protection of groundwater. To ensure the protection of quality of groundwater potable supplies, all wells within 150m of the proposed development boundary will be monitored for water quality monthly.
- All wells will be monitored for standard drinking water quality parameters monthly for 12 months before construction, during construction and for 12 months after construction. If the monitoring indicates that the Project has impacted on a supply, then mitigation will be applied

10.6.2.2.3 Specific Mitigation measures for GWDTE

As presented in the conceptual model in Section 10.3.4 the Project traverses groundwater bodies that supply a number of GWDTE. Those GWDTE that have been flagged as being at risk are all in areas where the groundwater pathways are karstic. In this regard the Karst Protocol, as detailed above in Section 10.6.2.2.1, forms part of mitigation to prevent groundwater quality or quantity being impacted. Additional mitigation is also employed to ensure that European sites are not impacted.

Construction activities represent a potential source of impact on the water quality of the Coolagh Lakes, which form part of the Lough Corrib SAC, from uncontrolled construction site runoff and potential contamination of the groundwater from construction spillages. There will be no surface water discharges to the Coolagh lakes and all runoff will be treated before being discharged to ground at infiltration basins. Infiltration basins are designed to include settlement to remove sediment and have an appropriate thickness of subsoil below invert level.

Pouring of the concrete in excavations (River Corrib Bridge, Menlough Viaduct and Lackagh Tunnel) will only be undertaken when the excavation has been inspected by a qualified hydrogeologist. Inspection of the full depth and extent of each excavation will be undertaken to identify if any significant flow paths, such as the karst enhancement of the bedrock permeability, are present. If no significant flow paths are present, then the hydrogeologist will document accordingly and confirm that there is no risk to groundwater from concrete leakage. If significant pathways are present then impacts which may arise from flow along these pathways shall be designed by the hydrogeologist based on the karst mitigation plan, these may comprise of installing a high permeability zone to replace the groundwater pathways which would be removed by the foundations and/or sealing the linkage from excavation to protect the karst. The design of the mitigation measures shall be approved by a qualified hydrogeologist to confirm that there will be no negative impacts to groundwater.

The above measures will ensure that the risk of pollution of groundwater bodies is controlled.

10.6.3 Operational Phase

During the operational phase of the Project inspection and maintenance will occur to ensure that the infiltration basins continue to operate as intended for the design life of the Project. Several measures were incorporated into the design of the Project to minimise their impact. These have been included in Section 10.4 above and are repeated here for clarity.

In the drainage design, the infiltration basin design uses over excavation below the design invert to place subsoil of an appropriate thickness and material that meets TII Guidelines (TII HD45/15). All the infiltration basins are more than 15m from surface karst mapped during the karst survey (refer to Figure 10.1.002) and will have sealed drainage up to the point of infiltration. All infiltration basins are designed to include the following features:

- A containment area
- A hydrocarbon interceptor
- A wetland

There is also a containment area in each drainage network that can manually be activated to contain spillage on the carriageway.

Networks S19a, S19b and S41 are located on the Lough Corrib Fen 1 (Menlough) GWB, which supports groundwater dependant terrestrial ecosystems (GWDTE) at Coolagh lakes. Due to the sensitivity of the Lough Corrib Fen 1 (Menlough) GWB those drainage networks that drain the carriageway above the GWB, which include S19a and S19b, also have a liner installed to ensure that the treated run-off percolates through the full thickness of the subsoil. S41 is located on a side road with a lower risk of accidental spillage and as such does not include this mitigation measure.

Infiltration basins require regular inspection to confirm that no observable subsidence in the infiltration has occurred due to karst. There are no guidelines on the inspection frequency for infiltration basins, however, based on the mitigation measures implemented the risk of subsidence occurring is considered to be low and inspection is recommended on 5-year frequency.

If karst features and potential pathways are found to be present during inspection, then the Karst Protocol developed for the construction phase will be implemented to ensure that no preferential pathways have formed within the infiltration basin.

10.7 Residual Effects

The residual impacts are those that will occur after the proposed mitigation measures have taken effect and are shown below in Table 10.27 and Table 10.28 for construction and operation respectively. There are no residual hydrogeological impacts to European sites and no residual impacts associated with GWDTE on the Visean Undifferentiated Limestone.

Construction and operation residual impacts are present for five Annex I habitats and four non-Annex I habitats, which are located on the Galway Granite Batholith in the Spiddal GWB and Maam-Clonbur GWB.

The 2018 EIAR did include residual impacts for Annex I and non-Annex I habitats. However, the location and extents of the GWDTE have been updated since the 2018 EIAR due to updated habitat mapping based on a 2023 survey (refer to Chapter 8 Biodiversity). There has been no change in the hydrogeological conceptual model for any of the groundwater bodies in the hydrogeological study area. However, due to the change of location and extents of the GWDTE relative to the Project, some of the impacts have changed and these are presented in this updated EIAR. The five Annex I habitats and four non-Annex I habitats where residual impacts are identified are:

- Na Foraí Maola Thoir Annex I (Ch. 1+250 to Ch. 1+500)
- Troscaigh Thiar Annex I (Ch. 1+850 to Ch. 2+400)
- Aille Annex I (Ch. 3+600 to Ch. 3+850)
- Ballyburke Annex I (Ch. 4+650 to Ch. 4+800)
- Knocknabrona Annex I (Ch. 7+700 to Ch. 7+750)
- An Baile Nua non-Annex I (Ch. 0+150)

- Na Forai Maola Thoir non-Annex I (Ch. 1+150)
- Barna non-Annex I (Ch. 3+100 and Ch. 3+400)
- Knocknabrona non-Annex I (Ch. 7+850 to Ch. 8+150)

Impacts are related to the removal of the habitat at Ballyburke and Knocknabrona Annex I habitat, removal of all four non-Annex I habitat, change in extents of habitat at Na Foraí Maola Thoir, addition of partial removal of the habitat (Troscaigh Thiar and Aille Annex I habitat) and permanent groundwater drawdown impacts (Na Foraí Maola Thoir, Troscaigh Thiar and Aille Annex I habitat). In total 5 (No.) Annex I habitat are impacted and 4 (No.) non-Annex I habitat.

The lowering of groundwater levels below these sites has the potential to reduce available water quantity. Where groundwater lowering occurs from cuttings, such as this, it is not possible to mitigate. On this basis, there is potential for profound residual effect on these five Annex I habitat and slight moderate residual effect on these four non-Annex I habitat.

A total of nine groundwater supply wells will be decommissioned as part of the Project. These wells will be compensated by a replacement well, connecting to mains supply where available or by financial compensation.

Table 10.27 Summary of Hydrogeological Residual Impacts to Receptors during the Construction Phase

Constraint	Importance		Construction Phase					
Name	Ranking	Justification	Magnitude of Hydrogeology Impact	Criteria for Hydrogeology Impact Assessment	Significance of Hydrogeology Impact	Mitigation Measure	Residual Hydrogeology Impact Magnitude	Residual significance of Hydrogeology impact
Groundwater resources and supplies								
Poor Bedrock Aquifer	Low	Poor Bedrock Aquifer	Small adverse	A small proportion of the aquifer is being removed	Imperceptible	Standard construction mitigation CEMP	Negligible	Imperceptible
Regionally Important Aquifer	Very High	Regionally Important Aquifer	Moderate adverse	A small proportion of the aquifer is being removed	Profound / Significant	Standard construction mitigation CEMP	Negligible	Imperceptible
Knocknacarra GWS (W50-01)	Medium	Group water scheme supplying approximately 50 houses	No impact	N/A	N/A	N/A	N/A	N/A
W50-02	Low	Agricultural supply and / or Domestic supply	Moderate adverse	Downgradient of K328 in the deep aquifer	Slight	Standard construction mitigation CEMP	Negligible	Imperceptible
UW50-03 04, 05, 06 and 07	Low	Agricultural supply and / or Domestic supply	No impact	N/A	N/A	N/A	N/A	N/A
W50-08	Low	Agricultural supply and / or Domestic supply	No impact	N/A	N/A	N/A	N/A	N/A
W50-09	Low	Agricultural supply and / or Domestic supply	No impact	N/A	N/A	N/A	N/A	N/A

Constraint	Importance		Construction Phase					
Name	Ranking	Justification	Magnitude of Hydrogeology Impact	Criteria for Hydrogeology Impact Assessment	Significance of Hydrogeology Impact	Mitigation Measure	Residual Hydrogeology Impact Magnitude	Residual significance of Hydrogeology impact
W50-10	Low	Agricultural / Domestic supply	Large adverse	Will be decommissioned as part of works	Slight / Moderate	Replace / compensate	N/A	N/A
W50-11	Low	Agricultural supply and / or Domestic supply	No impact	N/A	N/A	N/A	N/A	N/A
W50-12	Medium	Commercial supply	Large adverse	Will be decommissioned as part of works	Significant	Replace / compensate	N/A	N/A
W50-13 & 14	Very High	Commercial supply	Large adverse	Will be decommissioned as part of works	Profound	Replace	N/A	N/A
W50-15	High	Commercial supply	Large adverse	Will be decommissioned as part of works	Profound/ Significant	Replace / compensate	N/A	N/A
W50-20	Medium	Commercial potable supply 50m3/day	Moderate adverse	Downgradient of K328 in the deep aquifer	Moderate	Standard construction mitigation CEMP	Negligible	Imperceptible
W50-17	Low	Agricultural / Domestic supply	Large adverse	Will be decommissioned as part of works	Slight/ Moderate	Replace / compensate	N/A	N/A
W50-18	Low	Agricultural / Domestic supply	Large adverse	Will be decommissioned as part of works	Slight / Moderate	Replace / compensate	N/A	N/A
W50-19	Low	Agricultural / Domestic supply	Large adverse	Will be decommissioned as part of works	Slight / Moderate	Replace / compensate	N/A	N/A
W50-16	Low	Historic domestic / agricultural supply spring	Large adverse	Will be decommissioned as part of works	Slight / Moderate	Replace / compensate	N/A	N/A

Constraint	Importance		Construction Phase					
Name	Ranking	Justification	Magnitude of Hydrogeology Impact	Criteria for Hydrogeology Impact Assessment	Significance of Hydrogeology Impact	Mitigation Measure	Residual Hydrogeology Impact Magnitude	Residual significance of Hydrogeology impact
W50-21	High	Commercial	No impact	N/A	N/A	N/A	N/A	N/A
W50-22	Medium	Commercial	No impact	N/A	N/A	N/A	N/A	N/A
W100-01 & 02	Low	Agricultural supply and / or Domestic supply	No impact	N/A	N/A	N/A	N/A	N/A
W100-03, 04, 05 and 06	Low	Agricultural supply and / or Domestic supply	No impact	N/A	N/A	N/A	N/A	N/A
W500-01	Low	Agricultural supply and / or Domestic supply	Moderate adverse	Downgradient of K328 in the deep aquifer	Slight	Standard construction mitigation CEMP	Negligible	Imperceptible
W1000-01	Low	Agricultural supply and / or Domestic supply	No impact	N/A	N/A	N/A	N/A	N/A
W1000-03	Low	Agricultural supply and / or Domestic supply	Moderate adverse	Downgradient of K328 in the deep aquifer	Slight	Standard construction mitigation CEMP	Negligible	Imperceptible
W1000-04	Low	Agricultural supply and / or Domestic supply	No impact	N/A	N/A	N/A	N/A	N/A
G50-01	Low	Closed loop geothermal well	No impact	N/A	N/A	Well will be monitored for water level as within 150m of Assessment Boundary	N/A	N/A

Constraint	Importance		Construction Phase					
Name	Ranking	Justification	Magnitude of Hydrogeology Impact	Criteria for Hydrogeology Impact Assessment	Significance of Hydrogeology Impact	Mitigation Measure	Residual Hydrogeology Impact Magnitude	Residual significance of Hydrogeology impact
Groundwater dependent habitats								
Galway Bay Complex SAC	Extremely High	European site	Negligible	GWB with risk of impact is very small contributor to receiving water	Imperceptible	CEMP inc. karst protocol, runoff management and pollution control	Negligible	Imperceptible
Inner Galway Bay SPA	Extremely High	European site	Negligible	GWB with risk of impact is very small contributor to receiving water	Imperceptible	CEMP inc. karst protocol, runoff management and pollution control	Negligible	Imperceptible
Lough Corrib SAC (Groundwater contribution to Coolagh Lakes)	Extremely High	European site	Large adverse	GWB with risk of impact is main contributor to receiving water at Coolagh Lakes	Profound	CEMP inc. karst protocol, runoff management and pollution control	Negligible	Imperceptible
Lough Corrib SAC (Groundwater contribution to River Corrib)	Extremely High	European site	Negligible	The groundwater contribution from GWB to River Corrib is of insufficient magnitude to affect integrity	Imperceptible	CEMP inc. karst protocol, runoff management and pollution control	Negligible	Imperceptible
Lough Corrib SAC (Groundwater contribution to Terryland River when K87 and K96 active)	Extremely High	European site	Small adverse	Potential temporary quality deterioration of groundwater in karst pathways within contributing GWB could lead to water quality impact at Terryland River (within catchment of karst feature K328)	Significant	CEMP inc. karst protocol, runoff management and pollution control	Negligible	Imperceptible
Lough Corrib SPA	Extremely High	European site	No impact	N/A	N/A	N/A	N/A	N/A

Constraint	Importance		Construction Phase					
Name	**Ranking**	**Justification**	**Magnitude of Hydrogeology Impact**	**Criteria for Hydrogeology Impact Assessment**	**Significance of Hydrogeology Impact**	**Mitigation Measure**	**Residual Hydrogeology Impact Magnitude**	**Residual significance of Hydrogeology impact**
Ballindooley Lough	Very High	Support to European site	No Impact	N/A	N/A	N/A	N/A	N/A
Moycullen Bogs	Very High	Site of national importance	No Impact	N/A	N/A	N/A	N/A	N/A
Lough Corrib pNHA (Groundwater contribution to Coolagh Lakes)	Very High	Site of national importance	Large adverse	GWB with risk of impact is main contributor to receiving water at Coolagh Lakes	Profound	CEMP inc. karst protocol, runoff management and pollution control	Negligible	Imperceptible
Lough Corrib pNHA (Groundwater contribution to River Corrib)	Very High	Site of national importance	Negligible	The groundwater contribution from GWB to River Corrib is of insufficient magnitude to affect integrity	Imperceptible	CEMP inc. karst protocol, runoff management and pollution control	Negligible	Imperceptible
Lough Corrib pNHA (Groundwater contribution to Terryland River when K87 and K96 active)	Very High	Site of national importance	Small adverse	Damage to groundwater dependant habitat due to deterioration of water quantity or quality from accidental spills from construction works at Galway Racecourse (within catchment of karst feature K328)	Significant / moderate	CEMP inc. karst protocol, runoff management and pollution control	Negligible	Imperceptible
Galway Bay Complex pNHA	Very High	Site of national importance	Negligible	GWB with risk of impact is very small contributor to receiving water	Imperceptible	CEMP inc. karst protocol, runoff management and pollution control	Negligible	Imperceptible

Constraint	Importance		Construction Phase					
Name	**Ranking**	**Justification**	**Magnitude of Hydrogeology Impact**	**Criteria for Hydrogeology Impact Assessment**	**Significance of Hydrogeology Impact**	**Mitigation Measure**	**Residual Hydrogeology Impact Magnitude**	**Residual significance of Hydrogeology impact**
Na Foraí Maola Thiar (Ch. 0+650 to Ch. 0+750)	Very High	Annex I Habitat	Large adverse	Within area liable to contamination	Profound	CEMP	Negligible	Imperceptible
Na Foraí Maola Thoir (Ch. 1+250 to Ch. 1+500)	Very High	Annex I Habitat	Large adverse	Partially within drawdown zone of influence and partially within area liable to contamination	Profound	CEMP	Large adverse	Profound
Troscaigh Thiar (Ch. 1+850 to Ch. 2+400)	Very High	Annex I Habitat	Large adverse	Partially removed by road alignment. Partially within drawdown zone and area liable to contamination	Profound	CEMP	Large adverse	Profound
Bearna (Ch. 2+600 to Ch. 3+100)	Very High	Annex I Habitat	No impact	Outside of drawdown zone of influence and outside of area liable to contamination.	N/A	CEMP	N/A	N/A
Aille (Ch. 3+600 to Ch. 3+850)	Very High	Annex I Habitat	Large adverse	Partially removed by road alignment. Partially within drawdown zone and area liable to contamination	Profound	CEMP	Large adverse	Profound
Ballyburke (Ch. 4+650 to Ch. 4+800)	Very High	Annex I Habitat	Large adverse	Removed by road alignment	Profound	CEMP	Large adverse	Profound
Knocknabrona (Ch. 7+700 to Ch. 7+750)	Very High	Annex I Habitat	Large adverse	Removed by road alignment	Profound	CEMP	Large adverse	Profound
University of Galway (N)	Very High	Annex I Habitat	No impact	Upgradient	N/A	N/A	N/A	N/A

Constraint	Importance		Construction Phase					
Name	Ranking	Justification	Magnitude of Hydrogeology Impact	Criteria for Hydrogeology Impact Assessment	Significance of Hydrogeology Impact	Mitigation Measure	Residual Hydrogeology Impact Magnitude	Residual significance of Hydrogeology impact
(Ch. 8+800 to Ch. 8+950								
University of Galway (S) (Ch. 9+150 to Ch. 9+250	Very High	Annex I Habitat	Moderate adverse	Downgradient of site	Profound / Significant	CEMP inc. karst protocol, runoff management and pollution control	Negligible	Imperceptible
Turlough K20 (Menlough North East)	Very High	Annex I Habitat	No impact	N/A	N/A	N/A	N/A	N/A
Turlough K31 (Menlough East)	Very High	Annex I Habitat	Large adverse	Downgradient of site	Profound	CEMP inc. karst protocol, runoff management and pollution control	Negligible	Imperceptible
Turlough K72 (Coolagh North)	Very High	Annex I Habitat	No impact	N/A	N/A	N/A	N/A	N/A
Petrifying Springs (Lackagh Quarry)	Very High	Annex I Habitat	Negligible	Located above groundwater table	Imperceptible	Rock bolting used but no concreting	Negligible	Imperceptible
An Baile Nua (Ch. 0+150)	Low	Site of local importance	Large adverse	Removed by road alignment	Profound	CEMP	Large adverse	Slight / Moderate
Na Forai Maola Thoir (Ch. 1+150)	Low	Site of local importance	Large adverse	Removed by road alignment	Profound	CEMP	Large adverse	Slight / Moderate
Bearna (Ch. 3+100 and Ch. 3+400)	Low	Site of local importance	Large adverse	Removed by road alignment	Profound	CEMP	Large adverse	Slight / Moderate
Knocknabrona (Ch. 7+850 to Ch. 8+150)	Low	Site of local importance	Large adverse	Removed by road alignment	Profound	CEMP	Large adverse	Slight / Moderate
Calcareous springs (Lackagh Quarry)	Low	Site of local importance	Negligible	Located above groundwater table	Imperceptible	Rock bolting used but no concreting	Negligible	Imperceptible

Table 10.28 Summary of Hydrogeological Residual Impacts to Receptors during the Operational Phase

Constraint	Importance		Operational Phase					
Name	Ranking	Justification	Magnitude of Hydrogeology Impact	Criteria for Hydrogeology Impact Assessment	Significance of Hydrogeology Impact	Mitigation Measure	Residual Hydrogeology Impact Magnitude	Residual significance of Hydrogeology impact
Groundwater resources and supplies								
Poor Bedrock Aquifer	Low	Poor Bedrock Aquifer	Negligible	A small proportion of the aquifer is being removed	Imperceptible	None	Negligible	Imperceptible
Regionally Important Aquifer	Very High	Regionally Important Aquifer	Negligible	A small proportion of the aquifer is being removed	Imperceptible	None	Negligible	Imperceptible
Knocknacarra GWS (W50-01)	Medium	Group water scheme supplying approximately 50 houses	No impact	NA	N/A	N/A	N/A	N/A
W50-02	Low	Agricultural supply and / or Domestic supply	No impact	NA	N/A	N/A	N/A	N/A
W50-03 04, 05, 06 and 07	Low	Agricultural supply and / or Domestic supply	No impact	NA	N/A	N/A	N/A	N/A
W50-08	Low	Agricultural supply and / or Domestic supply	No impact	NA	N/A	N/A	N/A	N/A

Constraint	Importance		Operational Phase					
Name	**Ranking**	**Justification**	**Magnitude of Hydrogeology Impact**	**Criteria for Hydrogeology Impact Assessment**	**Significance of Hydrogeology Impact**	**Mitigation Measure**	**Residual Hydrogeology Impact Magnitude**	**Residual significance of Hydrogeology impact**
W50-09	Low	Agricultural supply and / or Domestic supply	No impact	NA	N/A	N/A	N/A	N/A
W50-10	Low	Agricultural supply and / or Domestic supply	Large adverse	Will be decommissioned as part of works	Slight / Moderate	Replace / compensate	N/A	N/A
W50-11	Low	Agricultural supply and / or Domestic supply	No impact	NA	N/A	N/A	N/A	N/A
W50-12	Medium	Commercial supply	Large adverse	Will be decommissioned as part of development	Significant	Replace / compensate	N/A	N/A
W50-13 & 14	Very High	Commercial supply	Large adverse	Will be decommissioned as part of development	Profound	Replace	N/A	N/A
W50-15	High	Commercial supply	Large adverse	Will be decommissioned as part of development	Profound / Significant	Replace / compensate	N/A	N/A
W50-16	Low	Historic domestic / agricultural supply spring	Large adverse	Will be decommissioned as part of works	Slight/ Moderate	Replace / compensate	N/A	N/A

Constraint	Importance		Operational Phase					
Name	Ranking	Justification	Magnitude of Hydrogeology Impact	Criteria for Hydrogeology Impact Assessment	Significance of Hydrogeology Impact	Mitigation Measure	Residual Hydrogeology Impact Magnitude	Residual significance of Hydrogeology impact
W50-17	Low	Agricultural / Domestic supply	Large adverse	Will be decommissioned as part of works	Slight/ Moderate	Replace / compensate	N/A	N/A
W50-18	Low	Agricultural / Domestic supply	Large adverse	Will be decommissioned as part of works	Slight/ Moderate	Replace / compensate	N/A	N/A
W50-19	Low	Agricultural / Domestic supply	Large adverse	Will be decommissioned as part of works	Slight/ Moderate	Replace / compensate	N/A	N/A
W50-20	Medium	Commercial potable supply $50m^3$/day	No impact	NA	N/A	N/A	N/A	N/A
W50-21	High	Commercial: quarry $400m^3$/day	No impact	N/A	N/A	N/A	N/A	N/A
W50-22	Medium	Commercial: golf course irrigation $250m^3$/day	No impact	N/A	N/A	N/A	N/A	N/A
W100-01 & 02	Low	Agricultural supply and / or Domestic supply	No impact	N/A	N/A	N/A	N/A	N/A
W100-03, 04, 05 and 06	Low	Agricultural supply and / or Domestic supply	No impact	N/A	N/A	N/A	N/A	N/A
W500-01	Low	Agricultural supply and / or	No impact	NA	N/A	N/A	N/A	N/A

Constraint	Importance		Operational Phase					
Name	**Ranking**	**Justification**	**Magnitude of Hydrogeology Impact**	**Criteria for Hydrogeology Impact Assessment**	**Significance of Hydrogeology Impact**	**Mitigation Measure**	**Residual Hydrogeology Impact Magnitude**	**Residual significance of Hydrogeology impact**
		Domestic supply						
W1000-01	Low	Agricultural supply and / or Domestic supply	No impact	NA	N/A	N/A	N/A	N/A
W1000-03	Low	Agricultural supply and / or Domestic supply	No impact	N/A	N/A	N/A	N/A	N/A
W1000-04	Low	Agricultural supply and / or Domestic supply	No impact	N/A	N/A	N/A	N/A	N/A
G50-01	Low	Closed loop geothermal well	No impact	N/A	N/A	Well will be monitored for water level as within 150m of fence line	N/A	N/A
Groundwater dependent habitats								
Galway Bay Complex SAC	Extremely High	European site	Negligible	Meets HD45/15	Imperceptible	CEMP inc. karst protocol, runoff management and pollution control	Negligible	Imperceptible
Inner Galway Bay SPA	Extremely High	European site	Negligible	Meets HD45/15	Imperceptible	CEMP inc. karst protocol, runoff management	Negligible	Imperceptible

Constraint	Importance		Operational Phase					
Name	Ranking	Justification	Magnitude of Hydrogeology Impact	Criteria for Hydrogeology Impact Assessment	Significance of Hydrogeology Impact	Mitigation Measure	Residual Hydrogeology Impact Magnitude	Residual significance of Hydrogeology impact
						and pollution control		
Lough Corrib SAC	Extremely High	European site	Negligible	Meets HD45/15	Imperceptible	CEMP inc. karst protocol, runoff management and pollution control	Negligible	Imperceptible
Lough Corrib SPA	Extremely High	European site	No impact	N/A	N/A	N/A	N/A	N/A
Ballindooley Lough	Very High	Support to European site	No impact	N/A	N/A	N/A	N/A	N/A
Moycullen Bogs	Very High	Site of national importance	No impact	N/A	N/A	N/A	N/A	N/A
Lough Corrib pNHA	Very High	Site of national importance	Negligible	Meets HD45/15 Road runoff is treated prior to infiltration	Imperceptible	CEMP inc. karst protocol, runoff management and pollution control	Negligible	Imperceptible
Galway Bay Complex pNHA	Very High	Site of national importance	Negligible	Meets HD45/15 Road runoff is treated prior to infiltration	Imperceptible	CEMP inc. karst protocol, runoff management and pollution control	Negligible	Imperceptible
Na Foraí Maola Thiar (Ch. 0+650 to Ch. 0+750)	Very High	Annex I Habitat	Negligible	Outside of drawdown zone of influence and outside of area	Imperceptible	CEMP	Negligible	Imperceptible

Constraint	Importance		Operational Phase					
Name	Ranking	Justification	Magnitude of Hydrogeology Impact	Criteria for Hydrogeology Impact Assessment	Significance of Hydrogeology Impact	Mitigation Measure	Residual Hydrogeology Impact Magnitude	Residual significance of Hydrogeology impact
				liable to contamination.				
Na Foraí Maola Thoir (Ch. 1+250 to Ch. 1+500)	Very High	Annex I Habitat	Large adverse	Partially within drawdown zone of influence	Profound	CEMP	Large adverse	Profound
Troscaigh Thiar (Ch. 1+850 to Ch. 2+400)	Very High	Annex I Habitat	Large adverse	Partially removed by road alignment. Partially within drawdown zone of influence	Profound	CEMP	Large adverse	Profound
Bearna (Ch. 2+600 to Ch. 3+100)	Very High	Annex I Habitat	No impact	Outside of drawdown zone of influence and outside of area liable to contamination.	N/A	CEMP	N/A	N/A
Aille (Ch. 3+600 to Ch. 3+850)	Very High	Annex I Habitat	Large adverse	Partially removed by road alignment. Partially within drawdown zone of influence	Profound	CEMP	Large adverse	Profound
Ballyburke (Ch. 4+650 to Ch. 4+800)	Very High	Annex I Habitat	Large adverse	Removed by road alignment	Profound	CEMP	Large adverse	Profound

Constraint	Importance		Operational Phase					
Name	**Ranking**	**Justification**	**Magnitude of Hydrogeology Impact**	**Criteria for Hydrogeology Impact Assessment**	**Significance of Hydrogeology Impact**	**Mitigation Measure**	**Residual Hydrogeology Impact Magnitude**	**Residual significance of Hydrogeology impact**
Knocknabrona (Ch. 7+700 to Ch. 7+750)	Very High	Annex I Habitat	Large adverse	Removed by road alignment	Profound	CEMP	Large adverse	Profound
University of Galway (N) (Ch. 8+800 to Ch. 8+950	Very High	Annex I Habitat	No impact	Upgradient	N/A	N/A	N/A	N/A
University of Galway (S) (Ch. 9+150 to Ch. 9+250	Very High	Annex I Habitat	Negligible	Downgradient	Imperceptible	CEMP inc. karst protocol, runoff management and pollution control	Negligible	Imperceptible
Na Foraí Maola Thiar (Ch. 0+650 to Ch. 0+750)	Very High	Annex I Habitat	Large adverse	Within area liable to contamination	Profound	CEMP	Negligible	Imperceptible
Turlough K20 (Menlough North East)	Very High	Annex I Habitat	No impact	Upgradient	N/A	N/A	N/A	N/A
Turlough K31 (Menlough East)	Very High	Annex I Habitat	Negligible	Downgradient	Imperceptible	N/A	Negligible	Imperceptible
Turlough K72 (Coolagh North)	Very High	Annex I Habitat	No impact	Upgradient	N/A	N/A	N/A	N/A
Petrifying Springs (Lackagh Quarry)	Very High	Annex I Habitat	No impact	Located above groundwater table	N/A	N/A	N/A	N/A

Constraint	Importance		Operational Phase					
Name	Ranking	Justification	Magnitude of Hydrogeology Impact	Criteria for Hydrogeology Impact Assessment	Significance of Hydrogeology Impact	Mitigation Measure	Residual Hydrogeology Impact Magnitude	Residual significance of Hydrogeology impact
An Baile Nua (Ch. 0+150)	Low	Site of local importance	Large adverse	Removed by road alignment	Profound	CEMP	Large adverse	Slight / Moderate
Na Forai Maola Thoir (Ch. 1+150)	Low	Site of local importance	Large adverse	Removed by road alignment	Profound	CEMP	Large adverse	Slight / Moderate
Barna (Ch. 3+100 and Ch. 3+400)	Low	Site of local importance	Large adverse	Removed by road alignment	Profound	CEMP	Large adverse	Slight / Moderate
Knocknabrona (Ch. 7+850 to Ch. 8+150)	Low	Site of local importance	Large adverse	Removed by road alignment	Profound	CEMP	Large adverse	Slight / Moderate
Calcareous springs (Lackagh Quarry)	Low	Site of local importance	No impact	Located above groundwater table	N/A	N/A	N/A	N/A

10.8 Cumulative Impacts

This section of the chapter presents the assessment carried out to examine whether the Project along with any other projects or plans could cumulatively result in likely significant effects.

The identification of planned and committed projects for the assessment of cumulative impacts has considered Galway City and County planning registers, with projects identified according to the methodology laid out in Chapter 21 of this updated EIAR. Thereafter, planned and committed projects have been scoped for assessment in this chapter based on relative proximity and potential hydrogeological impacts due to the proposed developments.

The identification of projects for the long list considered the following sources:

- An Bord Pleanála (ABP) website (http://www.pleanala.ie/index.htm) – for details of Strategic Infrastructure Developments (SIDs), Strategic Housing Developments (SHDs) and permissions made on appeal
- Local authorities (Galway City Council and Galway County Council) for up-to-date planning applications and local development plan designations

The types of projects considered:

- Local Planning Applications – those projects for which planning permission is applied for through the local planning authorities themselves and were identified from local authority planning application lists
- Strategic Housing Developments (SHDs) – housing developments of a certain type and scale (e.g., 100 or more houses or student accommodation units) where applications were lodged directly with An Bord Pleanála
- Large Scale Residential Developments (LRDs) – housing developments of a certain type and scale (e.g., 100 or more houses or student accommodation units comprising 200 bed spaces or more) for which planning permission is applied for through the local planning authorities
- Strategic Infrastructure Development (SIDs) – major infrastructure developments by local authorities and others for which applications are lodged directly with An Bord Pleanála

A five-year timeframe was deemed the most appropriate period for planning searches, as permissions granted more than five years ago would generally be constructed, partially constructed, or are under construction when the planning registers were viewed.

From a hydrogeology perspective, third-party projects have the potential to generate cumulative residual impacts in terms of deterioration of groundwater quality or changes to groundwater quantity. The residual impacts from the Project relate to areas where drawdown occurs in cuttings along the alignment or where groundwater quality could reduce due to accidental spills. All residual water quality impacts remain within the construction or operation footprint of the Project. However, some drawdown effects may extend outside of the construction and operation footprint.

This assessment is undertaken to assess any cumulative effects (at both construction and operation) from a hydrogeology perspective. Based on the assessment presented in Appendix A.10.9, there is one proposed development where there may be hydrogeological interaction. The proposed development is planning reference 2460270, which is a housing development that is located adjacent to a road cutting of the proposed N6 GCRR. This proposed development was refused permission by Galway City Council on 25 February 2025, but the assessment is retained in the appendix as this decision has subsequently been appealed to ABP.

The cutting on the proposed N6 GCRR is constructed through the local granite bedrock and there is likely to be a permanent lowering of groundwater level, which is conservatively calculated to extend onto the third-party land. As per the monitoring commitments of the Project, all buildings that lie within 50m of the Assessment Boundary or within 50m of the calculated drawdown extent (whichever is the greater) will be offered a building condition survey. The housing development has minimal earthworks or excavations, and potential dewatering is limited to trenching for service supplies. Therefore, this housing development will not add to the impacts already arising from the Project.

There are no cumulative construction or operational impacts identified from third-party proposed developments that are likely to further increase the adverse or negative impacts associated with the Project. The likely significant direct or indirect cumulative impacts in combination with the other proposed developments are in relation to the residual profound impacts on the water dependent habitats associated with the Project.

The projects considered in the cumulative assessment and the justification for their cumulative impact is provided in Appendix A.10.9.

10.9 Summary

The 2018 EIAR has been updated to incorporate all relevant hydrogeological information available since its publication including all information and data identified in the 2019 RFI Response and including all information and data that was submitted to the oral hearing held in 2020. Furthermore, this updated EIAR includes the updated hydrogeological assessment of the Project as well as all public hydrogeological datasets current at the time of publishing.

ABP's Inspectors' Report dated 22 June 2021provides the following conclusion in regard to hydrogeology:

Section 11.9.123

I am satisfied that potential impacts would be avoided, managed and mitigated by the measures which form part of the proposed scheme, the proposed mitigation measures and through suitable conditions. With regard to the profound residual impacts on certain areas of Annex I habitat outside of the SAC, as identified by the applicant, I consider that these impacts are associated with the loss of habitat where it is traversed by the PRD rather than due to the hydrogeological impacts of drawdown, noting the overestimation by the applicant of the drawdown zone of influence in the granite area.

Section 11.9.124

I am therefore satisfied that the proposed development would not have any unacceptable direct, indirect or cumulative impacts on hydrogeology.

The physical baseline environment has not changed since the 2018 EIAR, nor has the assessment process. Due to the time that has passed since the 2018 EIAR, 2019 RFI and 2020 oral hearing there have been updates to some datasets and information. The following outlines new information and data that has become available during the time.

Available public datasets have been reviewed and additional rounds of groundwater monitoring have been undertaken to assess if there are any changes since 2018 to the baseline conditions or hydrogeological features of importance. The desktop study included a review of publicly available data from statutory bodies as well as aerial photographs and recent surveys undertaken by Arup within the hydrogeology study area.

The EPA[5], Geological Survey of Ireland (GSI)[6] and Office of Public Works (OPW)[7] are statutory bodies that update publicly available hydrogeological datasets in Ireland. This data is used to develop the conceptual understanding of the baseline hydrogeological conditions.

- EPA data includes groundwater quality and quantity data (including for groundwater supplies), which are used to determine Water Framework Directive (WFD) status for each groundwater body. This data is continuously updated as timeseries data becomes available. The EPA define the status of groundwater bodies for each six-year cycle of the WFD.
- The GSI datasets include maps of wells and springs, karst features, groundwater vulnerability, aquifers, groundwater flooding and geology. The data was most recently updated by the GSI in 2023.

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[5] EPA (2024) Data Viewer, available: EPA Maps

[6] GSI (2023) Groundwater Data Viewer, available: Geological Survey Ireland Spatial Resources (arcgis.com)

[7] OPW (2023) Data Viewer, available: maps.opw.ie

- OPW data include water level and water quality data for watercourses. This data is continuously updated as timeseries data becomes available.

The updated EPA, GSI and OPW data have been reviewed and the baseline updated where necessary to inform this updated EIAR.

The findings from the ground investigations undertaken at Galway Racecourse in 2024 has also been incorporated into the updated baseline. This ground investigation included geophysical surveys, groundwater well drilling, groundwater level measurements and karst feature surveys. These assessments have confirmed the following:

- One additional karst feature in the project karst database, a swallow hole 65m north of Ballybrit Castle within the Galway Racecourse grounds. This addition has been included in the Project karst database and has been included in the hydrogeology assessment presented in this updated EIAR.
- The geophysical survey identified deep infilled karst palaeo-channels extending east-west across the western area of the racecourse and an infilled depression at the centre of the racecourse. This was confirmed with drilling within these palaeo-channels.
- The trial well drilling (TW101) identified a karst cavern (5m in height) located at a depth of 220mbgl.
- Monitoring of the deep trial wells (TW101 and TW103) confirmed the presence of a deep water table (45mbgl) and monitoring of the shallower boreholes (BH01, BH02 and BH03) confirmed a shallow perched water table at the subsoil/bedrock interface.

Taking the above updates to the baseline assessment then the conceptual model of the 2018 EIAR remains valid. The additional data has been included to extend timeseries datasets and support the conceptualisation.

During the 2019 RFI and the 2020 Oral Hearing an additional five groundwater supply wells (W50-16, W50-17, W50-18, W50-19 and W50-20) were identified. Since the 2019 RFI and 2020 Oral Hearing the following additional groundwater features have been identified:

- Two new groundwater wells W50-21 and W50-22
- One new karst feature K328

Furthermore, GWDTE datasets have been updated by the project ecologists and reviewed and assessed in terms of potential hydrogeological effects. Whilst there have been no significant changes to European or NHA boundaries, the mapping of Annex I habitat and non-Annex I habitat that are outside of designated sites have been updated. The updated mapping of Annex I habitat and non-Annex I habitat has been included into the hydrogeological assessment and this has led to revision of these impacts.

An assessment of all of these updated hydrogeology data has been included in this updated EIAR. In addition to updated datasets, assessments have been undertaken by statutory bodies (WFD and groundwater flooding) and these have also been reviewed and incorporated. The assessments by statutory bodies include:

- 2016-2021 Water Framework Directive (WFD) Cycle 2
- GSI groundwater flooding map assessments 2022 revisions

A summary of the hydrogeological assessment undertaken for the Project is presented below.

10.9.1 Hydrogeological Summary

The hydrogeology study area is divided into two main areas on the basis of the contrasting aquifer properties for the two main geological rock types in the region; the Galway Granite Batholith in the west and the Visean Undifferentiated Limestone in the east.

The western section is underlain by granite, which is a poor aquifer that is only productive in local zones. The combination of poor aquifer and blanket bog cover, where rock is not exposed, limits the quantity of recharge that can infiltrate to ground. The groundwater table remains close to the surface and generally follows topography. The area is divided into two groundwater bodies; the Spiddal GWB, which drains to Galway Bay and the Maam-Clonbur GWB which drains to the River Corrib. Groundwater flow in the

Galway Granite Batholith is isolated to weathered zones and fracture zones and pathways generally tend to be up to 100m. Based on hydrogeological observations during the ground investigation and field studies a maximum flow path of 100m is considered representative for the Galway Granite Batholith and is taken into account as part of the assessment of potential impacts.

In the eastern section the Visean Undifferentiated Limestone is a regionally important karstified aquifer, which is dominated by conduit flow. The aquifer can supply regionally important abstractions and is associated with the presence of karst landforms and features but also the relatively low abundance of surface water features and man-made drainage. The Visean Undifferentiated Limestone is subdivided into distinct groundwater bodies that are separated by boundaries or by watershed divides. Features within the groundwater bodies, including Coolagh Lakes, Ballindooley Lough and the Terryland River are located on valley fill which form boundaries between GWB and often cause the surface water features to become perched during low groundwater levels.

Groundwater receptors have been identified in both granite and limestone parts of the Project and include groundwater resources, groundwater abstractions, groundwater dependent habitat and groundwater dependent surface water features.

The potential impacts of the Project on the hydrogeological receptors including groundwater resources, groundwater supplies, groundwater dependant terrestrial ecosystems and groundwater contributions to surface water have been assessed and are summarised below.

10.9.1.1 Groundwater Resources and Supplies

Where road cuttings are proposed then part of the aquifer will be removed, however, this amounts to a very small part of the aquifers and will have no perceptible impact on groundwater quantity. The water quality of the aquifers will not deteriorate due to the Project and as such the Project meets the requirements of the European Water Framework directive. The assessment highlights that nine wells will be removed by the Project. These wells will be decommissioned based on IGI guidelines.

All wells within 150m of the Assessment Boundary (or within 150m of the drawdown zone of influence, whichever is the greater) will be monitored for 12 months before construction, during the duration of construction and for 12 months following completion.

10.9.1.2 Groundwater Dependant Terrestrial Ecosystems

Potential impacts from the Project have been assessed for the hydrogeological setting of ecological habitats within the hydrogeology study area. The assessment has identified that habitats are dependant on both the granite and limestone aquifers. The hydrogeological assessment has undertaken study of the groundwater regimes that support these habitats, and this understanding has been accommodated into the design of the Project. Where potential impacts have been identified, then mitigation has been incorporated.

As the habitat associated with the Visean Undifferentiated Limestone aquifer is associated with karst pathways in the aquifer, karst protocol has been developed between geotechnical and hydrogeological specialists to remove the risk of impact on the type of groundwater flows that occur in karst terrains and aquifers.

There are no significant negative residual hydrogeological impacts to European or NHA sites due to the Project. Residual impacts are present to Annex I and non-Annex I habitat that lie outside of designated sites. These impacts occur due to a combination of habitat being removed/partially removed by the alignment or from permanent drawdown occurring below these habitats. In total five Annex I and four non-Annex I habitat that are impacted are all located in the Galway Granite Batholith. The extent and number of Annex I and non-Annex I habitat impacted by the proposed N6 GCRR has changed since the 2018 EIAR. However, these changes are entirely due to changes in the mapped extents of these habitat, where extents have changed or in part been downgraded from Annex I to non-Annex I.

The proposed road alignment will remove all of the Annex I habitat at:

- Ballyburke (Ch. 4+650 to Ch. 4+800)
- Knocknabrona (Ch. 7+700 to Ch. 7+750)

The proposed road alignment will remove part of the following Annex I habitats at:

- Troscaigh Thiar (Ch. 1+850 to Ch. 2+400)
- Aille (Ch. 3+600 to Ch. 3+850)

Drawdown impacts have the potential to partially lower the groundwater table at:

- Na Foraí Maola Thoir (Ch. 1+250 to Ch. 1+500)
- Troscaigh Thiar (Ch. 1+850 to Ch. 2+400)
- Aille (Ch. 3+600 to Ch. 3+850)

The proposed road alignment will remove all four non-Annex I habitat as part of the proposed road. The four non-Annex I habitat are An Baile Nua (Ch. 0+150), Na Forai Maola Thoir (Ch. 1+150), Barna (Ch. 3+100 and Ch. 3+400), Knocknabrona (Ch. 7+850 to Ch. 8+150).

10.9.1.3 Groundwater Contributions to Surface Water

Groundwater contributions to surface water have been assessed as part of this study, which has included identification of the surface water to which groundwater bodies contribute. The study has identified that there will be no significant negative impact in the groundwater contribution to surface water.

10.9.2 Conclusions

The hydrogeology assessment has been updated to include seven additional groundwater wells and one additional karst feature, which have been identified since the 2018 EIAR. Furthermore, updated EPA groundwater body WFD assessments and GSI groundwater flooding assessments have been reviewed and included. These updates incorporate all available new information identified since the 2018 EIAR, including all information and data identified in the 2019 RFI Response and including all information and data that was submitted to the oral hearing held in 2020.

There is no change to the 2018 EIAR conclusion that the design of the project with mitigation measures employed prevents impact to European and NHA designated sites beyond scientific doubt. Furthermore, the profound residual impacts for Annex I habitat outside of designated sites remain associated with the loss of habitat due to removal by the Project with local hydrogeological impacts where drawdown from cuttings extends laterally from permanent drainage. There has been modification of mitigation measures to widen the area where building condition surveys are offered to landowners, so that this now extends 50m from the Assessment Boundary or 50m from the calculated drawdown extent (whichever is the greater). Except for the building condition survey commitment, there are no changes to the mitigation strategy and the residual hydrogeological impacts for the Project comprise of groundwater lowering below five Annex I habitat and four non-Annex I habitat and the decommissioning of nine groundwater supply wells.

The cumulative impact assessment has been updated to take account of any new planned or committed projects within the hydrogeology study area the conclusion of the cumulative impact assessment is also unchanged in that it is considered that there is limited potential for any significant cumulative impacts with other planned and / or committed projects and that these will not further increase the adverse or negative impacts associated with the Project. The likely significant direct or indirect cumulative impacts in combination with the other proposed developments are in relation to the residual profound impacts on the water dependent habitats associated with the Project. As concluded in the 2018 EIAR and 2020 oral hearing, it is considered that the hydrogeological investigations and hydrogeological conceptual model present a comprehensive conceptual model of groundwater within the Hydrogeological study area of the Project. It has been shown beyond reasonable scientific doubt that there will be no impacts to Natura designated sites.

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