

Appendix A.4.15.1

Preliminary Sources Study Report (PSSR)

Leitrim County Council

**N4 Carrick-on-Shannon to
Dromod Project**

Preliminary Sources Study Report

274219-ARUP-02-OS-RP-CG-000001

P02 | 11 March 2022

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 274219

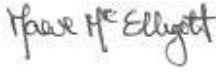
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Contents

	Page
1 Executive Summary	1
2 Introduction	3
2.1 Scope and Objective	3
2.2 Description of The Project	3
3 List of Figures and Drawings	5
4 Sources of Information	9
4.1 Topographical and Geographic Maps and Datasets	9
4.2 Publications	9
4.3 Solid Geology	10
4.4 Drift Maps	10
4.5 Geological Survey Ireland Datasets	10
4.6 Other Datasets	12
4.7 Historic Ground Investigation Reports	13
5 Field and Laboratory Studies	14
5.1 Previous Ground Investigations	14
5.2 Previous Assessments and Site Surveys	16
5.3 Arup Soils and Geology Field Studies	16
5.4 Arup Hydrogeological Field Studies	19
6 Review of Existing Site Information	26
6.1 Site Description	26
6.2 Topography and Geomorphology	26
6.3 Soil Deposits	28
6.4 Subsoil Deposits	30
6.5 Bedrock and Structural Geology	31
6.6 Karst Features	35
6.7 Landslide Susceptibility	35
6.8 Soft Ground and Compressible Soils	36
6.9 Current Land Use	36
6.10 Historical Land Use	37
6.11 Contaminated Sites and Unsuitable Material	40
6.12 Economic Geology	44
6.13 Geological Heritage	47
6.14 Hydrology	47
6.15 Hydrogeology	49
7 Ground Conditions Summary	55

7.1	Groundwater	55
7.2	Overburden	55
7.3	Bedrock	58
8	Preliminary Engineering Assessment	59
8.1	Earthworks	60
8.2	Classification and Acceptability for Re-use	61
8.3	Cuttings	62
8.4	Embankments	62
8.5	Natural Subgrade	64
8.6	Structures	64
8.7	Contaminated Land	67
9	Comparison of Project Options and Risks	68
10	Geotechnical Category of the Project	68
11	Phase 2 Ground Investigation	69
11.1	Objectives of the Ground Investigation	69
11.2	Phase 2 Ground Investigation	70
11.3	Site & Working Restrictions	74
11.4	Specialist Consultation	75
11.5	Programme, Cost and Contract Arrangements	75
11.6	Reporting	75

Appendices

Appendix A

Arup 2020 Soils and Geology Site Survey Plan and Photos

1 Executive Summary

Arup has been appointed to provide multi-disciplinary technical consultancy services for the delivery of Phase 1 – 4 of the TII Project Management Guidelines for the N4 Carrick-on-Shannon to Dromod Project (hereafter referred to as the Project).

The N4 national primary road, Dublin to Sligo, is a strategic corridor from Dublin to the northwest and border counties and is approximately 198km in length. It is recognised as being of particular importance in enhancing accessibility to some of the most peripheral areas northwest (including counties Leitrim, Roscommon, Sligo, and Donegal) and west of the River Shannon.

The section of the N4 under consideration falls within two local authority administrative areas with the River Shannon acting as the boundary. The area to the west of the River Shannon lies within County Roscommon and to the east of the River Shannon within County Leitrim. The town of Carrick-on-Shannon lies on the eastern side of the River Shannon while the town of Cortober lies on the western side of the river.

The section of the N4 under consideration passes through both rural and urban environments. It is approximately 21km long and extends from Drumharlow townland north of Carrick-on-Shannon to Faulties townland south of Aghamore.

This report presents a review of the findings of the Desk Study and documents the geotechnical and other investigations to assist in the option selection process.

The overall aim is to establish the history of the study area and the baseline ground conditions to understand the geotechnical risks and engineering considerations for each of the alternatives and options under consideration.

The report has been prepared using the following structure:

- i. The Introduction of the report details the limits of the study area, the scope and objective, the description of the Project and the geotechnical category of the Project.
- ii. The Sources of Information includes sources that were reviewed in order to gather relevant information for geotechnical, historical, and other general purposes to develop the desk study.
- iii. The Field and Laboratory Studies describes the field activities undertaken for this report, including previous ground investigations, walkovers and karst feature surveys.
- iv. The Existing Site Information includes a review of the topography, geomorphology, geology, man-made features, hydrology, hydrogeology within the study area. Possible contamination issues and geo-environmental considerations are also presented based on the historical development of the study area.

- v. The Ground Conditions Summary provides a description of the soils anticipated and other features of note within the study area based on the previous ground investigations and existing site information.
- vi. The Preliminary Engineering Assessment details any design implications associated with each of the Stage 1 Option Corridors.
- vii. The Comparison of Project Options is provided in the Stage 1 assessment in the Options Selection Report.

2 Introduction

2.1 Scope and Objective

The scope and objective of this Preliminary Sources Study Report (PSSR) is to examine the geological, geotechnical, geomorphological, hydrogeological and geo-environmental aspects of the N4 Carrick-on-Shannon to Dromod Project in accordance with the TII standard '*Managing Geotechnical Risk*' DN-ERW-03083 October 2019¹. This report also intends to research the historical development of the study area and identify geohazards that present a potential project risk.

This PSSR follows on from the Statement of Intent (274219-ARUP-02-OS-RP-YE-000008) which determined the Project Geotechnical Classification, established the Geotechnical Risk Management requirements and set out the roadmap of Phase 2 of the Project.

The information contained within this report will be used to scope future Ground Investigations.

2.2 Description of The Project

Arup has been appointed to provide multi-disciplinary technical consultancy services for the delivery of Phase 1 – 4 of the TII Project Management Guidelines for the N4 Carrick-on-Shannon to Dromod Project.

The N4 national primary road, Dublin to Sligo, is a strategic corridor from Dublin to the northwest and border counties and is approximately 198km in length. It is recognised as being of particular importance in enhancing accessibility to some of the most peripheral areas northwest (including counties Leitrim, Roscommon, Sligo, and Donegal) and west of the River Shannon.

The section of the N4 under consideration falls within two local authority administrative areas with the River Shannon acting as the boundary. The area to the west of the River Shannon lies within County Roscommon and to the east of the River Shannon within County Leitrim. The town of Carrick-on-Shannon lies on the eastern side of the River Shannon while the town of Cortober lies on the western side of the river. For the purposes of this report, where Carrick-on-Shannon is referenced it is taken to encompass both Carrick-on-Shannon and Cortober.

The section of the N4 under consideration passes through both rural and urban environments. It is approximately 21km long and extends from Drumharlow townland north of Carrick-on-Shannon to Faulties townland south of Aghamore. The main towns and villages along the road are Carrick-on-Shannon and Aghamore respectively. The N4 currently crosses the River Shannon at Carrick-on-Shannon via a narrow masonry arch bridge, dating from 1846.

The study area under consideration is presented on the Study Area Boundary Figure 4.1.1.1. The River Shannon runs through the study area from the northwest to the

¹ Transport Infrastructure Ireland (2019) Managing Geotechnical Risk DN-ERW-03083. Available from: <https://www.tiipublications.ie/library/DN-ERW-03083-01.pdf> [Accessed: 10 August 2020]

southeast. There are many tributaries located both east and west that feed into the River Shannon. Along the river's alignment there are numerous lakes, namely Lough Eidin which sits to the northwest of the study area on the river, Lough Corry to the south of Carrick-on-Shannon, Lough Tap and Drumgilra Lough which are located south of Drumsna. Lough Boderg, Lough Scannal and Lough Bofin are located along the river to the southeast of the study area.

The Jamestown Canal runs from east to west, north of the Dublin to Sligo railway line.

The current alignment of the N4 runs west to east in the northwest of the study area, crosses the River Shannon west of Carrick-on-Shannon and then veers south, south of Carrick-on-Shannon.

The Jamestown - Drumsna Bypass undertaken in 1996 constructed a wide single carriageway to the north of Jamestown and Drumsna. The Dromod-Roosky Bypass constructed in 1995 comprises a Type 2 Dual Carriageway.

The main Dublin to Sligo railway line for the most part traverses the western side of the study area south of the River Shannon, crossing the Killukin River in the northwest and the River Shannon west of Drumgilra Lough.

3 List of Figures and Drawings

The study area for the purpose of this study can be referenced in the Option Selection Report (Figure 4.1.1.1). There are seven sets of constraints drawings which are presented in the Option Selection Report:

1. Soil Deposits Map (Figure 4.15.1.0 to Figure 4.15.1.5) which shows the Environmental Protection Agency (EPA) National Soils mapping.²
2. Subsoil Deposits Map (Figure 4.15.2.0 to Figure 4.15.2.5) which shows the Geological Survey of Ireland (GSI) Quaternary deposits mapping and Quaternary Geomorphology.^{3 4}
3. Bedrock Geology Map (Figure 4.15.3.0 to Figure 4.15.3.5) which shows the GSI 1:100,000 scale bedrock mapping.⁵
4. Geological Pressures Map (Figure 4.15.4.0 to Figure 4.15.4.5) which shows a number of relevant constraints including:
 - a. Registered Quarries^{6 7 8}
 - b. GSI APM Historic Pit and Quarry Locations.⁹
 - c. GSI Geological Heritage Sites.^{10 11}
 - d. GSI Mineral Localities.¹²

² Environmental Protection Agency. National Soils Map. [Online] Available at: <https://gis.epa.ie/GetData/Download> [Accessed 10 August 2020]

³ Geological Survey of Ireland, 2020. Quaternary Sediments. [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=1bbf22e9391c484db4b84e4150313bae> [Accessed 10 August 2020]

⁴ Geological Survey of Ireland, 2019. Quaternary Geomorphology. [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=6ed00a12b7de4a3eb5535bc0875191ee> [Accessed 10 August 2020]

⁵ Geological Survey of Ireland, 2020. Bedrock Geology 1:100,000. [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=a40f6a8ca91f4340a86b12649d831d74> [Accessed 10 August 2020]

⁶ Geological Survey of Ireland, 2020. Active Quarries and Pits Ireland. [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=de18ea08ecd344b88c52b65b55fd9abb> [Accessed 10 August 2020]

⁷ Environmental Protection Agency, 2015. Extractive Industries Register. [Online] Available at: <http://www.epa.ie/ei/#/register> [Accessed 10 August 2020]

⁸ Environmental Protection Agency. WFD Article 5 Point Pressures. [Online] Available at: <https://gis.epa.ie/GetData/Download> [Accessed: 10 August 2020]

⁹ Geological Survey of Ireland, 2019. APM Pits and Quarries. [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=a205a046a2474e82944f9823b6568ea0> [Accessed 10 August 2020]

¹⁰ Geological Survey of Ireland, 2020. Geological Heritage Audited Sites. [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=35bb2b4ba2ca479ab7db513b445be7dc> [Accessed 10 August 2020]

¹¹ Geological Survey of Ireland, 2020. Geological Heritage Unaudited Sites. [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=5203261e602d477da69ef0171f6f403b> [Accessed 10 August 2020]

¹² Geological Survey of Ireland, 2020. Mineral Localities. [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=43d66cb2f2f24d81b7e03b8acda00c6a> [Accessed 10 August 2020]

- e. GSI aggregate potential mapping final scores from granular deposits.¹³
 - f. EPA Licenced Waste Facilities.^{14 15}
 - g. Waste Related Sites based on information received from local authorities
 - h. EPA Industrial Emissions (IE) Licences.^{16 17}
 - i. EPA Integrated Pollution Control (IPC) Sites.^{16 17}
 - j. Soft Soil Areas.²
 - k. Locations of known engineering issues based on information received from local authorities
 - l. Existing Piled Embankment location based on information received from local authorities.
 - m. Historic Heavy Industrial Sites.¹⁸
 - n. Water Framework Directive (WFD) Section 4 Discharges.¹⁹
 - o. Urban Waste Water Treatment Plant Locations.^{20 21}
5. Aquifer Vulnerability Map (Figure 4.14.10 to Figure 4.14.1.5) which shows the GSI Groundwater Vulnerability mapping.²²
 6. Aquifer Map (Figure 4.14.2.0 to Figure 4.14.2.5) which shows the GSI Aquifer Bedrock mapping.²³

¹³ Geological Survey of Ireland, 2019. APM Granular Aggregate Final Scores. [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=8306d891261e44928b240f18edaeb4cc> [Accessed 10 August 2020]

¹⁴ Environmental Protection Agency, 2020. Licenced Waste Facilities. [Online] Available at: <https://gis.epa.ie/GetData/Download> [Accessed 10 August 2020]

¹⁵ Environmental Protection Agency, 2020. Waste Licence Search. [Online] Available at: <http://www.epa.ie/terminalfour/waste/index.jsp?disclaimer=yes&Submit=Continue> [Accessed 10 August 2020]

¹⁶ Environmental Protection Agency, 2020. Industrial Emissions (IE) and Integrated Pollution Control (IPC) Facilities. [Online] Available at: <https://gis.epa.ie/GetData/Download> [Accessed 10 August 2020]

¹⁷ Environmental Protection Agency. IE / IPC Register. [Online] Available at <http://www.epa.ie/terminalfour/ippc/index.jsp?disclaimer=yes&Submit=Continue> [Accessed on 10 August 2020]

¹⁸ Ordnance Survey Ireland, 2020. GeoHive. [Online] Available at: <http://map.geohive.ie/> [Accessed 10 August 2020]

¹⁹ Environmental Protection Agency, 2016. WFD Section 4 Discharges. [Online] Available at: <https://gis.epa.ie/GetData/Download> [Accessed 10 August 2020]

²⁰ Environmental Protection Agency. EPA Licensed UWWT Plants and 2018 Status. [Online] Available at: <https://gis.epa.ie/GetData/Download> [Accessed 10 August 2020]

²¹ Environmental Protection Agency. Waste Water Discharge Authorisation Search. [Online] Available at: <http://www.epa.ie/terminalfour/wwda/wwda-search.jsp?countyName=Leitrim&Submit=Search+by+County> [Accessed on 10 August 2020]

²² Geological Survey of Ireland, 2020. Groundwater Vulnerability. [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=0a4dfd3097c64aada6eea057b33ba65f> [Accessed 10 August 2020]

²³ Geological Survey of Ireland, 2020. Groundwater Resources (Aquifers). [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=242c6793257b4f09bbbd966abc94cd70> [Accessed 10 August 2020]

7. Hydrogeological Constraints Map (Figure 4.14.3.0 to Figure 4.14.3.5) which shows a number of relevant constraints including:
- Proposed Natural Heritage Areas (pNHA).²⁴
 - GSI Well Localities.²⁵
 - GSI Karst Landforms.²⁶
 - GSI Groundwater Flooding Data.²⁷
 - EPA Groundwater Discharges and Emissions.^{14 19 16}
 - GSI Groundwater Resources.²⁸

²⁴ National Parks & Wildlife Service, 2018. NPWS Designated Areas. [Online] <https://dahg.maps.arcgis.com/apps/webappviewer/index.html?id=8f7060450de3485fa1c1085536d477ba> [Accessed 10 August 2020]

²⁵ Geological Survey of Ireland, 2020. Groundwater Wells and Springs. [Online] <https://dcenr.maps.arcgis.com/home/item.html?id=0feba9a2df4f13ad4f49ae8ab2f225> [Accessed 10 August 2020]

²⁶ Geological Survey of Ireland, 2020. Groundwater Karst Data. [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=aaa493208ff04f059ce5107e96089a71> [Accessed 10 August 2020]

²⁷ Geological Survey of Ireland, 2021. IE GSI Groundwater Flood Probability Historic. [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=d6079ee2e9554798b866a9d2771f7922> [Accessed 03 February 2021]

²⁸ Geological Survey of Ireland, 2020. Group Scheme and Public Supply Source Protection Areas. [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=aeea66e46ead408d91e39947451acf3b> [Accessed 10 August 2020]

A full list of the figures is given in **Table 1**.

Table 1: List of Soils, Geology and Hydrogeology Figures

Figure Number	Title	Sheet
Figure 4.1.1.1	Study Area Boundary	Sheet 1 of 1
Figure 4.15.1.0 – Figure 4.15.1.5	Soils and Geological Constraints - Soil Deposits Map	Sheet 1 to 6
Figure 4.15.2.0 – Figure 4.15.2.5	Soils and Geological Constraints - Subsoil Deposits Map	Sheet 1 to 6
Figure 4.15.3.0 – Figure 4.15.3.5	Soils and Geological Constraints - Bedrock Geology Map	Sheet 1 to 6
Figure 4.15.4.0 – Figure 4.15.4.5	Soils and Geological Constraints - Geological Pressures Map	Sheet 1 to 6
Figure 4.14.1.0 – Figure 4.14.1.5	A Soils and Geological Constraints - Aquifer Vulnerability Mapping	Sheet 1 to 6
Figure 4.14.2.0 – Figure 4.14.2.5	Soils and Geological Constraints - Aquifer Mapping	Sheet 1 to 6
Figure 4.14.3.0 – Figure 4.14.3.5	Soils and Geological Constraints - Hydrogeological Constraints Mapping	Sheet 1 to 6

4 Sources of Information

The following sources were studied in order to develop this PSSR.

4.1 Topographical and Geographic Maps and Datasets

The following mapping and geographical datasets were reviewed as part of this study:

- EPA Contours²⁹
- Google Maps (2020)³⁰
- Bing Maps (2020) base mapping³¹
- OSI Rivers and Lakes³²
- Corine Landcover³³
- OSI Historic Map 6 Inch 1837 - 1842¹⁸
- OSI Historic Map 25 Inch 1888 – 1913¹⁸
- OSI 6 Inch Cassini 1930's¹⁸
- 1995, 2000, 2005 OSI Aerial Photography¹⁸
- Ordnance Survey Discovery series Mapping (1:50,000)

4.2 Publications

The following publications were referenced and reviewed as part of this study:

- National Roads Authority. (2008). *Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes*. Ireland³⁴

²⁹ Environmental Protection Agency, 2019. EPA Contours. [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=088740d9f8ad466788fc25e268394656> [Accessed 10 August 2020]

³⁰ Google Maps, 2020. [Online] Available at: <https://www.google.ie/maps> [Accessed 10 August 2020]

³¹ Bing Maps, 2020. Bing Maps. [Online] Available at: <https://www.bing.com/maps/> [Accessed 10 August 2020]

³² Ordnance Survey Ireland, 2020. OSI Rivers and Lakes. [Online] Available at: <https://gis.epa.ie/GetData/Download> [Accessed 10 August 2020]

³³ Environmental Protection Agency, 2018. Corine Landcover. [Online] Available at: <https://gis.epa.ie/GetData/Download> [Accessed 10 August 2020]

³⁴ National Roads Authority, 2008. *Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes*, Ireland: s.n. Available at: <https://www.tii.ie/technical-services/environment/planning/Guidelines-on-Procedures-for-Assessment-and-Treatment-of-Geology-Hydrology-and-Hydrogeology-for-National-Road-Schemes.pdf>

- Matthew Parkes, R.M & S.P (2012). *The Geological Heritage of Roscommon*. An audit of County Geological Sites in Roscommon. Geological Survey Ireland³⁵
- TII 'Managing Geotechnical Risk' (2019) *DN-ERW-03083*¹

4.3 Solid Geology

The following digital datasets and maps from the GSI were reviewed as part of this study:

- Bedrock Geology of Ireland (1:100,000 scale)⁵

4.4 Drift Maps

The following drift maps were reviewed as part of this study:

- EPA National Soils Map (Teagasc Soils)²
- Teagasc Soils Map³⁶
- Quaternary Geology of Ireland (1:50,000 scale)³
- Quaternary Geomorphology (1:50,000 scale)⁴

4.5 Geological Survey Ireland Datasets

The following GSI datasets were consulted:

- GSI karst landform features and traced underground connections²⁶
- GSI landslide database³⁷
- GSI Landslide Susceptibility Classification³⁸
- GSI Active Quarries and Pits⁶
- GSI APM Historical Pits and Quarries⁹
- GSI mineral localities¹²

³⁵ Parkes, M., Meehan, R. & Preteseille, S., 2012. *The Geological Heritage of Roscommon*, An audit of County Geological Sites in Roscommon, s.l.: Geological Survey Ireland.

³⁶ Geological Survey of Ireland, 2020. Teagasc Soils. [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=82f09cca5c2c4221aa983d1a6d610c78> [Accessed 10 August 2020]

³⁷ Geological Survey of Ireland, 2020. National Database of past landslide events in Ireland. [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=cc35e0d1462d45698dda2a14d609c4db> [Accessed 10 August 2020]

³⁸ Geological Survey of Ireland, 2020. Landslide Susceptibility Classification. [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=1101f04b18e84ed790fa6e17021f57d8> [Accessed 10 August 2020]

- GSI aggregate potential mapping final scores for granular and rock deposits¹³
39
- GSI geological heritage sites^{10 11}
- GSI Geotechnical Boreholes Submitted by Industry⁴⁰
- GSI Verified Boreholes⁴¹
- GSI Geotechnical Sites Submitted by Industry⁴²
- GSI Unverified Boreholes⁴³
- GSI Groundwater Wells and Springs²⁵
- GSI Groundwater Source Protection Areas²⁸
- GSI Groundwater Catchment and WFD Management Units⁴⁴
- GSI Groundwater Recharge⁴⁵
- GSI Groundwater Vulnerability²²
- GSI Subsoil Permeability⁴⁶
- GSI Groundwater Resources (Aquifers)²³

³⁹ Geological Survey of Ireland, 2019. APM Crushed Rock Aggregate Final Scores. [Online] Available at:

<https://dcenr.maps.arcgis.com/home/item.html?id=647d87bb85c64c2691f0c1f21cfea273>
[Accessed 10 August 2020]

⁴⁰ Geological Survey of Ireland, 2020. Geotechnical boreholes submitted by industry to GSI. [Online] Available at:

<https://dcenr.maps.arcgis.com/home/item.html?id=a78d571ab90442e2a7ebc6d7d36c9a43>
[Accessed 10 August 2020]

⁴¹ Geological Survey of Ireland, 2020. Boreholes verified by the Geological Survey Ireland. [Online] Available at:

<https://dcenr.maps.arcgis.com/home/item.html?id=4737fa3211c54464b0a1d871f2093121>
[Accessed 10 August 2020]

⁴² Geological Survey of Ireland, 2020. Geotechnical Site Investigations with Links to Reports. [Online]

Available at:
<https://dcenr.maps.arcgis.com/home/item.html?id=f2ecd636745d4f50b78f9469750d6d8c>
[Accessed 10 August 2020]

⁴³ Geological Survey of Ireland, 2020. GSI Bedrock Borehole Locations (Unverified). [Online] <https://dcenr.maps.arcgis.com/home/item.html?id=28a500216eba49ce8a32910d2c799620>

[Accessed 10 August 2020]

⁴⁴ Geological Survey of Ireland, 2020. Groundwater Catchment and WFD Management Units. [Online] Available at:

<https://dcenr.maps.arcgis.com/home/item.html?id=ab3c613f499c4f0bbe32d6c73b7e1d08>
[Accessed 10 August 2020]

⁴⁵ Geological Survey of Ireland, 2020. Groundwater Recharge. [Online] Available at:

<https://dcenr.maps.arcgis.com/home/item.html?id=2c83a43c7f004ecb8a07f6889d814611>
[Accessed 10 August 2020]

⁴⁶ Geological Survey of Ireland, 2020. Subsoil Permeability. [Online] Available at:

<https://dcenr.maps.arcgis.com/home/item.html?id=6867581c23124ee5af5494e53d629088>
[Accessed 10 August 2020]

- GSI Hydrostratigraphic Rock Unit⁴⁷
- GSI Groundwater Flooding Data²⁷
- GSI Group Water Scheme Abstraction Points (NFGWS)⁴⁸

4.6 Other Datasets

The following datasets were also consulted:

- EPA Licenced Waste Facilities^{14 15}
- WFD: Article 5 Landfill⁸
- EPA Extractive Industries^{7 8}
- EPA Local Authority Waste Facility Register⁴⁹
- EPA Historic Landfill Register⁵⁰
- EPA IE and IPC Sites^{16 17}
- EPA UWWT Plants²⁰
- WFD: Article 5 Mine⁸
- WFD: Article 5 Wastewater Treatment Plants (WWTP)⁸
- WFD: Article 5 Water Treatment Plants (WTP)⁸
- WFD: Article 5 Section 4 Discharge Points⁸
- WFD Section 4 Discharge Points¹⁹
- OPALS Viewer – Mineral Exploration and Mining⁵¹
- NPWS Designated Ecological Areas²⁴
- OPW Flood Maps⁵²

⁴⁷ Geological Survey of Ireland, 2019. Hydrostratigraphic Rock Unit Groups. [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=968d2cfddd054c4cb262fd291708c7bb> [Accessed 10 August 2020]

⁴⁸ Geological Survey of Ireland, 2020. Group Water Scheme Abstraction Points (NFGWS). [Online] Available at: <https://dcenr.maps.arcgis.com/home/item.html?id=a9489ee192424280808c24da025657f3> [Accessed 10 August 2020]

⁴⁹ Environmental Protection Agency. Local Authority Waste Facility Register. [Online] Available at: <http://facilityregister.nwcpo.ie/> [Accessed on 10 August 2020]

⁵⁰ Environmental Protection Agency. Historic Landfill Application or Certificate of Authorisation. [Online] Available at: <http://www.epa.ie/terminalfour/HLF/index.jsp?disclaimer=yes&Submit=Continue> [Accessed on 10 August 2020]

⁵¹ Department of the Environment, Climate and Communications, 2021. Opals Viewer. [Online] Available at: <https://dcenr.maps.arcgis.com/apps/webappviewer/index.html?id=212642ca425f4739a36e247c64032b73> [Accessed 01 February 2021]

⁵² Office of Public Works. Flood Maps. [Online] Available at: <https://www.floodinfo.ie/map/floodmaps/> [Accessed on 10 August 2020]

- List and locations of licenced landfills, waste permitted sites, historic and active pits and quarries from Leitrim and Roscommon County Councils
- EPA Historic Mine Locations⁵³
- WFD Article 5: Quarry⁸

4.7 Historic Ground Investigation Reports

- Carrick-on-Shannon Bypass Ground Investigation Report No. 7435, IGSL 2001⁵⁴
- N4 Carrick-on-Shannon Bypass Geotechnical Ground Investigation Factual Report No. PC6044, Priority Geotechnical Limited 2006⁵⁵
- N4: Carrick-on-Shannon to Dromod Preliminary Ground Investigation – Contract 1 Factual Report No. PC9081 Priority Geotechnical Limited 2010⁵⁶
- N4 Slope Remediation Ground Investigation – Factual Report No. P16048, Priority Geotechnical Limited 2016⁵⁷

⁵³ Environmental Protection Agency. Historic Mines Project – Site Location. [Online] Available at: <https://gis.epa.ie/GetData/Download> [Accessed 01 August 2020]

⁵⁴ IGSL, 2001. Carrick-on-Shannon By Pass Ground Investigation Report No. 7435

⁵⁵ Priority Geotechnical Limited, 2006. N4 Carrick-on-Shannon Bypass Geotechnical Ground Investigation Factual Report No. PC6044

⁵⁶ Priority Geotechnical Limited, 2010. N4: Carrick-on-Shannon to Dromod Preliminary Ground Investigation – Contract 1 Factual Report No. PC9081

⁵⁷ Priority Geotechnical Limited, 2016. N4 Slope Remediation Ground Investigation – Factual Report No. P16048

5 Field and Laboratory Studies

5.1 Previous Ground Investigations

The GSI Geotechnical Sites and Verified Borehole Logs datasets show a number of ground investigations within the study area, these are presented in **Table 2** and **Table 3**.

Table 2: List of relevant ground investigation reports from GSI submitted by industry⁴⁰

GSI Ref.	Report Title	No. of Exploratory Holes within study area	Year Completed
6657	Report on a Site Investigation for Carrick-on-Shannon Retail Park	5 No. trial pits, 10 No. dynamic probes, 4 No. window samples, 5 No. slit trenches, 9 No. plate bearing tests	2006
6834	Report on a Site Investigation for Bridge Street, Carrick-on-Shannon	2 No. boreholes, 10 No. dynamic probes	2006

Table 3: List of relevant GSI verified borehole logs⁴¹

Borehole ID	Project Title	Year
SL-76-1	South Leitrim (Area 7)	1976
SL-77-4	South Leitrim (Area 7)	1977
SL-77-1	Log Not Available	
SL-85-6	Log Not Available	

A number of other ground investigations have been completed within the study area that are not included in the GSI datasets, these include:

- Carrick-on-Shannon Bypass Ground Investigation completed by IGSL in 2001, Factual Report No. 7435. Summarised in **Table 4**
- N4 Carrick-on-Shannon Bypass Geotechnical Ground Investigation completed by Priority Geotechnical Limited (PGL) in 2006, Factual Report No. PC6044. Summarised in **Table 5**
- N4: Carrick-on-Shannon to Dromod Preliminary Ground Investigation – Contract 1 completed by PGL in 2009, Factual Report No. PC9081. Summarised in **Table 6**
- N4 Slope Remediation Ground Investigation – completed by PGL in 2016, Factual Report No. P16048. Summarised in **Table 7**

Table 4: N4 Carrick-on-Shannon Bypass, IGSL 2001, Factual Report No. 7435

Exploratory Hole Type	Quantity	Depth Range (mBGL)
Mackintosh Probing	341	0.2 to 8.5
Cable Percussive Borehole	6	6.0 to 8.0

Table 5: N4 Carrick-on-Shannon Bypass, PGL 2006, Factual report No. PC6044

Exploratory Hole Type	Quantity	Depth Range (mBGL)
Cable Percussive Borehole	19	1.2 to 7.3
Rotary Borehole	61	6.4 to 25.3
Trial Pit	81	0.78 to 5.5
Slit Trench	11	0.95 to 1.3
Dynamic Probe	196	0.2 to 6.2
Cone Penetration Tests	30	1.46 to 6.27

Table 6: N4 Carrick-on-Shannon to Dromod, PGL 2009, Factual Report No. PC9081

Exploratory Hole Type	Quantity	Depth Range (mBGL)
Cable Percussive Borehole	14	0.45 to 11.6
Cable Percussive Borehole with Rotary Core follow on	2	7.2 to 11.6
Trial Pit	18	0.6 to 4.7
Slit Trench	12	1.2 to 1.42
Macintosh Probe	24	0.27 to 6.5
Dynamic Probe	221	0.3 to 11.5
2D Resistivity Profiling	9	-

Table 7: N4 Slope Remediation Ground Investigation, PGL 2016, Factual Report No. P16048

Exploratory Hole Type	Quantity	Depth Range (mBGL)
Trial Pits	5	4.5

5.2 Previous Assessments and Site Surveys

5.2.1 Previous Assessments

Summary of Roughan & O'Donovan 2009 Site Reconnaissance

Roughan & O'Donovan (ROD) conducted a site reconnaissance visit on 17 June 2009 to verify areas highlighted by the GSI database as soft soils. The following were highlighted from the site walk over in the 2010 Roughan & O'Donovan N4 Carrick-on-Shannon to Dromod Road Project Constraints Study

Report:⁵⁸

- At the edge of the River Shannon northwest of Carrick-on-Shannon it was noted that the river flows through a valley where there appears to be extensive areas of low-lying alluvium floodplains either side of the river.
- A number of areas highlighted as possible peat lands were inspected but were not thought to pose any significant constraint due to expanding residential development and the presence of tall trees and specific plant types found thriving in these areas.
- An area of peat bog in the townland of Attirory (Easting: 195339, Northing: 298604) was inspected, it was noted that the road through this section was in bad condition, there was a lack of tall trees, potentially indicating deep soft, low strength acidic peat soils and the area was heavily vegetated with low scrub vegetation. It was also noted that these lands did not appear to be improved by drainage and the in-situ soils could be quite soft and significantly deep in parts.
- The Fen areas identified by the GSI were inspected. It was noted that these have residential dwellings recently constructed within their boundaries and that it appeared these lands had been improved with drainage to permit use as pasture.
- It was observed that much of the lands identified as peat by the GSI on the outskirts of Carrick-on-Shannon, (particularly to the south) have been improved by local farmers to be used for cattle grazing and to grow silage.
- An area of made ground or fill material to the southwest side of the Ballynamony landfill was inspected. It was noted that the ground level is artificially much higher than surrounding areas. The material underfoot was noted as being a mixture of clay, gravel, peat etc. This site was subsequently identified as three old waste permit facilities which have since been filled in.

5.3 Arup Soils and Geology Field Studies

2020 Arup Site Survey

Arup conducted a site survey on 21 October 2020. 24 No. locations within the study area were visited in total, namely those which are identified as constraints on Figure 4.15.4.0 to 4.15.4.5. The locations of the site survey are referenced on the

⁵⁸ Roughan & O'Donovan, 2010. N4 Carrick-on-Shannon to Dromod Road Project Constraints Study Report

Site Survey Locations drawing (Drawing 274219-ARUP-02-OS-DR-YEGEO-000117) in Appendix A. Site photographs are also presented in Appendix A. The weather conditions on the day of the visit were dry, however there was heavy rainfall during the days prior to the site visit. As a result, the River Shannon was in flood. Access to private lands was not permitted for this survey therefore observations and notes on ground conditions were taken from the roadside. The following sites were visited, and observations made:

- Location 1 – Carrick-on-Shannon landfill in Ballynamoney: the site consists of a mound approximately 6.0m to 7.0m above the existing road level. Gas ventilation pipes were noted at the top of the mound. Drainage is in place at the base of the slope on the Keadew side.
- Location 2 – Waste permit site registered to a Mr. Brian Kenny north of Carrick-on-Shannon: the site is approximately 1.0m lower than the existing road level and the land rises towards the north of the site. Ground conditions were observed as marshy, wet ground with a drainage ditch running through the middle. A stream was also noted running parallel to the road.
- Location 3 – Historic waste permit site at the Carrick-on-Shannon Townparks: The site is now occupied by a football field with an adjacent marina that is on the River Shannon to the west. The elevation of the site is approximately 2.0m below the existing road level.
- Location 4 – The eastern River Shannon crossing approach from the emerging preferred route from the Roughan O'Donovan route option selection report.⁵⁹ Access was not possible to this location during the survey but from the opposite bank of the river, the ground conditions appeared waterlogged, marshy and possibly difficult to cross on foot.
- Location 5 – The western River Shannon crossing approach from the emerging preferred route from the Roughan O'Donovan route option selection report.⁵⁸ Access to this location was achieved via the local road. The lands approaching the River Shannon are grassed and traversable on foot and with machinery. However, the low-lying ground on the river floodplain is waterlogged and populated with reeds and rushes. It is likely that a tracked machine will be required for ground investigation access. The river was in flood at the time of the survey.
- Location 6 – An area of soft ground (peat) underlying and adjacent to the existing N4 approximately 1.0km west of Carrick-on-Shannon: The existing ground elevation is approximately 1.0m lower than the N4 road but the ground rises towards the east. The ground adjacent to the roadside is wet as reeds and rushes are present.
- Location 7 – An area of alluvium intersecting the existing N4 approximately 0.5km west of Carrick-on-Shannon: Soft ground observed on the eastern side of the N4. The ground level on the western side is approximately 2m below the existing N4. There are reeds and rushes present indicating the ground is wet.

⁵⁹ Roughan & O'Donovan, 2011. N4 Carrick-on-Shannon to Dromod Road Project Route Corridor Selection Report

- Locations 8 and 9 – A historic waste permit site in the Cloongownagh Townland along the existing N4, approximately 2.5km west of Carrick-on-Shannon: It appears that the ground increases in elevation at the location of the old waste permit site on the western side of the N4. The waste permit site no longer appears active and is covered over. Reeds and rushes were noted in this area.
- Location 10 – A historic waste permit site and area of soft ground (peat) just west of Carrick-on-Shannon in the Drishoge Townland: This site seems to be partially redeveloped into apartments to the south and a commercial building to the west adjacent to the existing road. The site is on the floodplain of the River Shannon. Existing ground conditions are wet, marshy with access possible on foot only. The waste permit site is no longer active and appears to be covered over.
- Location 11 – A historic gas works site located on the western side of Carrick-on-Shannon near the Carrick-on-Shannon station: The site of the former gas works has been replaced with a commercial building, there is no evidence of the former gas works. The railway line that passes adjacent to this site is on a 3.0m high embankment. The topography rises to the north and south, therefore the embankment is short in length. To the southeastern side of the railway embankment, there is a green area that might be a suitable location to undertake GI.
- Location 12 – An area of peat south of Carrick-on-Shannon along the western banks of the River Shannon: The site of this soft ground peat deposit is in a natural west to east trending valley with the ground rising towards the north and south. A stream/river runs along the alignment of this valley and outfalls to the River Shannon to the east. The ground conditions are wet, marshy and very soft.
- Location 13 – Potential alternative River Shannon crossing south of Carrick-on-Shannon (western side of river): This area is located at the eastern end of the valley identified at location 12 on the bank of the River Shannon near Carrick Camping. From this area it can be seen that less marshy and wet ground exists along the southern end of the valley recorded at Location 12. However, once this valley intersects the railway line embankment which is inland, the ground on the western side of this appears to get poor again. The better ground is further north from this point onwards.
- Location 14 – Potential alternative River Shannon crossing south of Carrick-on-Shannon (eastern side of river): better ground conditions in the field immediately south of the housing estate Glas na hAbhainn. There is a substation at the western end of the development. From this point onwards the ground conditions become poor towards the River Shannon. The low ground > 200m south of the estate was flooded during the site visit.
- Location 15 – This area, 1.5km east of Carrick-on-Shannon, has been identified as an area of soft ground, however there are no visible signs of soft ground at this location. The N4 is in a 7m high embankment over a river crossing in this area.
- Location 16 – The Corbally embankment approximately 2.0km east of Carrick-on-Shannon along the existing N4: The N4 is in an approximately 5.0m high embankment (possibly higher) in this section of the road. The ground either side

of the embankment is overgrown. There are few visible signs of poor ground, aside from localised reeds noted on the western side of the embankment which indicates the ground here maybe waterlogged. 300m to the north east of this location, Kiltycarney quarry is a disused quarry that was identified during the constraints study. Access to the quarry was not permitted at the time of completing the site walkover.

- Location 17 – An area of soft ground alluvial deposits adjacent to the footprint of an existing embankment north of Jamestown: This site was not accessible from the road therefore a drive by view of the site had to be undertaken. From what was visible from the car, the southern side of the embankment appears to be soft and wet within the floodplain of the River Shannon. The ground rises quickly to the north and appears to be dry.
- Location 18 – An area of soft ground at Gortconnellan Lough near Drumsna: At this location there appears to be soft ground, very close to the existing N4 which is an embankment. The ground on the eastern side was flooded during the survey.
- Location 19 –(19A) The N4 piled embankment adjacent to the Drumgilra Lough: The ground either side of this 2m high embankment is noted by Arup during the site survey as being populated by reeds and rushes which indicates that the ground may be waterlogged. A drive by survey was only possible at this location. (19B) This location also captured the historic pit and quarry that is to the east of the N4. There was no evidence of a pit or quarry at this location.
- Location 20 – The site of three historic quarries on the southern side of the Drumgilra Lough: It is possible to see that the ground along the side of the lough is raised and hummocky which could possibly be as a result of the backfilling of the historic quarries.
- Location 21 – The site of three historic quarry sites on the eastern side of the existing N4 near Aghamore: No sign of these historic quarry sites being in use, all maybe backfilled.
- Location 22 – The site of two registered Jon's Civil Engineering Company waste permit sites near Fearnaght: The ground conditions at the location of these permitted sites are waterlogged as observed from the presence of reeds and rushes. The sites are approximately 0.5m lower than the existing N4 road.
- Location 23 – Finnalaghta Quarry was surrounded in vegetation and could not be seen from the roadside. Aerial photographs are the best way to see this quarry.
- Location 24 – An area of soft ground peat deposits adjacent to the existing N4 near Faulties: At this location there is no significant elevation difference between existing road and the recorded area of soft ground. There is no visual evidence that soft ground exists at this location. The road embankment in this area is possibly part of the Dromod to Roosky Scheme.

5.4 Arup Hydrogeological Field Studies

Hydrogeological Feature Survey

Arup conducted a hydrogeological field survey on 21 and 22 October 2020. The survey included a desk-based study to identify sites of potential interest followed up with a site visit. This included a review of available information on karst features from the Geological Survey of Ireland databases, historical and ecological mapping. Sites of interest identified during the desk study were visited during the site survey. The site survey took the form of a “site” survey with the inspection limited to closest point accessible from the road verge or public land. Sites where sufficient access was not possible were noted for future access when landowner liaison is underway, and access is permitted.

The sites visited during the survey are shown in **Plate 1** along with the GSI karst features, some of which were included in the site visits. **Table 8** lists the sites visited during the survey and a note on the nature of the feature identified at that location.

Table 8: List of sites visited during the hydrogeological feature survey

Site ID	Desk Study Feature Identified	Site Visit Result
1	Drainage feature	Observed from afar
2	Pond	Ornamental garden pond, no indication of natural water level fluctuations. Possible additional feature behind (south of) of this. Boyle River crosses the N4 near here, very small flow.
3	Drainage feature	Observed from afar
4	Drainage feature	Channel flowing north from culvert, moderate flow, adjacent field covered in rushes
4a	Shallow Groundwater	Observed from afar
5	Groundwater Feature	Poor Drainage, rushes in field
6	Enclosed Feature	Observed from afar
7	Drainage feature	Observed from afar
8	Shallow Groundwater	Very soft saturated ground.
9a	Drainage feature	Observed from afar
9b	Drainage feature	Observed from afar
10	Drainage feature	Observed from afar
11	Drainage feature	Observed from afar
12	Drainage feature	No access but adjacent field filled with rushes and pond
13	Drainage feature	Observed from afar
14	Drainage feature	Observed from afar
15	Spring	Observed from afar
16	Spring	Observed from afar
17	Herringbone Drainage	No access, but drainage appears moderately poor
18	Spring	Observed from afar
19	Shallow Groundwater	Observed from afar
20	Shallow Groundwater	Observed from afar

Site ID	Desk Study Feature Identified	Site Visit Result
21	Shallow Groundwater	Observed from afar
22	Groundwater Feature	Observed from afar
23	Groundwater Feature	Observed from afar
24	Groundwater Feature	Observed from afar
25	Groundwater Feature	Observed from afar
26	Groundwater Feature	Observed from afar
27	Isolated Vegetation	Observed from afar
28	Groundwater Feature	Observed from afar
29	Poor Drainage	No direct access but appears very wet/poorly drained
30	Poor Drainage	Very wet field. Channel emerging north possible spring or drainage
31	Poor Drainage	Observed from afar
32	Shallow Groundwater	Very poor drainage, wide stagnant drainage channels. Possible groundwater discharge feature at higher water levels not fully enclosed
33	Groundwater Feature	Observed from afar
34	Linear Feature	Observed from afar but possible spring channel visible.
35	Groundwater Feature	Observed from afar
36	Groundwater Feature	Observed from afar
37	Poor Drainage	Stagnant Marsh Pond. Channels with bright green flora indicative of groundwater discharges
38	Poor Drainage	Observed from afar
39	Poor Drainage	Observed from afar
40	Possible Dry Channel	Observed from afar
41	Possible Dry Channel	Poor drainage at base of the field, possible channel inside wooded area
42	Poor Drainage	Dry channel/ditch in the field with rushes.
42a	Pond	Pond, no groundwater influence evident
43	Groundwater Drainage	Poor drainage, rushes in the field
44	Groundwater Drainage	Rushes in the field, poor drainage
45	Groundwater Drainage	Observed from afar
46	Groundwater Drainage	Observed from afar
47	Lake/Pond	Pond
48	Ponding Groundwater	Moderately poor drainage
49	Groundwater Drainage	Observed from afar
50	Groundwater Drainage	Could not see the feature from afar
51	Groundwater Drainage	Could not see the feature from afar
52	Groundwater Drainage	Could not see the feature from afar

Site ID	Desk Study Feature Identified	Site Visit Result
53	Groundwater Drainage	Observed from afar
54	Poor Drainage	Field covered in reeds
55	Prone to flooding	No karst evident
56	Prone to flooding	No karst evident
57	Groundwater Drainage	Indicators of poor drainage (reeds)
58	Groundwater Drainage	Indicators of poor drainage (reeds) land sloping to Lough
59	Groundwater Drainage	Ponding at edge of road embankment
60	Groundwater Feature	Ponding at edge of road embankment
61	Groundwater Feature	Poor drainage
62	Groundwater Pond	Poor drainage
63	Groundwater Drainage	Low point in local topography with deep drainage ditches
64	Groundwater Feature	Does not appear to be karst feature.
65	Quarry	Discharging stream at 230uS/cm (limited groundwater influence)
66	Bog	Poor drainage
67	Drumgilra Lake	Lake, does not appear to have groundwater/turlough influence
68	Turlough	Large Turlough Outside the Study Area.
69	Turlough	Large Turlough Outside the Study Area.
70	Spring	Observed from afar
71	Spring	Observed from afar
72	Spring	Observed from afar
73	Groundwater Drainage	Reeds in the field, channel flowing east possibly draining shallow groundwater. Possible spring emergence shown in Photo B. Photo C shows limestone outcrop at road cut.
74	Groundwater Drainage	Poor drainage
75	Poulnamease Spring	Outside the Study Area. Confluence of two springs. Upwelling conductivity 500uS/cm.
76	Historic Spring	Reeds covering channel emergence, flow appears very small.
77	Historic Spring	Spring emergence at old tree flowing towards the road, no direct access.
78	Historic Spring	Approx. 3L/m flow; 440uS/cm, possible karst spring, warrants further assessment, emerges with river upstream of bridge.
79	Historic Spring	Observed from afar
80	Historic Spring	Outside corridor
81	Historic Spring	Observed from afar

Site ID	Desk Study Feature Identified	Site Visit Result
82	Historic Sulphur Spa Well	Spoke to landowner who owns sulphuric water with healing properties. Offers spa treatments - https://www.spacottage.ie/ . Warrants further attention.
83	Tobercnellan Spring	Observed from afar
84	Pond	Local dip in ground levels with reeds and pond adjacent N4. No clear groundwater features.

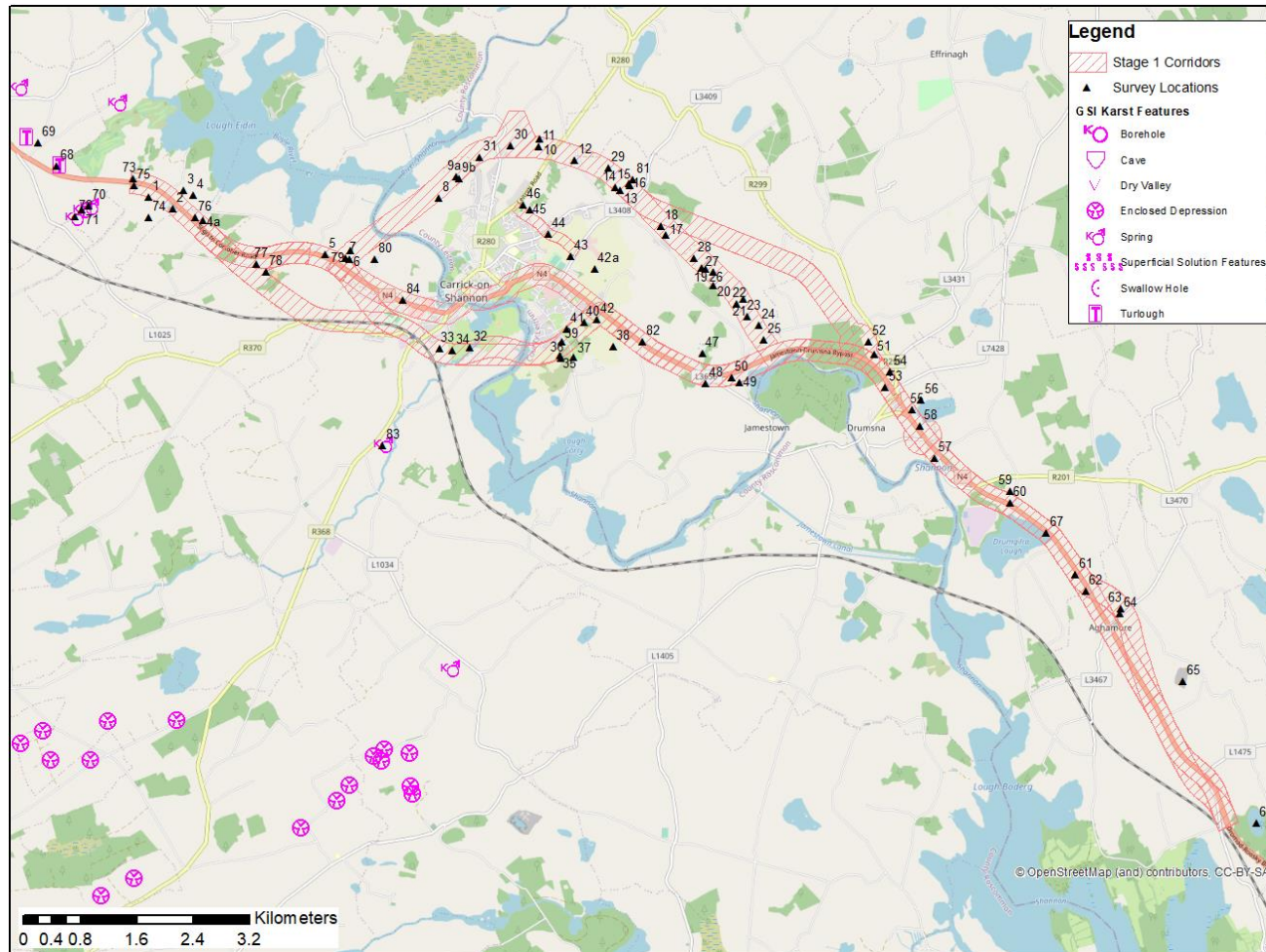


Plate 1: Site Survey Locations

There were no significant karst features identified during the site survey, other than has previously been mapped by the Geological Survey of Ireland. Some potential karst springs were noted, however the flows were generally quite low and could equally be land drainage channels and are not considered to have a high significance in terms of the Project constraints. The landscape character is not indicative of karst geomorphology, it is more typically rolling drumlins and the broad flat river valley closer to the River Shannon.

The site survey did confirm numerous areas of poor drainage and shallow groundwater which could be indicative of groundwater dependant habitats and areas of soft soil.

6 Review of Existing Site Information

6.1 Site Description

The study area is generally bounded by agricultural areas to the north, south, west and east. Kilronan Mountain and Slieve Anierin are located north of the study area near Lough Allen, the Curlew Mountains are located northwest of the study area near the town of Boyle and Slieve Bawn is located south of the study area. The River Shannon runs through the study area from the northwest corner to the southeast corner. There are many tributaries located both east and west that feed into the River Shannon. Along the rivers alignment there are numerous lakes, for example Lough Eidin which sits to the northwest of the study area on the river, Lough Corry to the south of Carrick-on-Shannon, Lough Tap and Drumgilra Lough which are located south of Drumsna. Lough Boderg, Lough Scannal and Lough Bofin are located along the river to the southeast of the study area.

The Jamestown Canal runs from east to west, just south of Jamestown.

The current alignment of the N4 runs west to east in the northwest of the study area, crosses the River Shannon west of Carrick-on-Shannon and then veers south, to the southeast of Carrick-on-Shannon. The Jamestown - Drumsna Bypass undertaken in 1996 and located to the southeast of Carrick-on-Shannon is a wide single carriageway located to the north of Jamestown and Drumsna. Further south, the Dromod-Roosky Bypass constructed in 1995 comprises a Type 2 Dual carriageway.

The main Dublin to Sligo railway line for the most part occupies the western side of the study area south of the River Shannon, crossing the Killukin River in the northwest and the Shannon west of Drumgilra Lough.

The primary land use within the study area is agricultural, with a number of areas of private managed forestry plantations. There are settlements within the study area, such as Carrick-on-Shannon, Cortober, Drumsna, Jamestown and Aghamore.

6.2 Topography and Geomorphology

6.2.1 Topography

The regional topography and the surrounding landscape are dominated by mountains to the north of the study area surrounding Lough Allen with peaks greater than 580mOD. The Curlew Mountains (250mOD) are located west of the study area near Boyle and the Slieve Bawn mountain range (260mOD) is located south of the study area. On the lowlands, the topography is dominated by an undulating landscape with elevations ranging from 40mOD (along the River Shannon) up to 90mOD (at the peaks of drumlins).²⁹ There are extensive areas of floodplain along the banks of the River Shannon which are relatively flat lying at less than 40mOD. The landscape of the study area predominately comprises a hummocky landscape with peaks of 90mOD and hollows between the peaks less than 50mOD.

The alignment of the existing N4 passes through elevations ranging from 40mOD to 70mOD.²⁹

6.2.2 Geomorphology

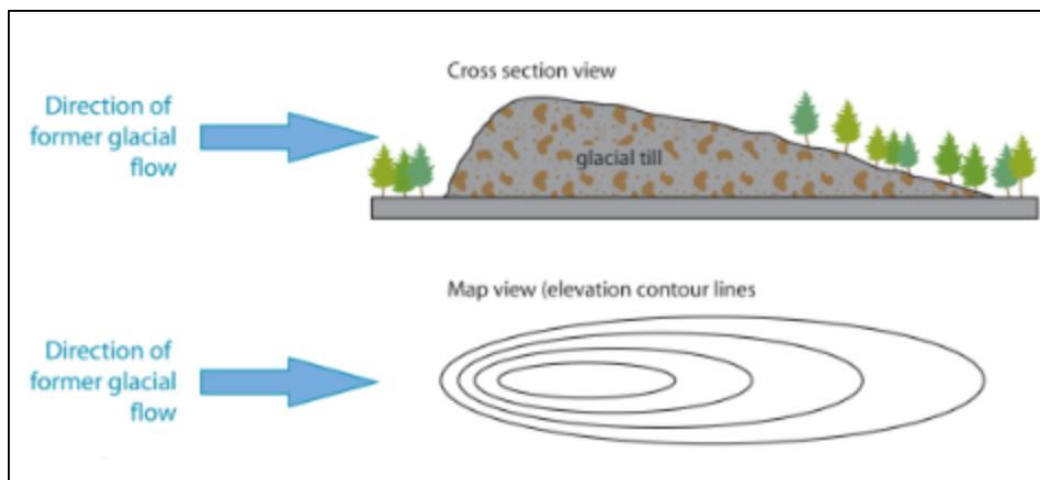
Geomorphology is the study of the landforms which comprise the earth's surface, the processes which have modified and shaped it in the past and which continue to modify and shape it at the present time.

Ireland has been most influenced by two epochs of glaciation, the Munsterian and Midlandian. The geomorphology presented within the study area is from the younger Midlandian glaciation which originated between Lough Ree and Lough Neagh and lasted approximately 60,000 years during the Upper Pleistocene. This glacial period ended about 10,000 years ago. The deposits of the Midlandian ice were not 're-worked' by any subsequent glaciation and remain in a relatively unsmoothed or 'young' condition. As the glaciers were retreating, they left behind glacial landforms and deposits known as Drumlins and Ribbed Moraines which occur frequently across the study area and are responsible for the undulating landscape. The swarm of Drumlins to the south of the River Shannon within the study area is known as the Irish southwestern most extreme of the 'Drumlin Belt'.³⁵

Drumlins

Drumlins are smooth, oval shaped hills made up of till or rock that create an undulating landscape of small glacial till hills and hollows. Till drumlins are comprised of compact, unstratified glacial till or drift. In contrast, rock drumlins are mostly made up of rock core with a concentric covering of drift. Rock drumlins tend to have a slightly better drainage status than till drumlins. However, within the study area till drumlins dominate comprising of a gley lead soil series with deposits of peat located in the hollows between the drumlins. Poor natural drainage represents a major limitation of these landforms for agriculture.⁴ **Plate 2** presents the typical cross-section and map view of a drumlin feature.

Plate 2: Typical drumlin cross-section and map view



Ribbed Moraines

Ribbed Moraines (Rogen Moraines) are subglacial formed landforms that occur in groups. They typically form in central portions of former ice sheets and are often closely and regularly spaced and consist of glacial drift, with till being the most common constituent. The individual moraines are large, wavy ridges orientated transverse to ice flow. Ribbed Moraines can contain many superimposed drumlins on their crests. South of the River Shannon has traditionally been known as the southwestern-most extreme of the ‘Drumlin Belt’.⁴

The location of Drumlins and Ribbed Moraines can be seen on the Subsoil Deposits Map in Figures 4.15.2.0 to 4.15.2.5.

Other glacial meltwater features recorded in the County Roscommon area are Eskers, Fans and Deltas, all of which are outside of the study area.⁴

6.3 Soil Deposits

The soil deposits are predominately a function of the underlying parent material subsoils as detailed in Table 9. The soil types are shown on the Soil Deposits Map in Figures 4.15.1.0 to 4.15.1.5.

Areas of made ground are extensive around Carrick-on-Shannon and extend westward out along the R368 and R370 for approximately 1km and eastwards along the N4 for approximately 0.6km. Other areas of made ground include:²

- An area associated with a licensed landfill (Active licence number W0064-01) just north of Carrick-on-Shannon at Ballynamoney. This location was used for the disposal of domestic, commercial and industrial waste in addition to sewerage sludge between 1965 and 2005.
- Near the intersection of the N4 and L3656 north of Jamestown, an area associated with a disused quarry (Kiltycarney Quarry), the nature of the material at this location is unknown.
- At the location of the Rosderra Meats industrial facility near Jamestown, the nature of the material at this location is unknown
- At the intersection of the N4 and R299 near Drumsna, the nature of the material at this location is unknown
- At Drumsna, the nature of the material at this location is unknown

Typically Made Ground is comprised of variable materials of varying strengths and depths with a potential for contamination.

Large areas of alluvium deposits are recorded along the banks of the River Shannon and its associated tributaries. A large area of alluvium is also recorded intersecting the Dublin to Sligo railway line and the R370 approximately 1.5km west of the Carrick-on-Shannon Railway Station.²

Isolated pockets of lacustrine deposits exist throughout the study area adjacent to the tributaries of the River Shannon at the following locations:²

- Approximately 2.0km southwest of Carrick-on-Shannon

- Adjacent to Drumgilra Lough
- Adjacent to Lough Tap
- Approximately 1.7km north of Faulties

Two areas of blanket peat are recorded at the eastern end of the site, approximately 1.3km north of Faulties.²

Large areas of cutover/cutaway peat deposits exist throughout the study area, mainly in the hollows between the drumlin peaks.²

Three areas of fen peat are shown throughout the study area at the following locations:²

- Northwest of Carrick-on-Shannon
- Along the most easterly banks of Lough Corry
- Along the eastern bank of a smaller lough just south of Lough Corry

Though there are a large number of soil types throughout the study area, these can be summarised as follows:

- Made ground considered low importance for agriculture
- Well drained soils considered high importance for agriculture
- Poorly drained soils considered low importance for agriculture
- Alluvium considered medium importance for agriculture
- Peaty soils considered low importance for agriculture

Soils are also major components of ecosystems and a non-renewable resource. In accordance with the Environmental Impact Assessment Directive (2014/52/EU),⁶⁰ threats to soil functions such as organic matter, erosion, compaction and sealing from increased landtake needs to be limited and considered in the assessment of infrastructural projects.

Table 9: Summary of soils within the study area (Teagasc Classification)^{2 36}

Soil Type	Teagasc Description ³⁶	EPA National Soils Description ²
Made	Made ground	Made
AlluvMIN	Alluvial (mineral)	Mineral alluvium
Lac	Lacustrine type soils	Lacustrine
BktPt	Blanket peat	Blanket peat
Cut	Cutover / cutaway peat	Raised Bog cutaway / cutover
FenPt	Fen peat	Fen peat
AminDW	Deep well drained mineral (Mainly acidic)	Acid Brown Earths / Brown Podzolics
AminPD	Mineral poorly drained (Mainly acidic)	Surface water Gleys / Ground water Gleys Acidic

⁶⁰ European Union, 2014. Directive 2014/52/EU of the European Parliament and of the Council. Official Journal of the European Union.

Soil Type	Teagasc Description ³⁶	EPA National Soils Description ²
AminPDPT	Peaty poorly drained mineral (Mainly acidic)	Peaty Gleys Acidic
AminSP	Shallow poorly drained mineral (Mainly acidic)	Surface water Gleys / Ground water Gleys Shallow
AminSRPT	Shallow, rocky, peaty / non-peaty mineral complexes (Mainly acidic)	Podzols Peaty
BminDW	Deep well drained mineral (Mainly basic)	Grey Brown Podzolics / Brown Earths Basic
BminPD	Mineral poorly drained (Mainly basic)	Surface water Gleys / Ground water Gleys Basic
BminPDPT	Peaty poorly drained mineral (Mainly basic)	Peaty Gleys Basic Parent Materials Basic
BminSP	Shallow poorly drained mineral (Mainly basic)	Surface water Gleys / Ground water Gleys Shallow
BminSRPT	Shallow, rocky, peaty/non-peaty mineral complexes (Mainly basic)	Lithosols Peats
BminSW	Shallow well drained mineral (Mainly Basic)	Renzinas / Lithosols

6.4 Subsoil Deposits

Subsoil deposits comprise the unconsolidated geological deposits which cover the solid geology and are shown on the Subsoil Deposits Map in **Figure 4.15.2.0 to 4.15.2.5**.

The subsoils mapping of the region indicate that the study area is dominated by glacial till derived from limestones. There are large areas of cutover raised peat and areas of alluvium. These are located along the alignment of the River Shannon and in the hollows between the drumlin peaks. The remainder of the study area consists of made ground, blanket peat, fen peat, lacustrine sediments, till derived from Namurian sandstones and shales, bedrock outcrop or subcrops. The subsoil types as classified by the GSI Quaternary mapping within the study area are listed in Table 10.³

The thickness of subsoil deposits is variable throughout the study area, with thinner subsoils in areas of shallow bedrock, including towards the northwest and southeast of the study area. Karstified bedrock outcrops are present at the western end and north of Carrick-on-Shannon.³

Large areas of alluvium deposits are evident in many areas surrounding the River Shannon, with isolated pockets associated with the tributary streams such as the Killukin and Knockananima Rivers south of Carrick-on-Shannon.³

A large number of extensive peat deposits (blanket peat and cutover raised peat) are located across the study area, along the alignment of the River Shannon and in the hollows between the drumlin peaks.³

Three fen peat deposit areas are present within the study area, the first is just northwest of Carrick-on-Shannon, one is located on the most easterly banks of

Lough Corry and one located on the banks of a smaller lough just south of Lough Corry.³ A fen is a wetland system with a high water level at, or just below, its surface. They are characterised by their distinct water chemistry which is mineral rich and differ from bogs which are acidic and low in minerals. Fens developed after the last glaciation in depressions occupied by shallow lakes. The soils in fens comprise normally consolidated highly organic soils that are extremely compressible.

Four areas are shown as comprising lacustrine sediments, the first two are on the southern bank of Drumgilra Lough, one on the eastern bank of Lough Tap and the fourth approximately 1.7km north of Faulties. A number of areas comprising lacustrine sediments are also shown to be sitting just outside of the study area to the west and east.³

One small area of made ground is shown within the Drumgilra Lough.³

Table 10: Summary of subsoils (GSI Quaternary) within the study area³

Soil Type	Description
Fill	Made Ground
A	Alluvium
L	Lacustrine sediments
BktPt	Blanket Peat
Cut	Cut over raised peat
FenPt	Fen Peat
TLs	Till derived from limestones
TNSSs	Till derived from Namurian sandstones and shales
KaRck	Karstified bedrock outcrop or subcrop
Rck	Bedrock outcrop or subcrop

6.5 Bedrock and Structural Geology

The rock formations encountered in the study area are detailed in Table 11 and shown on the Bedrock Geology Map in Figures 4.15.3.0 to 4.15.3.5.

6.5.1 Geological History

The bedrock geology of the study area is dominated by 330 million old Lower Carboniferous Limestones of the Oakport, Croghan, Ballymore, Bricklieve Formations. Much older Ordovician rocks from the Finnlaghta and Aghamore formations are exposed at the surface in the Slieve Bawn mountains to the south of the study area. These are remnants of a former ocean floor that have been lifted up on the east side of the Strokestown Fault that trends northeast to southwest through the study area.³⁵

There are other faults also trending northeast to southwest within the study area, one separating the Oakport and Ballymore Formation in the northwest and another separating the Bricklieve and Croghan Formations. There is a parallel northeast to

southwest fault to the east of the Strokestown Fault. There are two northwest to southeast trending faults to the north and south of the Aghamore Formation across the eastern end of the study area.⁵

ERA: PALAEOZOIC	Period: Carboniferous (355 million years ago)	Mudbank Lst Fmn Age: Arundian - Asbian
		Bricklieve Lst Fmn Age: Arundian - Asbian
		Ballymore Lst Fmn (Age: Chadian-Asbian)
		Croghan Lst Fmn (Age: Chadian-Asbian)
		OakPort Lst Fmn (Age: Chadian-Asbian)
		Fernaght sst/conglomerate Fmn (Age: Courceyan)
	Period: Ordovician (488 million years ago)	Aghamore Fmn (Age: Ashgill)
		Finnalaghta Greywacke Fmn (Age: Caradoc)

Plate 3: Geological Time Scale

The older Ordovician meta sediments and volcanistic breccias to the southeastern end of the study area are possibly a harder rock type than the adjacent limestones mostly due to how they were formed. The chemical make-up of these formations increase the acid sulphate rock potential which could be significant if reusing this material as engineering fill.

6.5.2 Lithology

Oakport Limestone underlies a small portion towards the western extent of the study area near the Carrick-on-Shannon Golf Club for approximately 100m, transitioning to the Ballymore Limestone which is one of the predominant rock types within the study area. The GSI mapping shows a fault line in a northeast to southwest direction separating the Oakport and Ballymore Limestone formations.⁵

The Ballymore Limestone consists of a basal unit of medium bedded crinoidal calcarenites, followed by a middle unit of thin bedded dark nodular limestones with thick interbeds of calcareous shale. A large number of outcrop areas within this formation are shown on the GSI mapping across the study area.⁵

Moving along the existing N4 through the study area in an eastward direction the Ballymore Limestone transitions into the Croghan Limestone at the intersection of the N4 and the Boyle River. The Croghan Limestone is one of the predominant rock types within the study area consisting of muddy limestone with irregular developments of shale partings. The GSI mapping shows a large number of

outcrops within this formation south of the River Shannon and Carrick-on-Shannon.⁵

A portion of the study area north of Carrick-on-Shannon and the Croghan Limestone formation is underlain by Bricklieve Limestone, described as bioclastic cherty limestone. The GSI mapping shows a fault line in a northeast to southwest direction intersecting the study area at the boundary of the Croghan Limestone and the Bricklieve Limestone formations, near the intersection of the R299 and the L3409.⁵

The Croghan Limestone is the underlying rock as far as the eastern side of Carrick-on-Shannon, transitioning back into the Ballymore Limestone until just south of the Drumgilra Lough.⁵

The southeastern portion of the study area transitions back into the Oakport Limestone before transitioning into the Aghamore formation for approximately 1km, described as lava and volcanoclastic breccia. Two fault lines lying in a northeast to southwest direction sit on the west and east boundary of the Aghamore formation.⁵

As the study area moves along the N4 the Aghamore formation transitions into the Fearnaght formation, described as a cream conglomerate and red sandstone. The Fearnaght formation is intersected by the Finnlaghta formation for approximately 1.5km, described as blue-grey greywacke & black argillite. The boundary between the Fearnaght and Finnlaghta formations is shown on the GSI mapping as being an unconformity.⁵

Table 11: Summary of bedrock geology within the study area⁵

Geological Period	Formation	Description
Carboniferous	Mudbank Limestone	Mudbank Limestone.
Carboniferous	Bricklieve Limestone	Lithological Summary: Bioclastic cherty limestone. The formation comprises 6 informal groups, which consist of medium to thickly bedded grey bioclastic limestones, generally wackestones and packstones devoid of internal bedding features. The groups are separated by lithostrotionid-rich intervals.
Carboniferous	Ballymore Limestone	Lithological Summary: Black calcarenites and shales. A basal unit of medium bedded crinoidal calcarenites, followed by a middle unit 40m thick of thin bedded dark nodular limestones with thick interbeds of calcareous shale. A small carbonate mudbank occurs within the middle unit.
Carboniferous	Croghan Limestone	Lithological Summary: Muddy limestone and calcarenites. The lowest member comprises 40m of thin-bedded brown-weathering muddy limestone with irregular development of shale partings. The middle member is a distinctive 15m massive even-bedded crinoidal, occasionally oolitic, calcarenite.

Geological Period	Formation	Description
Carboniferous	Oakport Limestone	Lithological Summary: Dark crinoidal calcarenites and shales. A basal member, 27m thick, of clean fine calcarenite contains occasional coarse crinoidal beds and argillaceous wackestones. It is overlain by a distinctive unit dominated by fine peloidal calcilutites and laminated calcilutites.
Carboniferous	Fearnaght Formation	Lithological Summary: Cream conglomerate and red sandstone. It is composed of cream coloured quartz-pebble conglomerate with a sandy matrix, subarkose and red and purple micaceous flaggy sandstones and purple and brown quartzites.
Ordovician	Aghamore Formation	Lithological Summary: Lava and volcanoclastic breccia. Principally spilitic lavas and volcanoclastic conglomerate, with only relatively minor amounts of interflow sediments. These include greywacke, and chert and shale, which are most abundant in the southern parts.
Ordovician	Finnalaghta Formation	Lithological Summary: Blue-grey greywacke & black argillite. Almost entirely consists of bluish-grey, non-calcareous greywacke, which is composed of quartz, felsic igneous and micaschist detritus. Black argillites, 1m to 15m thick, also occur.

6.5.3 Depth to Bedrock

A review of the GSI Bedrock Outcrop, GSI Quaternary map and GSI Groundwater Vulnerability map was completed, locations of bedrock outcrops or subcrops provide an indication of areas with a greater potential of shallow bedrock.^{5 3 22}

The following areas have been identified as having a greater potential to shallow bedrock:

- Across the western end of the study area
- South of Carrick-on-Shannon
- North of Carrick-on-Shannon
- North of Jamestown
- South of Jamestown and River Shannon
- Large areas across the eastern portion of the study area east of Drumgilra Lough

From the available existing ground investigation information, the depth to bedrock across the study area varies from 0.6mBGL to 20mBGL.

6.6 Karst Features

The GSI Karst database was consulted to determine if the Carboniferous limestone formations within the study area are karstic and contain karst solution features. There is one recorded feature within the study area in the Croghan Limestone formation; the Toberconellan spring located approximately 2.0km south of Carrick-on-Shannon, south of the railway station.²⁶

There are a significant number of karst features (including springs, enclosed depressions, turloughs and swallow holes) surrounding the study area (some of these features are approximately 500m offset from the study area boundary) recorded to the south and west of Carrick-on-Shannon within the Oakport Limestone, Ballymore Limestone and Croghan Limestone formations.²⁶

This indicates that these lithologies could be susceptible to karstification and karst features could exist within the study area. The karst features have either not been mapped or the limestone is locally less susceptible to karstification. This could be due to a lower calcium carbonate content, or it is overlain by subsoils which impede karstification or have infilled karst features. It is also notable that there is a relatively high density of small streams, tributaries to the River Shannon, in the study area which in places flow through areas mapped where rock is close to surface. This relatively high drainage density (length of river channels per unit area) is not expected in karst aquifers where drainage is predominately underground and again may suggest that the bedrock is less susceptible to karstification in the study area.

6.7 Landslide Susceptibility

The GSI has developed a landslide susceptibility map for the entire area of the Republic of Ireland.³⁸

Generally, landslide susceptibility is correlated to the topography, so the areas with higher landslide susceptibility are in the higher, steeper elevations, coastal cliffs and valley sides. The majority of the study area has a low landslide susceptibility with localised areas having a moderately low to moderately high susceptibility. These locations are recorded mainly in areas of peat and along the banks of the River Shannon. One significant area with a moderately high susceptibility rating is located along the R368 south of Carrick-on-Shannon in the town land of Killukin. This area appears to be located on the eastern side of a drumlin in glacial till and shallow bedrock. There are no recorded landslides by the GSI within the study area.³⁷

A request has been made to Leitrim and Roscommon County Councils for details and locations of any instabilities throughout the study area. The following has been reported and the location is shown on Figure 4.15.4.0 to 4.15.4.5:

- **Cut Slope Failure at Lisseeghan:** a 150m long section of failing cut (1V:1.5H to 1V:2H) on the existing N4, 2km southeast of Carrick-on-Shannon towards the townland of Lisseeghan. Shallow failures (possibly due to an existing over steepened slope) were noted on the slope and stabilised using a 3m high Terramesh wall.

6.8 Soft Ground and Compressible Soils

The extent of soft ground is a key constraint within the study area, soft ground areas recorded on the GSI Quaternary map are shown on Figure 4.15.4.0 to 4.15.4.5. The deposits are so widespread that any potential option will impact these deposits. Typically, these subsoils will be excavated and replaced with suitable engineering fill or undergo ground improvement. The excavated soft ground may require a repository within the study area. In areas of cut, landtake in soft ground could be significant. It should be noted that the organic content of the peat deposits will significantly impact the CO₂ rating for the potential options in the study area. Refer to Section 6.4 for further details on locations of the soft soil deposits across the study area.

A request has been made to Leitrim and Roscommon County Councils for details and locations of any engineering problems and instabilities associated with soft ground throughout the study area. The following have been reported and are shown on Figures 4.15.4.0 to 4.15.4.5:

- **Embankment Failure at Corbally:** It was reported in the 2010 Roughan & O'Donovan N4 Carrick-on-Shannon to Dromod Road Project Constraints Study Report that in 2003 a localised section of the Jamestown Drumsna Bypass embankment failed near the townland of Corbally. The cause was deemed to be failure of the soft soils (approximately 3.0m deep) under the existing embankment during remedial works to widen the road.

The following significant area of soft ground was reported in the 2010 Roughan & O'Donovan N4 Carrick-on-Shannon to Dromod Road Project Constraints Study Report:⁵⁸

- **N4 Piled Embankment:** A Piled embankment was constructed in 2001/2002 as part of the Jamestown to Drumsna Bypass, north of Drumgilra Lough across a 300m long section of soft ground, soft ground depths up to 8mBGL.

Soft organic soils such as peat and alluvium are highly compressible and subject to instability and significant long-term settlement if not engineered properly.

6.9 Current Land Use

The primary land use within the study area is agricultural with farming and the agri-food industry important elements of local economies.

A number of areas of private managed forestry plantations are located within the study area.

The River Shannon and its associated loughs also form part of the study area and large areas adjoining these water bodies are identified as flood risk zones.

These areas also have strong amenity value to the study area and significant parts along the river are identified as being of High Visual Amenity value in the Leitrim County Development Plan 2015 – 2021.

There are a number of settlements within the study area. These include Carrick-on-Shannon, Cortober, Drumsna and Jamestown. These settlements are the focus for the majority of residential populations within the study area as well as local businesses and public, community, sporting and educational facilities.

In addition, the study area exhibits dispersed one-off rural dwellings in the open countryside and a number of small development clusters, often in the form of ribbon development along existing public roads.

There are a number of protected structures and other heritage listed buildings within the study area, mainly concentrated within the urban settlements.

The 2018 Corine Land Cover Map³³ also shows a number of inland marshes located north and northwest of Carrick-on-Shannon, along the western and northern banks of Lough Corry and on the western bank of Drumgilra Lough.

The 2018 Corine Land Cover Map³³ also shows a mineral extraction area located on the north western bank of Drumgilra Lough at the location of the current Masonite Ireland industrial facility,

6.10 Historical Land Use

A review of historical maps and contemporary aerial photographs available from the OSI (Geohive)¹⁸ and Google Maps³⁰ was completed. Findings of this review are summarised in **Table 12** and the relevant identified constraints are presented on Figure 4.15.4.0 to 4.15.4.5.

Table 12: Review of historical maps and aerial photographs^{18 30}

Year	Description
Historic Map 6" 1837-1842 (OSI)	The study area is shown to predominantly comprise agricultural land with occasional wooded areas, and intermittent farm buildings connected by various roads and tracks. Larger developed areas are recorded at Carrick-on-Shannon, Jamestown and Drumsna. These areas are shown to comprise a number of small to medium sized buildings, gardens and wooded areas. The Carrick-on-Shannon bridge is shown connecting the northern and southern portions of Carrick-on-Shannon over the River Shannon. Large wooded areas are shown adjacent to the River Shannon between the Jamestown and Drumsna in the townlands of Charlestown and Mount Campbell. The River Shannon is shown as meandering through the study area from north to south with a number of tributaries throughout. The "line of winter floods" is shown either side of the River Shannon, intersecting the town of Carrick-on-Shannon. The Jamestown canal is shown running from Ardannafrin (just south of Jamestown) to Lough Nanoge. A number of small loughs are shown south of the River Shannon, possibly used for agricultural purposes. Several quarries are recorded throughout the study area, these are included in Section 6.11 and on the Soils and Geology Constraints Map (Figures 4.15.4.0 to 4.15.4.5) Two iron mines are shown south of Aghamore at the eastern end of the study area.

Year	Description
	Other industrial sites shown throughout the study area include corn and flour mills and corn kilns. Other items to note include forts and spa wells and areas labelled as ‘water’. The location of the current N4 is shown as being occupied by agricultural land, wooded areas, roads, with parts sitting within areas labelled as ‘Liable to Floods’.
Historic Map 25” 1888-1913 (OSI)	The study area is generally unchanged, predominately comprising agricultural land. Some further developments have taken place, these include the MGWR rail line running northwest to southeast through the study area. The Carrick-on-Shannon station and Drumsna station sit south of the River Shannon. Other developments include the subdivision of several properties throughout the study area, a new Union Workhouse and hospital in Carrick-on-Shannon, an Electric Light Works & Pumping Station on the western side of Carrick-on-Shannon, the Carrick-on-Shannon water works reservoir, a disused gasworks site near the Carrick-on-Shannon station and some minor changes to the Jamestown Canal alignment. Several spa wells, wells and springs are shown throughout the study area with some of these labelled ‘sulphur’, a new quarry is also shown in the Townland of Dangan (Nugent) south of the MGWR rail line and Jamestown Canal. In the townland of Drumcleavry south of the River Shannon there appears to be a new embankment or flood defence labelled ‘The Doon’. A number of other areas adjacent to the River Shannon also appear to have new embankments or flood defences that were not previously recorded. The quarries previously recorded are either not shown or are labelled as disused or no longer labelled. A disused gravel pit is shown in Kildorragh near an area previously recorded as a quarry. The two iron mines previously recorded near the townland of Moher are no longer shown. Several graveyards are shown throughout the study area. The location of the current N4 is shown as being occupied by agricultural land, wooded areas or roads, with parts sitting within areas labelled as ‘Liable to Floods’ and adjacent to disused quarries.
6” Cassini 1930s (OSI)	The study area is still shown to be predominately used for agricultural purposes. Some residential developments are shown around Carrick-on-Shannon. A pumping station is shown adjacent to the River Shannon near the Electric Light Works & Pumping Station site. Two pumping houses are shown within Carrick-on-Shannon along with a reservoir. Several graveyards, cemeteries, and burial grounds are shown throughout the study area. A number of areas are labelled as ‘water’ throughout the study area. No quarries are noted within the study area. Several locations are labelled ‘Spa Well (sulphur)’. The areas adjacent to the River Shannon are labelled ‘Liable to Floods’. The location of the current N4 is shown as being occupied by agricultural land, wooded areas or roads, with parts sitting within areas labelled as ‘Liable to Floods’.
Aerial 1995 (OSI)	The study area is still predominately used for agricultural purposes. Further developments have occurred within Carrick-on-Shannon, including residential buildings, the N4 bypass between R903 and R280 and part of the St Mary’s GAA sports club.

Year	Description
	The construction of the Jamestown to Drumsna N4 bypass is shown, with what appears to be an active quarry shown adjacent to the N4 near the intersection of the N4 and L3656, at the location of the Kiltycarney Quarry. What appear to be borrow / waste sites potentially used as part of the Jamestown to Drumsna N4 bypass are shown near the intersection of the N4 and the R299. Some developments have occurred in Jamestown, including at the location of the current Rosderra Irish Meats site. A number of residential developments are shown throughout Drumsna. The Finnalaghta Quarry is shown as being active. The location of the landfill sites named Tom Cullen, Sean McWeeney and John Beirne (detailed in Section 6.11) adjacent to Leitrim Road north of Carrick-on-Shannon appear to be active.
Aerial 2000 (OSI)	The study area is still predominately used for agricultural purposes. The commencement of construction of the N4 within the townland of Cloongownagh is shown. Further developments are shown in Carrick-on-Shannon including shopping, residential and industrial areas. The St Mary's GAA Sports club appears to be completed. The construction of the Jamestown to Drumsna N4 bypass appears to be completed, the Kiltycarney quarry is shown as being infilled with part of the site now occupied by a lake. The development of the Masonite (Ireland) Limited site adjacent to Drumgilra Lough is shown. The site of the Finnalaghta Quarry is shown as still being active. The construction of an additional canal adjacent to the Jamestown Canal is shown. The location of the landfill sites named Tom Cullen, Sean McWeeney and John Beirne (detailed in Section 6.11) adjacent to Leitrim Road north of Carrick-on-Shannon appear to still be active.
Aerial 2005 (OSI)	The study area is still predominately used for agricultural purposes. The construction of the N4 across the townland of Cloongownagh appears to be completed. Further residential developments are shown in Carrick-on-Shannon, Jamestown and Drumsna. Some developments along the River Shannon are shown which appear to be small boat docks. The construction of the additional canal adjacent to the Jamestown Canal is complete and in operation. The Finnalaghta Quarry site appears to have been expanded and still in operation. The location of the landfill sites named Tom Cullen, Sean McWeeney and John Beirne (detailed in Section 6.11) adjacent to Leitrim Road north of Carrick-on-Shannon appear to be disused.
Aerial 2020 (Google Maps)	The study area is still predominately used for agricultural purposes. Further developments are shown within Carrick-on-Shannon, including industrial, shopping and residential areas. The Finnalaghta Quarry site appears to be disused with parts filled with water. There are seven petrol stations recorded within Carrick-on-Shannon. There is one petrol station recorded within the Drumsna.

6.11 Contaminated Sites and Unsuitable Material

Potential sources of contamination within the study area have been investigated and identified into the following four categories as described in the following sections:

- Landfills (licensed and historical)
- Pits, quarries and mines (historical)
- Industrial facilities (licensed and historical)
- Historical land use contamination

Publicly available records both online and within Leitrim and Roscommon County Councils have been consulted to determine the type and location of sites that are possibly contaminated or possibly store unsuitable material. It is possible there are such facilities that are not officially recorded and therefore these are not shown on the Constraints Figures or reported in this document.

6.11.1 Landfills

In 1996 the EPA began licensing certain activities in the waste sector. These include landfills, transfer stations, hazardous waste disposal and other significant waste disposal and recovery activities. These are potential geological constraints as they may act as areas of contamination.

There is one EPA licensed waste facility^{14 15} (and Water Framework Directive Article 5 Landfill⁸) recorded within the study area as shown on Figure 4.15.4.0 to 4.15.4.5, this facility has the following details:

- Carrick-on-Shannon Landfill, Ballynamoney – Active Licence Number W0064, operations ceased in 2005. Operated as a waste disposal facility for domestic, commercial and industrial waste in addition to sewerage sludge between 1965 and 2005.

According to the EPA there are no known historical (or ‘legacy’) landfills within the study area.⁵⁰

According to the EPA there are no Waste Facility Permits or Certificates of Registration within the study area.⁴⁹

Leitrim and Roscommon County Councils have been consulted for their records of landfills and waste related sites. The following areas of potential fill have been identified from information provided by Leitrim and Roscommon County Council on surveys undertaken to inform a previous road scheme through the study area in the early 2010s and are shown on Figure 4.15.4.0 to 4.15.4.5

- To the south of the Ballynamoney Landfill is an area of made ground or fill material. This site was identified as three old waste permit facilities which have since been filled in. These sites have been reported by Roughan & O’Donovan in 2010 as comprising a mixture of clay, gravel and peat.⁵⁸

- A waste permit site is located near the R280, north of Carrick-on-Shannon. This site is surrounded by heavily developed residential areas while this site remains undeveloped. The nature of the material at this site is unknown.
- Close to Carrick-on-Shannon, west of the R280 is an old waste permit site, this site is situated to the rear of some older houses with large gardens and therefore remains somewhat undeveloped. The nature of the material at this site is unknown.
- St Mary's GAA sports grounds were once registered as an old permit site and therefore as an alternative land use this site has been developed as a sports facility. The nature of the material at this site is unknown.
- A waste permit site just west of Carrick-on-Shannon in the Drishoge Townland, operator unknown. The nature of the material at this site is unknown.
- Three old permit sites were identified in the Roscommon area in the Cloongownagh Townland along the existing N4, approximately 2.5km west of Carrick-on-Shannon. These are thought to have been used for the recovery and disposal of material as part of the N4 realignment.
- Three sites south of Carrick-on-Shannon station which have been reported as being used for the importing of natural subsoil to raise the level of the agricultural land.
- A waste site is located close to Finnalaughta with an area of 26,690m²; this site is located parallel to the existing N4. The nature of the material at this site is unknown.
- Jon's Civil Engineering Company who was the main Contractor on the Dromod-Roosky Bypass which was constructed in 2006/2007 has two registered waste sites in this area, a small site close to the road and a larger site near Fearnaght with an area of 15,421m². It is possible that these areas were used as borrow pits for earthworks on the Dromod-Roosky Bypass and subsequently for disposal of unsuitable soft soils that were excavated and replaced along this section of new road. The 2009 ground investigation completed by Priority Geotechnical Ltd reported a mixture of peat, clay, silt, sand and sandstone, siltstone and limestone gravel.

6.11.2 Historical Pits, Quarries and Mines

Historical pits and quarries are potential sources of ground contamination or unsuitable material as the nature of backfill material is generally highly variable and unregulated. According to the GSI records there are 39 historical pits and quarries within the study area.⁹

The Department of the Environment, Climate and Communications show no historic mines within the study area.⁵¹

The EPA records show there are no known WFD Article 5 Mines within the study area.⁸

According to the EPA there are no historic mines within the study area.^{8 53}

From the review of the OSI 6 Inch 1837 to 1842 historic mapping there are two iron mines shown south of Aghamore at the eastern end of the study, these two sites are not shown on the OSI 25 Inch 1888 to 1913 historic mapping.¹⁸ The location of these two sites are currently listed as mineral locations (Mineral Location Reference 1736 and 1737) within the GSI Mineral Localities dataset.¹²

Leitrim and Roscommon County Councils have been consulted for their records of historic pits, quarries and mines within the study area. The following site has been reported within the study area:

- Kiltycarney Quarry (Quarry currently not endorsed by the local County Council), was authorised for activity during the construction of the Jamestown - Drumsna Bypass. A condition of the permission given was that the quarry is rehabilitated within six months of completion of the scheme. This did not occur and therefore this quarry is unauthorised and at present it is not active.

The known historic quarries, pits and mines to the Local Authorities, the GSI and the EPA are shown on Figure 4.15.4.0 to 4.15.4.5.

6.11.3 Industrial Facilities

Existing and historic industrial sites may potentially be a source of local contamination and/or restrictions due to site activities or licence controls. However, these sites operate within the EPA Industrial Emissions (IE) and Integrated Pollution Control (IPC) licence framework and due to the regulated nature of their activities, the risk of contamination is low. A request has been made to Leitrim and Roscommon County Councils for information pertaining to industrial facilities within the study area. The IE/IPC licenced sites listed in Table 13 and shown on Figure 4.15.4.0 to 4.15.4.5 have been reported within the study area.^{16 17}

Table 13: IE/IPC licenced industrial facilities^{16 17}

RegCD	Name	Licence Status	Licence Type	Address
P0641-01	Irish Rubber Components Limited	Surrendered	IE	Tullyleague, Carrick-on-Shannon Roscommon
P0021-02	Masonite Ireland	Licenced	IPC	Derryoughter, Drumsna, Carrick-on-Shannon, Leitrim

Similarly, sites which have been granted a wastewater discharge licence may be a source of contamination or development restrictions. There are a number of wastewater discharge sites listed by Irish Water and the EPA within the study area, summarised in Table 14.²⁰

Table 14: Urban Wastewater Treatment Plant locations (UWWTP) with a wastewater discharge licence recorded by Irish Water and the EPA within the study area²⁰

Irish Water Reg No.	Name	Authorisation Type	Agglomeration Name	Licence Status	Category
D0154-01	Irish Water	Licence	Carrick-on-Shannon	Licensed	Urban Waste Water
A0465-01	Irish Water	Certificate	Jamestown	Certified	Urban Waste Water
A0467-01	Irish Water	Certificate	Drumsna	Certified	Urban Waste Water

There are two WFD Section 4 discharge points within the study area, these are summarised in Table 15.^{19 8}

Table 15: WFD Section 4 Discharge Points within the study area^{19 8}

Registration Number	Status	Name	Location
WP 1-11A	Unknown	Jones Oil Ltd	Carrick-on-Shannon
WPL/11/02	Unknown	Rosderra Meats	Leitrim

There are two WFD Article 5 Waste Water Treatment Plants (WWTP) and one WFD Article 5 Water Treatment Plant (WTP) within the study area, these are summarised in Table 16.⁸

Table 16: WFD Article 5 WWTP and WTP Locations within the study area⁸

Point Code	Type	Name
SH_WWTP0073	WWTP	Carrick-on-Shannon
SH_WWTP0076	WWTP	Drumsna
SH_WTP0017	WTP	South Leitrim Regional Water S

6.11.4 Historic Land Use Contamination

Land contamination is related to site history and previous land use which can leave contaminants in the ground depending on historic site activities. The extent of soil contamination from historic land uses are typically localised. The NRA guidelines³⁴ do not define specifically what is a heavy or light industry. The following categories are recommended:

Heavy industries include;

Medium to large scale industries, such as power stations, gas works, wastewater treatment plants, other municipal facilities, etc.

According to the review of the OSI 1830's and 1890's historic mapping and the EPA records, the following medium to large-scale industries are located within the study area and presented on Figure 4.15.4.0 to 4.15.4.5:¹⁸

- One historic gas works site located on the western side of Carrick-on-Shannon near the Carrick-on-Shannon Railway Station (E:593042, N: 798676)
- One historic power station labelled as "Electric Light Works & Pumping Station" on the 25 Inch 1888-1913 historic map, located within Carrick-on-Shannon (E:593734, N: 800030)

Industries that involve significant amounts of harmful chemicals or metals such as dry cleaning, soap works, smithy, foundry, lime kilns etc.

According to the review of the OSI 1830's and 1890's historic mapping the following are located within the study area and are presented on Figure 4.15.4.0 to 4.15.4.5:¹⁸

- Three historic corn mills; one south of Carrick-on-Shannon (E:592907, N:797726), one north of Carrick-on-Shannon and the other east of the River Shannon adjacent to the R201 (E: 602404, N:796798)
- Two Historic rail station sites; one on the western side of Carrick-on-Shannon called the Carrick-on-Shannon station (E:592993, N: 798776) and the other south of Jamestown called Drumsna station (E: 598800, N: 795684)

Light Industries include;

According to the OSI 1830's, 1890's and Cassini historic mapping the following light industries exist across the study area:¹⁸

- One Historic Flour Mill in the town of Jamestown
- One Historic corn store in the town of Drumsna
- Two Historic corn kilns:
 - One in the townland of Corry
 - One on the western side of Lough Tap
- Four Historic water pumps:
 - Two in Carrick-on-Shannon
 - One in Jamestown
 - One approximately 600m east of Drumgilra Lough
- The Carrick-on-Shannon Water Works site located next to the St Patricks Community Hospital in Carrick-on-Shannon
- One Historic pumping station adjacent to the South Leitrim Regional Water Treatment Plant in Carrick-on-Shannon

6.12 Economic Geology

The economic geological features within the study area have been subdivided into the following categories:

- Crushed rock aggregate potential
- Granular aggregate potential
- Active pits, mines and quarries
- Mineral resource locations
- Areas containing deep, well drained soils suitable for agriculture as detailed in Section 6.3

6.12.1 Granular Aggregate Potential

The GSI Granular Aggregate Potential Mapping categorises granular deposits in terms of aggregate resource into five levels, from very high potential to very low potential.¹³ The study area has portions with very low to high potential. There are several zones of granular aggregate potential within the study area. The moderate to high potential granular aggregate deposits are located in the alluvial deposits along the alignment of the River Shannon and its tributaries as shown on Figure 4.15.4.0 to 4.15.4.5.

6.12.2 Crushed Rock Aggregate Potential

GSI carried out national crushed rock aggregate potential mapping between 2007 and 2013.³⁹ The maps are compiled based on the lithology, as well as existing and historic quarry activity. The final scores have five bands ranging from very low potential (blue) to very high potential (red) and have been applied to the entire area of the Republic of Ireland. The portion of the study area north and east of the River Shannon ranges between moderate to very high potential with some pockets of low potential. The portion of the study area south of the River Shannon typically has a low potential with some large areas of moderate to high potential.

6.12.3 Active Pits, Mines and Quarries

The GSI 2014 Quarry Directory was consulted.⁶ There are no recorded active pits, mines or quarries within the study area.

The Department of the Environment, Climate and Communications show no active mines within the study area.⁵¹

Leitrim and Roscommon County Councils have been consulted for their records of active pits, quarries and mines within the study area. The following areas of potential pits, quarries and mines have been reported as being within the study area:

- Finnalaghta Quarry (not endorsed by the local County Council) situated to the east of the River Shannon, according to the GSI database, this was once a disused sandstone quarry. Presently it is a registered quarry, register number QS0226, EPA register details are presented in Table 17.

The EPA Extractive Industries Register (2015) was consulted.⁷ There is one recorded active quarry within the study area, details are provided in Table 17. The EPA Extractive Industries Register did not distinguish what the quarry is used for, i.e. sand/gravel or rock.

Table 17: EPA 2015 Registered Quarry Locations within the study area⁷

Register Number	Name	Site Address
QS0226	Ballyfeeney Rock Ltd.	Aghamore, Carrick-on-Shannon, Co. Leitrim

The active and inactive pits and quarries known to the Local Authorities and according to the GSI and EPA records are shown on Figure 4.15.4.0 to 4.15.4.5.

6.12.4 Mineral Resource Locations

The location of mineral resources is shown on Figure 4.15.4.0 to 4.15.4.5. There are ten licences held for prospecting within the study area.⁵¹

Six of these are ‘Open – Exploration Incentives’ as follows:

- Prospecting Licence 2769
- Prospecting Licence 2766
- Prospecting Licence 4462
- Prospecting Licence 4463
- Prospecting Licence 1668
- Prospecting Licence 2705

Four are ‘Open’ as follows:

- Prospecting Licence 3585
- Prospecting Licence 3888
- Prospecting Licence 3889
- Prospecting Licence 3686

There are a number of mineral resource locations within the study area according to the GSI Mineral Localities database¹², these are summarised in Table 18.

Table 18: Summary of mineral localities (GSI) within the study area¹²

Mineral location reference	Key mineral	Townland
5054	Limestone	Hughestown
2589	Ironstone	Dergvone
4821	Fluorspar and pyrite	Tully
4822	Fluorspar and pyrite	Tully
4820	Fluorspar	Carrick
1736	Haematite	Gortinee
1737	Haematite	Gortinee
1734	Greywacke	Finnalaghta
1735	Sandstone	Fearnaghta

6.13 Geological Heritage

A database of geological heritage sites is maintained by the GSI in partnership with the National Parks and Wildlife Service (NPWS).^{10 11} There are no geological sites of national importance within the study area.

There is one County Geological Site (CGS) and two unaudited sites within the study area. The GSI was consulted on whether there are any imminent changes to the geological heritage sites database for County Leitrim and County Roscommon. There are no imminent changes for County Roscommon. It was noted by the GSI that County Leitrim is an ‘unaudited’ county and is currently being audited with more information becoming available over the coming months. The three sites are detailed in Table 19 and are shown on Figure 4.15.4.0 to 4.15.4.5.

CGS do not receive statutory protection like Natural Heritage Areas (NHA) but receive an effective protection from their consideration in the planning system. However, GSI consider many of the County Geological Sites to be of national importance as they are the best representative example of particular geological formations or features. They will be formally proposed by the GSI, for designation as NHAs by the National Parks and Wildlife Service after due survey and consultation with landowners.

Table 19: Geological Heritage Sites^{10 11}

Site name	Site code	Designation	Characteristics
Mid Roscommon Ribbed Moraines	RO022	CGS	This field of ribbed moraine forms part of a small, discrete field northwest of Slieve Bawn.
Gortinee	-	CGS (Unaudited)	Iron ore in tholeiitic volcanics, Mined as early as the 16thC; smelted at Dromod and Arigna.
Finnalaghta Quarry	-	CGS (Unaudited), may be recommended for NHA	Lower Palaeozoic D1 structure, termed “transected monocline”.

6.14 Hydrology

6.14.1 Surface Water Features

The River Shannon is the most notable river within the study area. The River Shannon is Ireland’s longest river, flowing from the Shannon Pot, County Cavan to the Shannon Estuary, at the border of Counties Clare and Kerry. The river meanders through the study area from north to south. The primary river crossing, on the existing N4, is by the River Shannon Bridge in Carrick-on-Shannon. In the townland of Cloonavery, on the L3656 there are two local road crossings of the River Shannon where it forms a horseshoe bend.

The study area lies between the major lakes of Lough Allen and Lough Ree which are connected by the River Shannon. There are two smaller lakes, Lough Corry and Lough Tap, along the river within the study area.

There are a number of other smaller watercourses within the study area including the Killukin River, Jamestown Canal and numerous tributaries and streams either side of the River Shannon.

The flow in the River Shannon has been controlled for over 200 years to aid navigation and was further modified in the 1920's to facilitate the ESB hydro-electric power station at Ardnacrusha. The water levels in Lough Allen and the discharge from the lake are regulated by a control structure at Bellantra at the outlet of the lake. The present policy of the ESB is to maintain a minimum discharge of 5m³/s from Lough Allen under normal flow conditions and to discharge such flow as will result in a desirable maximum water level in the lake of 46.98mOD during flood conditions.

All the lands within the study area are drained to the River Shannon through the extensive network of tributaries and lakes.

The fall between Lough Allen and Lough Derg, a distance of 190km is only 13m. the results of this slow-moving river are evident in the developed meanders along the river which indicate that the river has a relatively low energy level.

6.14.2 Catchments

From the GSI Groundwater Catchment and WFD Management Units map the study area intersects the Upper Shannon catchment (catchment IDs: 26C, 26B, 26A).

The Upper Shannon catchment covers an area of 8,900 km². The catchment has two distinctive reaches and has a very shallow gradient within the study area.

6.14.3 Flooding

Based on the OPW River Flood Extent maps, the study area is shown to have extensive areas with a high risk to fluvial (rivers) flooding.⁵² In addition, the OPW Past Flood Events database shows multiple past flood events across the study area, including locations which have been affected by more than one flood event.⁵²

The GSI Winter 2015/2016 Surface Water Flooding Map shows a large number of surface water flood types recorded along the River Shannon and in adjacent lakes within the study area.²⁷

The GSI Groundwater Flood Data Maps²⁷ were consulted and two small areas of historic groundwater flooding are recorded within the study area. One area, with GSI reference GW3236, is located around 3km south of Carrick-on-Shannon within the townland of Kiltycarney. The area of groundwater flooding recorded was 1.2ha. The second, is located approximately 0.5km west of Cartron Lough, with a groundwater flooding area of 0.4ha recorded.

The two areas of historic groundwater flooding within the study area are identified on the Hydrogeological Constraints Map (Figure 4.14.3.0 to 4.14.3.5).

6.15 Hydrogeology

6.15.1 Aquifer Classification and Groundwater Bodies

The Geological Survey Ireland (GSI) have classified geological strata for hydrogeological purposes based on the value of the groundwater resources and the hydrogeological characteristics. There are three principal categories of aquifer, corresponding to whether they are major, minor or unproductive resources whereby:

- Regionally Important Aquifers are capable of supplying regionally important abstractions (e.g. large public water supplies), or excellent yields ($>400 \text{ m}^3/\text{d}$)
- Locally Important Aquifers are capable of supplying locally important abstractions (e.g. smaller public water supplies, group schemes), or good yields ($100\text{--}400 \text{ m}^3/\text{d}$)
- Poor Aquifers are capable of supplying small abstractions (e.g. domestic supplies), or moderate to low yields ($<100 \text{ m}^3$)

The three principal aquifer categories are further subdivided into 10 aquifer sub-categories²³ in Table 20.

Table 20: Aquifer category²³

Aquifer category	Sub-category description	Code
Regionally Important (R)	Karstified Bedrock dominated by diffuse flow	(Rkd)
	Karstified Bedrock dominated by conduit flow	(Rkc)
	Fissured bedrock	(Rf)
	Extensive sand & gravel	(Rg)
Locally Important (L)	Sand & gravel	(Lg)
	Bedrock which is Generally Moderately Productive	(Lm)
	Bedrock which is karstified to a limited degree or limited area	(Lk)
	Bedrock which is Moderately Productive only in Local zones	(Ll)
Poor (P)	Bedrock which is Generally Unproductive except for Local zones	(Pl)
	Bedrock which is Generally Unproductive	(Pu)

Examples of significant impacts to aquifers due to construction works and operation of transport infrastructure are as follows:

- The disruption of groundwater flow paths during earthworks
- Reduced yield and groundwater levels in groundwater supplies adjacent to earthworks or road cuttings
- Disruption of baseflow to groundwater fed rivers or fens
- Contamination of the aquifer through accidental spillage

The aquifer classification and groundwater bodies within the study area are summarised in Table 21. Four aquifer classifications are present in the study area as shown on Figure 4.14.2.0 to 4.14.2.5. These are also listed in Table 21.

There are five types of groundwater rock units present within the study area:

- The Dinantian Pure Bedded Limestones are mapped across the majority of the study area and are classified as a Regionally Important Aquifer (Rkc)
- The Dinantian Sandstones are located in the southwestern part of the study area and are classified as a Locally Important Aquifer (Lm)
- The Mudbank Limestone is located in a small section to the south of the site and is classified as a Locally Important Aquifer (Ll)
- To the southwest of the study area, Ordovician Volcanics and Ordovician Metasediments are present which are classified as a Poor Aquifer (Pl)

There are no gravel aquifers mapped by the GSI within the study area.

Table 21: Aquifer classification²³ and groundwater bodies⁴⁴ within the study area and NRA importance ranking³⁴

Aquifer classification	Bedrock formation (1:100,000 GSI Bedrock Map)	Groundwater rock unit	Groundwater body	Constraint importance ranking (NRA)
Rkc	Croghan Limestone Formation & Bricklieve Limestone Formation & Ballymore Limestone Formation & Oakport Limestone Formation	Dinantian Pure Bedded Limestones	Carrick-on-Shannon	Very High
Lm	Fearnaght Formation	Dinantian Sandstones	Scramoge North	Medium
Ll	Mudbank limestone	Dinantian Pure Unbedded Limestones	Carrick-on-Shannon	Medium
Pl	Aghamore Formation	Ordovician Volcanics	Kilglass Dromod	Low
Pl	Finnalaghta Formation	Ordovician Metasediments	Scramoge North	Low

Refer to Section 6.6 for information on karst features.

6.15.2 Aquifer Vulnerability

Aquifer vulnerability is the term used to describe the intrinsic geological and hydrogeological characteristics which determine the ease with which a groundwater body may be contaminated by human activities.

Aquifer vulnerability is determined mainly by the permeability and thickness of the subsoils that underlie the topsoil. For example, bedrock with a thick, low permeability overburden is less vulnerable than bedrock with a thin, high permeability, gravel overburden. This is due to the ability of potential contaminants to reach the aquifer in a relatively short period and with little or no contaminant attenuation due to the thin or absent overburden.

Aquifer vulnerability classification guidelines, as published by the GSI²², are given in Table 22.

Table 22: GSI Vulnerability Rating Matrix²²

Vulnerability rating	Hydrogeological conditions				
	Subsoil permeability (type) and thickness			Unsaturated zone	Karst features
	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 1-2 meters below ground surface

Groundwater vulnerability within the study area ranges from ‘Extreme’ where bedrock is close or at the surface to ‘Low’ vulnerability in areas where thick subsoil deposit is present, refer to the Aquifer Vulnerability Mapping on Figure 4.14.1.0 to 4.14.1.5.

6.15.3 Recharge

The GSI Groundwater Recharge map indicates that the study area has a typical annual recharge rate between 1 and 200mm with some areas having a recharge rate of 601 to 700mm and 401 to 450mm. Higher recharge rates occur where the karst aquifer is overlain by a thinner subsoil covering such as areas of extreme vulnerability.⁴⁵

6.15.4 Groundwater Sources

Groundwater sources include springs, wells or boreholes which are used for groundwater abstraction by domestic, agricultural, commercial, industrial, local authority or group water scheme users. Groundwater sources can be impacted by lowering of the water-table which may reduce available supply and by accidental spillages or releases of contaminants which may impact the water quality.

Source Protection Zone (SPZ) reports have been produced by the GSI and the EPA. The reports aim to guide development planning and regulation to provide protection to groundwater sources. To date, there are no SPZ reports produced for any location within the study area. In addition, there are no groundwater Group Water Scheme abstraction points located in the study area.

69 features from the GSI Wells and Spring database are located within the study area, however, the records do not state which wells are currently used for abstraction. Note, 50 of the 69 features are listed as geotechnical boreholes, installed as part of previous ground investigations in the area. It is expected that the 19 remaining features are potable water sources supplying less than 50 homes, which is considered to be of low importance as a constraint (based on NRA Guidelines (2009) Box 4.3: Criteria for Rating Site Attributes).³⁴

In terms of feature location accuracy (which refers to the location of a well or spring within a defined radius, the exact location is not known), there are 62 features within 10m, 20m and 50m accuracy, one within 200m, one within 500m and five within an accuracy of 1km.²⁵

The wells and springs are identified on the Hydrogeological Constraints Mapping in Figure 4.14.3.0 to 4.14.3.5.

6.15.5 Groundwater Contamination

The EPA datasets were consulted for their records of discharges and emissions which may affect groundwater quality within the study area. The discharge licences and emissions considered relevant are listed in **Table 23** and identified on the Hydrogeological Constraints Map (Figure 4.14.3.0 to Figure 4.14.3.5).

Table 23: Discharge and Emissions Licences within the Study Area^{8 14 15 16 17 19}

Licence No. / Reference Number	Discharge / Emission
WPL/11/02	Rosderra Meat, Jamestown, Co. Leitrim – Wastewater Discharge Point
P0021-02	Masonite Ireland – Integrated Pollution Control (IPC) Site Emission Licence
W0064-01	Carrick-on-Shannon – Landfill Site

Sites containing potentially contaminated land are outlined in detail in Section 6.11. Some of these sites such as landfills and historical land use contamination may contain contaminated groundwater.

6.15.6 Hydro-Ecology

Groundwater dependant habitats are hydrogeological constraints as they have the potential to be impacted as a result of changes in groundwater levels, flows or quality through, for instance, accidental spillages and dewatering causing deterioration in the flow and or quality of the baseflow to the habitat.

A conservative approach is taken regarding water dependent habitats. All water dependant habitats are included as hydrogeological constraints until it is established, during the assessment of the preferred transport solution, if they are dependent on groundwater and/or surface water.

There are no European sites i.e. Special Protection Areas (SPA) designated under the Birds Directive or Special Areas of Conservation (SAC) designated under the Habitats Directive, within the study area or in immediate proximity to it.

The nearest SAC sites to the study area are Clooneen Bog SAC and Lough Forbes SAC, Lough Forbes Complex SAC lies approximately 10km downstream of the study area, along the River Shannon. There are also four SAC sites at greater distances further downstream of the study area in the River Shannon catchment: Lough Ree SAC, River Shannon Callows SAC, Lough Derg, Northeast Shore SAC, and the Lower River Shannon SAC.

The nearest SPA site to the study area is Ballykenny-Fishertown Bog SPA, which lies approximately 10km downstream. There are also four SPA sites at greater distances further downstream of the study area in the River Shannon catchment: Lough Ree SPA, Middle Shannon Callows SPA, Lough Derg (Shannon) SPA, and the River Shannon and River Fergus Estuaries SPA.

There are no Natural Heritage Areas (NHA) located within the study area. The nearest NHA site to the study area is Corracramph Bog NHA which is located approximately 1.9km to the south of the study area.

There are two proposed Natural Heritage Areas (pNHA) within the study area: Lough Drumharlow pNHA to the immediate northwest of Carrick-on-Shannon and Lough Boderg / Lough Bofin pNHA to the south of Drumsna. Both pNHAs are located partially within the study area. These habitats are listed in **Table 24** and presented on the Hydrogeological Constraints Mapping (Figure 4.14.3.0 to 4.14.3.5). There are also five pNHA sites downstream of the study area in the River Shannon catchment: Lough Ree pNHA, River Shannon Callows pNHA, Lough Derg pNHA, Fergus Estuary and Inner Shannon, North Shore pNHA and Inner Shannon Estuary – South Shore pNHA.

The constraint importance ranking shown in **Table 24** is only related to the hydrogeological importance ranking due to the site being a water dependant habitat.

Table 24: Water Dependant Habitats and NRA Importance Ranking³⁴

Site name	Site code	Designation	Characteristics	Constraint importance ranking (NRA)
Lough Boderg and Lough Bofin	001643	pNHA	Lake and associated wetlands	Very High
Lough Drumharlow	001643	pNHA	Lake, wetlands, overwintering birds	Very High

6.15.6.1 Non-designated Areas of Annex I Habitat

The Biodiversity Constraints Study has preliminarily identified, via desk study and interpretation of orthophotography and a site visit, habitat types present or likely to be present within the study that may also include important flora and fauna sites and populations.

The following non-designated Annex I groundwater dependent habitats have been identified within the study area but outside a European site (*indicates priority habitat):

- * Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*, *Alnion incanae*, *Salicion albae*) [*91E0]
- Transition mires and quaking bogs [7140]
- *Bog woodland [*91D0]

Annex I habitats are of national importance from a biodiversity perspective.

7 Ground Conditions Summary

This section provides a summary of the anticipated ground conditions across the study area based on a review of the previous ground investigations (summarised in Section 5.1), site walkover, ground investigation 2021 and published datasets.

Note that the majority of the existing historic ground investigation data is located across the portion of the study area north of the River Shannon, therefore the coverage of ground investigation information is not as extensive across the southern and eastern portion. This historic data was utilised for the Stage 1 assessment with the caveats noted that there was less information about the option corridors to the south of Carrick-on-Shannon, but noting that a ground investigation would be available for Stage 2 assessment of the Project to assist in differentiating between the option corridors and their impact on Soils and Geology within the study area. The GI is discussed in Section 11.

7.1 Groundwater

Groundwater standpipes were installed as part of the 2006 ground investigation, no groundwater standpipes were installed as part of the 2002 and 2009 ground investigations. One round of groundwater monitoring was completed during the 2006 ground investigation on 15 May 2007. Groundwater levels were recorded during boring and trial pitting as part of the 2006 and 2009 ground investigations. The recorded groundwater levels are highly variable across the study area and are summarised below.

- **North of the existing N4 from the townland of Drumsna to the northern end of the Study Area):** 44 No. groundwater readings were made north of the River Shannon, the recorded groundwater levels range from 0.0mBGL to 18.76mBGL, one location recording 'Dry', with a median of 2.0mBGL and an average of 3.95mBGL.
- **South of the existing N4 from the townland of Drumsna to the southern study area boundary:** 7 No. groundwater readings were made south of the River Shannon, the recorded groundwater levels range from 0.47mBGL to 6.11mBGL.
- **East of Drumsna to Faulties:** 4 No. groundwater readings were made east of the River Shannon, the recorded groundwater levels range from 1.4mBGL to 9.0mBGL. Note that only groundwater levels recorded during boring and trial pitting are available across this portion of the study area.

7.2 Overburden

7.2.1 Topsoil

Where recorded, topsoil is generally described as sandy gravelly CLAY with roots and described as peaty in some locations. The general thickness of the topsoil is typically between 0.1m to 0.7m.

7.2.2 Made Ground

Made ground consisting of variable soil composition and waste and thickness is expected throughout Carrick-on-Shannon and the other settlements within the study area and at the locations of historical landfills, quarries and pits.

The possibility of contaminated ground is a key risk and should be investigated as part of the intrusive investigations.

Made ground is typically not considered a suitable formation material and is typically excavated and replaced as part of the construction works.

7.2.3 Lacustrine

Localised lacustrine deposits have been recorded in the previous ground investigations at the following locations:

- Adjacent to the existing N4 approximately 1.5km west of Carrick-on-Shannon in an area noted as being alluvial deposits by the EPA National Soils Mapping² and peat deposits by the GSI Quaternary dataset³.
- An area approximately 2.4km southeast of Carrick-on-Shannon, noted as being underlain by peat deposits on the EPA National Soils Mapping² and the GSI Quaternary dataset³.
- An area approximately 2.3km northwest of Jamestown, noted as being underlain by peat deposits on the EPA National Soils Mapping² and the GSI Quaternary dataset³.
- An area approximately 2.4km north of Jamestown, noted as being underlain by peat deposits on the EPA National Soils Mapping² and the GSI Quaternary dataset³.

The lacustrine deposits have been described as grey/blue and cream, very soft to soft, slightly sandy slightly gravelly SILT, noted as organic in some areas. The thickness of the localised lacustrine deposits has been recorded as being between 0.6m and 2.4m.

According to the EPA National Soils mapping² and the GSI Quaternary dataset³ there are isolated pockets of lacustrine deposits across the study area, refer to Section 6.3 and 6.4 for more details.

7.2.4 Peat

Peat deposits have been recorded throughout the study area, the location of the areas recorded as part of the existing ground investigations are typically consistent with the areas noted by the EPA² and GSI³. The recorded thickness of peat is highly variable, ranging between 0.3m and 8.5m. The deeper peat deposits, where the recorded base of peat is greater than 5.0mBGL are at the following locations:

- Adjacent to the existing N4 approximately 1.6km west of Carrick-on-Shannon
- Across the R280 road approximately 2.2km north of Carrick-on-Shannon

- Approximately 2.3km northeast of Carrick-on-Shannon
- Approximately 2.2km north of Jamestown
- Across the site of the N4 Piled Embankment, north of Drumgilra Lough, discussed in Section 6.8.

According to the EPA National Soils mapping² and GSI Quaternary dataset³ large cut and fen peat deposits exist across the entire study area and have been identified as a key constraint, likely to impact all Option Corridors.

7.2.5 Alluvium

Alluvium deposits have been recorded across the portion of the study area north of Carrick-on-Shannon and along the existing N4 as part of the previous ground investigations. There is a risk of alluvium deposits being present adjacent to rivers and other surface water features throughout the study area.

Alluvium deposits are recent deposits of waterborne clay, silt, sand and gravel deposited close to watercourses, with the nature of the soil varying laterally and with depth. Alluvium deposits have been classified into the following two types:

- Cohesive (fine grained) alluvium: mainly comprising silts and clays, occasionally described as peaty/organic, typically soft in consistency
- Granular (coarse grained) alluvium: mainly comprising sands and gravels, occasionally with low cobble content, typically loose density

Cohesive alluvium deposits may be inter-bedded with granular alluvium deposits.

The recorded thickness of alluvium deposits range between 0.1m and 4.8m.

7.2.6 Glacial Till

Glacial till deposits have been recorded across the entirety of the study area and have generally been described as brown, grey or black firm to stiff, sandy gravelly CLAY/SILT, with cobbles and boulders, with occasional medium dense to dense GRAVEL layers recorded.

The glacial till deposits have been described as comprising organic clay at some locations north of Carrick-on-Shannon. It is a possibility that organic peat material from higher up in the soil profile may have dragged some of this organic material into the glacial till in the Cable Percussion boreholes and therefore it appears in the samples from the boreholes. It would be unusual for a glacial till to have organic material in it. Alternatively this could also be an inter-glacial deposit.

The upper portion of the glacial till deposits may have a soft consistency and higher moisture content and may not be suitable as a formation material, requiring either excavation and replacement or treatment.

7.3 Bedrock

7.3.1 Limestone

Limestone bedrock has been recorded in the available ground investigation information across the northern portion of the study area, within Carrick-on-Shannon and adjacent to the existing N4 surrounding Drumgilra Lough. The limestone bedrock has generally been described as moderately strong to very strong.

The depth to bedrock varies from 0.6mBGL to 20mBGL.

The GSI Bedrock Geology map shows limestone bedrock underlying the entire study area up until the south eastern portion just south of Drumgilra Lough.⁵

7.3.2 Conglomerate and Sandstone

The GSI Bedrock Geology map shows conglomerate and sandstone bedrock underlying a small portion of the south eastern end of the study area just north of Fearnaght.⁵

No existing ground investigations have recorded conglomerate or sandstone bedrock.

7.3.3 Spilite Igneous Rock

Spilite volcanic igneous bedrock has been recorded at two locations at the eastern end of the study area and has been described as moderately strong to strong, moderately weathered, green, with quartz veining.

The depth to bedrock has been recorded as 2.5mBGL and 5.5mBGL.

The GSI Bedrock Geology map shows volcanic rock formations (Aghamore and Finnalaghta) underlying the south eastern end of the study area, these are described as lava and volcanoclastic breccia and blue-grey greywacke & black argillite.⁵

Due to the chemical make-up of volcanic rock types there is a risk of acid sulphate rock potential which could have a significant impact on the reusability of this material as engineering fill.

8 Preliminary Engineering Assessment

The following sections provide preliminary geotechnical recommendations for the proposed Stage 1 Option Corridors, based on information available at the time of the Stage 1 assessment which comprised the data sets and historic information outlined in Section 4 above, as well as some incoming data from the Phase 2 Ground Investigation (GI) which was on site in parallel.

The Stage 1 assessment included for an assessment on both ‘Alternatives’ and ‘Options’. The alternatives refer to a specific transport mode (road, rail, bus, air, walking and cycling etc.) or demand management proposal (fiscal, control, ITS measures etc.). Options refer to the specific road based options. This section of the report focusses on the preliminary Engineering Assessment of the nine option corridors. Six option corridors are to the west of Node J at Drumsna Junction (Purple, Dark Green, Black, Orange, Cyan and Blue) and four option corridors are to the east of Node J (Purple, Green, Yellow and Blue). Refer to **Plate 4** for an overview of the option corridors and nodes.

The option corridors are 300m wide with the exception of the Black Option Corridor which is 150m wide. A vertical alignment of a possible design for each of the option corridors was used to assess the impact of bulk earthworks volumes on the Soils and Geology.

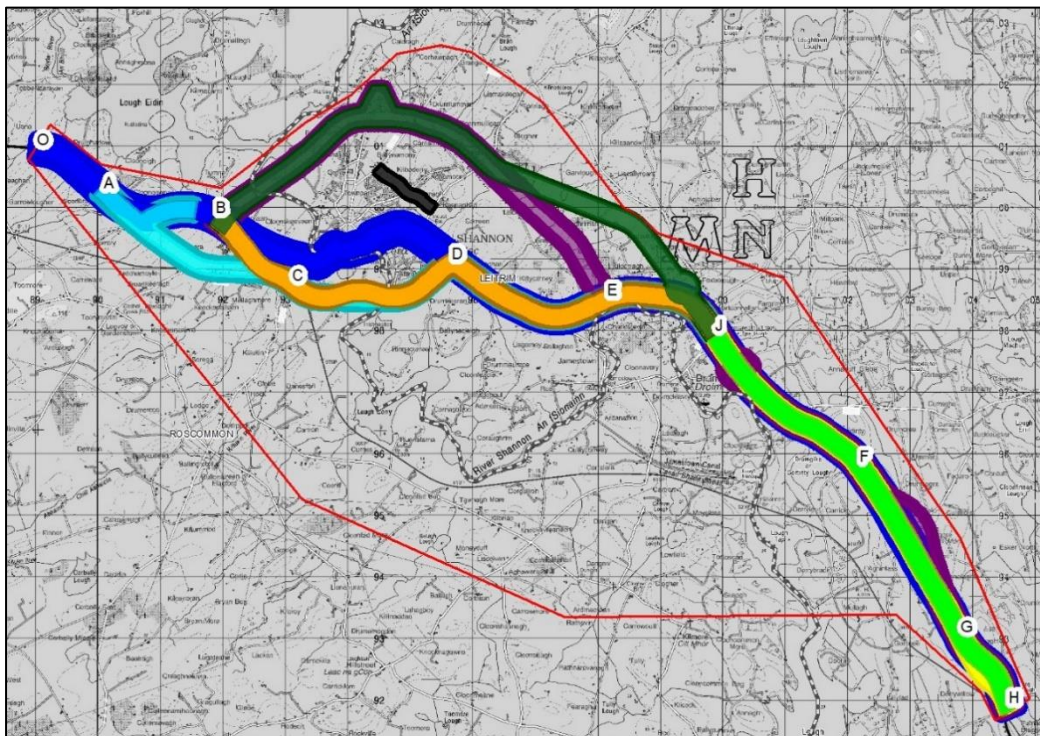


Plate 4: Option Corridors

8.1 Earthworks

An earthworks assessment was undertaken to estimate the potential bulk cut/fill and soft soil deposit (alluvium, peat and lacustrine) earthwork volumes for the mainline roads only i.e. side roads and drainage earthworks have been excluded.

The topography across the study area is dominated by an undulating landscape which has resulted in a substantial bulk cut and fill requirement along all of the Stage 1 Option Corridors. The tables below present the Stage 1 bulk cut and fill volumes for each of the Stage 1 Option Corridors.

Table 25: Bulk cut and fill volumes for the Option Corridors West of Drumsna Junction

Option Corridor	Bulk Cut (m ³)	Bulk Fill (m ³)
Cyan Option Corridor	197,000	735,000
Orange Option Corridor	114,000	503,000
Dark Green Option Corridor	793,000	1,020,000
Purple West Option Corridor	709,000	751,000

Table 26: Bulk cut and fill volumes for the Option Corridors East of Drumsna Junction

Option Corridor	Bulk Cut (m ³)	Bulk Fill (m ³)
Purple East Option Corridor	221,000	127,000
Green Option Corridor	81,000	47,000
Yellow Option Corridor	170,000	107,000

Soft soil deposits are also extensive across the study area, occurring on the low-lying ground between drumlin features and across the floodplains of the River Shannon. A number of these areas are intersected by the Stage 1 Option Corridors and will either require significant ground improvement or excavation and replacement to achieve a suitable bearing stratum, resulting in significant soft soil volumes and increasing the overall material deficit.

In addition to the significant earthwork requirements, the Stage 1 Option Corridors are also intersected by the River Shannon. The River Shannon is considered a significant constraint for the earthworks for the Project as there will not be a suitable bridge crossing available to haul material east and west of the River Shannon during construction.

8.2 Classification and Acceptability for Re-use

Soft soils including peat, cohesive alluvium and lacustrine and made ground are considered unsuitable for reuse as engineering fill.

In addition to the soft soils there will be a portion of the glacial till cut volumes that will be unsuitable for reuse as engineering fill without treatment. The soils have been classified and assessed in accordance with Table 6/1 of TII Specification for Road Works CC-SPW-00600 (March 2013).

A reusability assessment was undertaken using the laboratory testing information available from sources identified in Section 4 above together with data from the Phase 2 GI as follows:

1. The Natural Moisture Content (NMC) testing demonstrated that the glacial till deposits within the upper 2m typically have a higher NMC value than the deposits below 2m, therefore, a separate reusability assessment was undertaken for the upper 2m and for the deposits below 2m
2. Particle Size Distribution (PSD) testing was used to understand if the glacial till deposits across the study area fall within the grading limits for Class 1 and Class 2 materials in accordance with TII Specification for Road Works CC-SPW-00600 (March 2013)
3. Maximum dry density and optimum moisture content (MDD/OMC) testing was used to determine the OMC value for the glacial till deposit along with the upper and lower bound limits
4. California Bearing Ratio (CBR) laboratory tests were undertaken to determine the CBR of the glacial till at natural moisture content and also the moisture content at which a $\text{CBR} \geq 3\%$ could be achieved
5. Moisture Condition Value (MCV) testing was used to determine the MCV of the glacial till at natural moisture content and also the upper and lower moisture content values required to achieve an MCV between 7 and 14
6. Following analysis of the laboratory test information, the upper and lower moisture content values that the glacial till will perform as a suitable engineering fill were established. The percentage of tests completed on glacial till deposits that fell within these limits was used to calculate the % reusability of the upper 2m of the soil profile and the till >2m depth

Based on the reusability assessment the following are considered appropriate:

- 20% of the upper 2m of glacial till is considered directly reusable or marginal. These upper layers are typically wetter deposits
- 70% of the glacial till below 2m is considered directly reusable or marginal

Unsuitable glacial till cut material will either require treatment/improvement for reuse or alternatively this material will be excavated and replaced with suitable fill. The volume of unsuitable glacial till cut material is an important aspect of this

project as it is adding to the considerable bulk material deficits associated with the option corridors.

8.3 Cuttings

Cuttings along the Stage 1 Option Corridors are up to 20m in height and are anticipated to be primarily in cohesive glacial till material. Cuttings at a maximum slope angle of 1V:2H are considered appropriate in the glacial till deposit, benching may be required at some locations. Granular water bearing soils when encountered may require shallower slope angles. Cuttings through soft soils will require shallower slope angles and possibly benching.

Cuttings shall incorporate appropriate in-slope drainage to manage and control water, including groundwater issues onto slope faces: e.g. granular surface drainage layers. The sources of seepage and areas of potential seepage shall be observed for a period before applying topsoil, as they may not become active until sometime after exposure especially in periods of sustained dry weather.

Where support to permanent cut slopes is required, this may comprise retaining walls or soil nailing.

8.4 Embankments

Embankments are required across low-lying areas between drumlin features and across the River Shannon floodplain. The embankments will be constructed using Engineering Fill and where embankments are situated on soft soil areas, the soft material will be required to be excavated and replaced with suitable fill or significant ground improvement of the soft soils to achieve a suitable bearing stratum prior to the construction of the overlying embankment. Piled embankments may be appropriate in some locations. Embankment heights are up to 16.0m along the proposed Stage 1 Option Corridors. Embankment slopes of 1V:2H are considered to be appropriate.

Drainage measures will be required to ensure significant surface water flow is not directed into the embankment as surface water flow into the embankments may result in softening of the fill material and an increase in porewater pressure. Also, as the embankments are located on the floodplain of the River Shannon that are subject to flooding, a granular drainage/starter layer maybe required at the base of the embankments. The location of embankments and the interaction with the surface water flow within the catchment area is also a consideration at these locations as any impediment in drainage could result in a flood risk.

8.4.1 Approach Embankments to the River Shannon Crossing North of Carrick-on-Shannon

A significant portion of the approach embankments for the River Shannon crossing north of Carrick-on-Shannon will sit within the floodplain of the river.

A review of the ground investigation information from the sources identified in Section 4 above together with data from the Phase 2 GI demonstrates that the

ground conditions underlying the western approach embankment will comprise soft organic material (up to 3.0m thick at the eastern end towards the River Shannon which will require excavation and replacement or ground improvement) overlying firm becoming stiff glacial till over limestone bedrock. Limestone bedrock is approximately 7.2mBGL (36.31mOD). The western approach embankment cuts through an Alluvial Woodland area.

The eastern embankment will comprise soft alluvium material (up to 4.5m thick at the western end towards the River Shannon) overlying firm glacial till over limestone bedrock. The limestone bedrock ranges in depth from 9.40m BGL (33.20mOD) east of the River Shannon to 8.7mBGL (32.6mmOD) at the River Shannon on the approach embankment.

This embankment cuts through an ecologically sensitive area (pNHA and Molinia meadows and a potential Alluvial Woodland) which needs to be factored into the embankment design. Also, as the embankments are located in areas subject to flooding, granular drainage/starter layers will likely be required at these locations.

8.4.2 Approach Embankments to the River Shannon Crossing South of Carrick-on-Shannon

The approach embankments for the River Shannon crossing south of Carrick-on-Shannon will sit within the floodplain of the river.

A review of the ground investigation information from the sources identified in Section 4 above together with data from the Phase 2 GI demonstrates that the ground conditions underlying the western approach embankment will comprise soft peat and alluvium material (up to 11.0m thick which will require piled support or ground improvement) overlying firm becoming hard glacial till over limestone bedrock. The limestone bedrock is 8.0mBGL(32.68mOD) west of the River Shannon and 12mBGL (29mOD) at the River Shannon

The eastern embankment will be underlain by soft peat material (up to 6.0m thick which will require excavation and replacement, ground improvement, or piled support) overlying stiff glacial till over limestone bedrock. The limestone bedrock is 8mBGL (33.96mOD) east of the River Shannon to 8.50mBGL (33.05mOD) at the River Shannon.

This embankment cuts through Alluvial Woodland areas, potential Alluvial Woodland areas and a Transition Mire which will need to be factored into the design. As the embankments are located in areas subject to flooding, granular drainage/starter layers will likely be required at these locations.

8.4.3 Widening of the Existing Gortinty Piled Embankment

A piled embankment exists along the N4 at Gortinty. At this location, any widening of the embankment would be most likely on the eastbound carriageway only, to allow for a dual carriageway and any side roads.

Based on information from Leitrim County Council the existing piled embankment is described as:

- Circa 300m long embankment that is 1.3m to 1.8m high
- Supported on 200mm square precast segmental concrete driven piles
- Pile spacing of 1.6m c/c
- Embankment supported on a load transfer platform consisting of 6F1 granular fill and two orthogonal layers of Paragrid 150/15 geogrid placed directly above pile caps

Based on ground investigation information from the sources identified in Section 4 above the ground conditions at this location comprise up to 8.0m of peat overlying stiff and medium dense cohesive and granular glacial till over limestone bedrock.

8.5 Natural Subgrade

Areas of made ground and soft, highly compressible or organic soils will not be suitable as subgrade and shall be excavated and replaced with suitable engineering fill as part of the construction works. Suitable design values will be adopted based on the GI, and the capping and pavement design will be undertaken based on this.

Quality control testing shall be undertaken during construction, to confirm that the CBR of the exposed subgrade conforms with the design value.

8.6 Structures

The following is a list of structures proposed at the time of writing this report:

- Major structure: River Shannon Bridge crossing
- Other structures: Culverts and retaining walls

8.6.1 River Shannon Crossing

8.6.1.1 River Shannon Bridge Crossing North of Carrick-on-Shannon

A review of the information from the sources identified in Section 4 above together with data from the Phase 2 GI was undertaken to determine the underlying ground conditions and likely foundation requirements at the proposed River Shannon Bridge crossing north of Carrick-on-Shannon.

This ground investigation shows the following ground conditions:

- Western abutment: up to 3.0m of soft organic material overlying a thin stratum of stiff glacial till over strong, slightly weathered limestone bedrock at 3.25mBGL. The thickness of the soft material decreases towards the west.

- Eastern abutment: up to 6.0m of soft organic and alluvial material overlying stiff glacial till over strong limestone at 9.0mbgl. The thickness of soft material reduces towards to the east.

Based on this information piled foundations socketed into bedrock are considered an appropriate foundation solution at this location.

Groundwater monitoring installation on the eastern side of the River Shannon revealed groundwater levels to range from to 4.45m BGL to ground level between February 2011 to May 2011. Groundwater levels may be subject to seasonal fluctuations.

8.6.1.2 River Shannon Bridge Crossing South of Carrick-on-Shannon

A review of the available information from the sources identified in Section 4 above together with data from the Phase 2 GI was undertaken to determine the underlying ground conditions and likely foundation requirements at the proposed River Shannon Bridge crossing west of Carrick-on-Shannon.

This ground investigation shows the following ground conditions:

- Western abutment: Up to 11.0m of soft peat and alluvium material overlying firm to hard glacial till over very strong, fresh to locally weathered limestone at 12mBGL(29mOD) The thickness of soft material reduces towards the west
- Eastern abutment: Up to 6.0m of soft peat overlying stiff glacial till over medium strong to strong, fresh to locally moderately weathered limestone at 8.5mBGL(33.05mOD).

Based on this information piled foundations socketed into bedrock are considered an appropriate foundation solution.

One groundwater strike was recorded as part of the previous ground investigations at 8.3mBGL.

8.6.1.3 Foundations

Foundation solutions at other structures (such as retaining walls and culverts) will require shallow foundations for lightly loaded structures or where excavations are less than 2m in depth. Piled foundations may be appropriate for heavily loaded structures or where excavations are >2m depth.

In areas of shallow bedrock, piles may be designed as end bearing, deriving most of their capacity from a rock socket in the underlying bedrock. In areas where bedrock is deeper, friction piles maybe achievable with the piles deriving most of their capacity through shaft adhesion within the glacial till.

8.6.2 Retaining Structures

At this stage there are no known retaining structures proposed along the Stage 1 Option Corridors.

Where the construction of stable full height embankment side slopes is not possible due to space constraints, strengthened earthworks or retaining walls (gravity or cantilever) may be required.

Similarly, where a stable cutting slope is not possible due to lack of land take, retaining walls (gravity, cantilever or embedded) or stabilisation methods such as soil nailing may be appropriate.

The stability and structural design of retaining structures should also consider hydrostatic pressures arising from groundwater, additional lateral earth pressures caused by loadings on the retained surface and by compaction equipment used during backfilling.

8.6.3 Ground Improvement

Soft, highly compressible or organic ground are considered unsuitable as a bearing or foundation stratum. Across these areas suitable ground improvement techniques to achieve the required formation bearing capacity may be considered.

Typical ground improvement techniques include:

- Surcharging
- Vertical Drainage
- Deep soil mixing
- Stone columns
- Soil stabilisation

The design of ground improvement solutions should also consider constructability and site constraints, construction programme, the influence of secondary consolidation and groundwater levels.

8.6.4 Soil Chemistry

Chemical analyses testing was undertaken on groundwater and soil samples during the previous ground investigations. The chemical analyses testing undertaken on the groundwater samples were assessed against the IS EN 2006:2013+A2 2021 requirements and limits, in order to detect the environmental chemical aggressiveness toward buried concrete elements. The pH and sulfate content recorded in the groundwater samples are within the limits of Class XA1, which corresponds to an environment with a low chemical aggressivity.

The pH and sulfate content (SO₄) has also been assessed against Table C1 of BRE Special Digest 1 to determine the Design Sulfate (DS) Class and the class necessary to meet the Aggressive Chemical Environment for Concrete (ACEC)

requirements. The pH and sulfate content recorded in the soil and groundwater samples are within the limits for DS Class DS-1 and ACEC AC-1 Class.

Part D of BRE Special Digest 1 provides guidance on the design of underground cast in-situ concrete: the maximum free-water / cement ratio, minimum cement content and cement types.

8.7 Contaminated Land

The possibility of contaminated ground cannot be discounted due to the presence of Made Ground and historical land use within the study area, refer to Section 6.11.

The following identified potentially contaminated sites are intersected by the option corridors:

- The Cloongownagh historic waste site between Hughestown and Cultyconeen
- An historic waste site south of Carrick-on-Shannon
- The Carrick-on-Shannon Landfill, Ballynamoney – Active Licence Number W0064
- An historic waste site located close to Finnalaghta, parallel to the existing N4
- Areas of made ground identified by the EPA National Soils Mapping² surrounding Carrick-on-Shannon, Cortober and Drumsna
- The Carrick-on-Shannon Railway Station
- An historic gasworks site located near Carrick-on-Shannon Railway Station
- Historic Quarry and Pit Sites

It is assumed at Phase 2, that the material used to backfill the historic pits and quarries is a waste material.

9 Comparison of Project Options

Based on the information previously presented in this report the following constraints are identified as key differentiators between the option corridors and have been assessed as part of the Stage 1 Preliminary Options Assessment:

- Contaminated sites and unsuitable material
- Economic Geology
- Earthworks (bulk cut and fill volumes)
- Earthworks (soft soil deposit volumes)

Refer to the Stage 1 assessment in the Options Selection Report for the comparison of project options.

10 Geotechnical Category of the Project

Based on the geotechnical works to be undertaken and associated risk implications, this project is classified as a Category 2 project. A Category 2 project is defined as:

- *‘Geotechnical Category 2 should include conventional types of structure and foundation with no exceptional risk or difficult soil or loading conditions.*
- *Designs for structures in Geotechnical Category 2 should normally include quantitative geotechnical data and analysis to ensure that the fundamental requirements are satisfied.*
- *Routine procedures for field and laboratory testing and for design and execution may be used for Geotechnical Category 2 designs.*

Reference ‘Section 2.1 Design Requirements paragraphs 17 – 19 I.S. EN 1997-1:2005’⁶¹

⁶¹ Eurocode 7: Geotechnical Design. General Rules (+A1:2013) IS EN 1997-1:2005

11 Phase 2 Ground Investigation

11.1 Objectives of the Ground Investigation

The aim of the Phase 2 Ground Investigation was to target ground conditions that were identified above as a constraint in the study area and are likely to impact the selection of options.

The following key ground conditions were identified that necessitated the need for ground investigation:

1. **Soft Soil Deposits:** there are large extents of soft soil deposits across the study area, including peat, alluvium and lacustrine deposits. The deposits are so widespread that any corridor option chosen will impact these areas. It is critical that the Phase 2 Ground Investigation identified the extents and depths of these deposits to understand the excavate and replace earthwork volumes across each corridor option.
2. **River Crossings:** there are a number of river crossings throughout the study area, including the major crossings at the River Shannon and also across smaller tributaries. It is important to identify the ground conditions at these crossings to understand the foundation and earthwork requirements.
3. **Cuts through drumlins/ribbed moraines:** There are a significant number of drumlins and ribbed moraines across the study area, these are considered to be of high importance due to the possible cut requirements through these features as a result of the variability in topography. In addition, there is a potential for the cut material to have variable reusability as engineering fill and also potential for variability in the groundwater table which would impact excavation requirements.
4. **Contaminated Ground and Unsuitable Material:** A number of sites of potential areas of contamination or unsuitable material have been identified as these are considered to be key constraints relevant to the Phase 2 Option Selection:
 - The historic gasworks site and made ground areas south of Carrick-on-Shannon Town
 - A historic quarry site at the intersection of the existing N4 and L3657 (at the same location as an area of potential soft ground)
 - The waste permit site adjacent to the existing N4 close to Finnalaughta with a square area of 26,690m.

At this phase all other sites identified as containing potential contaminated or unsuitable material are assumed to be unsuitable for reuse as engineering fill, requiring excavation, treatment and disposal.

5. **Shallow Bedrock:** Large areas of shallow bedrock have been identified from a review of the GSI Bedrock Geology and GSI Groundwater Vulnerability mapping. It is important to gain an understanding of the bedrock topography across the study area to identify areas of high variability which will have significant impacts on the transition requirements, earthworks and foundation

types. In addition, areas of shallow bedrock will offer an opportunity to win rock that can be reused as aggregate and also for potential use as borrow pits if required.

11.2 Phase 2 Ground Investigation

Following identification of the ground conditions that are likely to be key differentiators in the Options Selection process a ground investigation was undertaken comprising of the following:

- 50 No. cable percussive boreholes with 26 rotary core follow on
- 9 No. rotary percussive boreholes
- 50 No. trial pits
- 237 No. dynamic probes
- 9 No. Macintosh probes
- 6 No. window samples
- 29 No. groundwater standpipe installations
- 1 No. combined groundwater and gas monitoring installation
- 3 No. push in vibrating wire groundwater piezometers
- 137 km of electromagnetic conductivity (EM-31)
- 14 km of electrical resistivity tomography profiles
- 5 km of 2D MASW profiles
- Laboratory testing
- Groundwater monitoring in all groundwater installations to be completed for 12 months following the completion of the ground investigation works with a further option to extend this monitoring for a period of 12 months.

The following depths were scheduled for each of the intrusive exploratory techniques:

- Cable percussive boreholes with rotary core follow on in areas of soft ground were scheduled with the minimum recovery requirement of 5m of competent bedrock core to gain an understanding of the depth to competent bedrock along with the strength and weathering characteristics.
- Cable percussive boreholes with rotary core follow on at the location of water crossings and other potential structures were scheduled with the minimum recovery requirement of 10m of competent bedrock core to ensure sufficient information on the strength and weathering of the bedrock was gained for the selection and design of bridge foundations.
- Cable percussive boreholes with rotary core follow on at locations of drumlin features were scheduled to gain an understanding of the overburden and bedrock, the depth of these boreholes vary depending on localised changes in topography.

- The depth of rotary percussive boreholes were scheduled based on the depths of adjacent historic groundwater installations that were selected for reconditioning.
- Dynamic probes were scheduled to refusal to understand the vertical extents of soft soil.
- Window samples were scheduled to a depth of 10mBGL as this is the typical maximum extent of this exploratory technique.
- Trial pits were scheduled to 4.5mBGL as this is the maximum extent for this exploratory technique without the requirement for benching or excavation equipment with a larger reach.

The scope of this investigation was as follows:

1. Determine the vertical and horizontal extents of areas of potential soft ground
2. Establish the soil stratigraphic profile and strength of soils
3. Determine the depth to bedrock and bedrock topography
4. Characterise the bedrock lithologies and strength
5. Establish if there are karst features within the area under investigation
6. Establish the reusability of the soils and rock
7. Determine the depth to groundwater, direction of groundwater flow, static groundwater levels and water quality
8. Investigate the areas of potential contaminated ground.

The fieldworks programme for the GI was established to ensure that the GI factual data was available for input into the Phase 2 Options comparison and selection. This involved scheduling GI locations that would require reusability laboratory testing (which would take a number of weeks to complete) at the start of the GI programme to ensure that by the time the fieldworks were complete all laboratory information would be available for use as part of the Phase 2 Options Selection.

11.2.1 Ground Investigation Techniques

The following techniques were chosen to investigate the ground conditions across the study area:

- **Soft Soil Deposits:** Dynamic probes and geophysics were used as the primary investigation techniques to investigate soft soil deposits as they would allow for the greatest likelihood of getting access to these locations. These techniques also offered a fast way for determining vertical and horizontal extents of soft soil deposits given the programme constraints at the time of scoping the GI. In addition to these techniques, window samples and boreholes were also used to ground truth the stratigraphy and to gain numerical data for the soil and rock deposits. Window samples were scheduled within the floodplain of the River Shannon as this technique allowed for the greatest likelihood of getting access to these areas. The

following geophysical survey techniques were selected to investigate the soft soil deposits:

- ERT and 2D MASW were used to determine the stratigraphy, top of bedrock and engineering properties of both the soil and rock.
- EM-31 was used in certain areas as this technique offered a quick and more cost-effective method to determine the extents of soft soil deposits with depths less than 6m (typically alluvium and lacustrine deposits).
- **River Crossings:** Boreholes comprising cable percussive technique through the overburden with rotary core follow on into bedrock were used to achieve the sampling and depth requirements to gain sufficient information needed for the selection and design of foundations.
- **Drumlins and ribbed moraines:** Trial pits and Boreholes (cable percussive technique through the overburden with rotary core follow on into bedrock) were used to investigate the stratigraphy of drumlins and ribbed moraines. Boreholes were used to determine the stratigraphy at greater depths and trial pits were used to obtain large bulk samples required for compaction related laboratory testing.
- **Contaminated ground and unsuitable material:** Trial pits were used to investigate potential key areas of contaminated ground or unsuitable material to allow for the collection of sufficient samples for geo-environmental laboratory testing. One borehole was used to install a combined groundwater and gas installation to investigate the potential contamination from an adjacent historical gasworks site. Due to access restrictions the borehole was completed further away from the potential site of contamination than originally scheduled.
- **Shallow bedrock:** boreholes (cable percussive technique through the overburden with rotary core follow on into bedrock) and trial pits were used to investigate areas of potential shallow bedrock. Trial pits were used to confirm shallow bedrock in areas of recorded outcropping.

11.2.2 Geotechnical and Geo-Environmental Laboratory Testing

The scheduled geotechnical and geo-environmental laboratory testing for the ground investigation is presented in **Table 27**.

Table 27: Scheduled Geotechnical and Geo-Environmental Laboratory Testing

Type	Laboratory Test	Purpose
Classification	Moisture Content	To classify and understand the properties of the soil deposits for design of structures, cut/fill slopes and pavement subgrade build up and for reusability purposes
	Liquid and Plastic Limit	
	Particle Size Distribution by Wet Sieving	
	Sedimentation by Hydrometer	

Type	Laboratory Test	Purpose
Chemical and Electrochemical	Organic Matter Content	To understand the exposure classification of the soil deposits at river crossings and across the study area for concrete requirements at structures
	Resistivity	
	Redox Potential	
	Test Suite B	
Reusability	Dry density/moisture content relationship using 4.5 kg rammer (5 pt)	To understand the reusability of glacial soils across the study area.
	Moisture Condition Value at natural moisture content	
	Moisture Condition Value/moisture content relationship (5 pt)	
	California Bearing Ratio on re-compacted disturbed sample at natural moisture content	
	California Bearing Ratio/moisture content relationship (5 pt)	
Shear Strength	Shear strength of a single 300 mm x 300 mm square specimen by direct shear, test duration not exceeding 1 day	To understand the shear strength properties of the soil deposits across the study area for design of cut/fill slopes and structures.
Rock and Aggregate Testing	Slake durability	To determine the reusability of the rock.
	Water absorption	
	Magnesium sulphate soundness	
	Flakiness index	
	Los Angeles abrasion	
	Aggregate crushing value	
	Soaked 10% fines	
	Methylene Blue	
	Water Soluble Sulphur (TRL447)	
	Acid Soluble Sulphur (TRL 447)	
	Total Sulphur (TRL 447)	
	Oxidisable Sulphates (TRL 447)	
	pH Value	
	Uniaxial compressive strength	To understand the strength of the bedrock for design of foundations, structures and

Type	Laboratory Test	Purpose
	Point Load Strength Index on rock core (axial and diametral)	rock cuts and for reusability purposes
Geo-environmental	Test Suite E (soils)	To understand the contamination and chemical properties of soil deposits in made ground areas, groundwater and at historically contaminated sites across the study area. The laboratory testing will also lead to a better understanding of disposal and treatment requirements for contaminated ground.
	Test Suite F (groundwater)	

11.3 Site & Working Restrictions

The following site and working restrictions were relevant to this ground investigation and are detailed below:

1. **Access Difficulties:** A number of proposed ground investigation locations were within the floodplains of the River Shannon and its associated tributaries and also in peat bog areas. Floodplains across the study area are known to be in flood for a number of months during the year which may cause further issues with access. Soft ground conditions that may be difficult to traverse were anticipated in these areas. The Contractor was not allowed to cross or break through any existing ditches or boundaries. The Contractor used existing access routes, and where existing access routes were not available, the Contractor had to allow for the construction of temporary access routes and reinstatement of such routes to the original condition to complete the investigation works.
2. **Designated Sites:** There are no Special Protection Areas (SPA), Special Areas of Conservation (SAC) or Proposed Natural Heritage Areas (pNHA) within the site, however, there are sensitive ecological receptors downstream of the River Shannon that construction works adjacent to the River Shannon and its tributaries need to take into consideration. The Contractor has to allow for appropriate measures to minimise the impact on the sensitive ecological receptors.
3. **Archaeological Areas:** The constraints study identified a number of suspected or known archaeological or heritage constraints for the site. All proposed ground investigation locations were positioned a minimum distance (as agreed with the Project archaeologist) from any archaeological or heritage constraints.
4. **Non-native Invasive Species:** A number of areas of Japanese Knotweed were recorded across the study area, all proposed intrusive ground investigation locations (i.e. boreholes, trial pits, window samples, dynamic probes) were

positioned outside of these areas to avoid the spread of non-native invasive species.

5. **Traffic Management:** A number of proposed ground investigation locations were located adjacent to live roads, including the existing N4, and in areas where pedestrians may be present. The Contractor provided and maintained adequate traffic and pedestrian safety and management measures to safeguard the public and site works during the execution of the works, including but not limited liaising with all relevant stakeholders, providing and maintaining access to all existing properties and facilities, obtaining and completing all licences and permits.
6. **Landowners:** A number of proposed ground investigation locations were located within private properties, the Contractor was responsible for liaising with the Project Liaison Officer (PLO) to ensure that access to private properties was agreed and a minimum of 1 weeks' notice was given to the landowners prior to undertaking the works. During the course of the works the Contractor had to ensure that boundaries were not disturbed, and gates closed during the execution of the site works.

11.4 Specialist Consultation

The following specialists were consulted to review the proposed ground investigation locations:

- The PLO with regards to land access and agreements
- The Project ecologist with regards to protected and sensitive environmental areas
- The Project archaeologist with regards to archaeological and heritage sites

After consultation with the above specialists any required updates were made to the proposed ground investigation locations prior to issuing for construction.

11.5 Programme

The Phase 2 Ground Investigation cost and programme details are detailed below.

The Phase 2 Ground Investigation was on site for 11 weeks. The laboratory testing and reporting followed on from the fieldwork.

Arup undertook on-site monitoring throughout the Ground Investigation.

11.6 Reporting

11.6.1 Factual Reporting

The factual report for the Phase 2 Ground Investigation includes all of the completed intrusive exploratory hole records with coordinates and levels, AGS data, all geotechnical and geo-environmental laboratory testing, gas and groundwater monitoring records and the final geophysical interpretative report. This report is an appendix to the Option Selection Report A.8.8.12.1.

11.6.2 Geophysics Reporting

The final interpretative report incorporates all geophysical results acquired and their interpretation. The interpretation is calibrated with any other geophysical or intrusive investigations and includes:

- A description of the operational field procedures, the field and post-processing procedures and the methodology and assumptions used for interpretation
- Survey methodology and location table(s), indicating location on site and coordinates for each profile
- Summary interpretation table(s) presenting ground layer(s) properties
- Figures and maps showing interpreted sections and levels reported relative to Ordnance Datum
- Digital contour plots of soft ground
- Plan view maps showing the locations of the geophysical profiles, overlaying Ordnance Survey or GIS output information
- Individual scaled plates of the modelled seismic data, with topography shown.

In addition to the information provided in the report, the raw data such as seismic traces for inspection of such geophones and for such shots was also provided.

This report is an appendix to the Option Selection Report A.8.8.12.1.

12 Summary and Risk

The Phase 2 Geotechnical Investigation was scoped to provide information on the key constraints identified and to inform the key differentiators between the alternatives and options from a soils and geology perspective. The Stage 2 assessment of alternatives and options was undertaken utilising this data and is included in the Option Selection Report.

Appendix A

Arup 2020 Soils and Geology
Site Survey Plan and Photos

A1

A2

Location 1

L1.1 Looking North



Location 2

L1.1 Looking southwest



L1.2 Looking northwest



Location 3

L3.1 Looking West



L3.2 Looking southwest



L3.3 Looking northwest



L3.4 Looking northwest



L3.4 Looking East



L3.5 Looking East



Location 4

This location on the eastern side of the northern River Shannon crossing was earmarked as an area to visit during but was not accessible at the time of the site visit. The site was observed from the western river bank.

Location 5

L5.1 Looking east from the public road on the western side of the River Shannon. The higher ground in the foreground is dry but the ground gets wet and marshy on the floodplain



L5.2 Looking east from the public road on the western side of the River Shannon.



L5.3 Looking southeast from the western side of the River Shannon



Location 6

L6.1 Photograph taken on the existing N4 facing towards Carrick-on-Shannon. The photograph is of the adjacent fields on the right-hand side (western) of the road



L6.2 Photograph taken on the existing N4 facing towards Carrick-on-Shannon. The photograph is of the adjacent fields on the left-hand side (eastern side) of the road



Location 7

L7.1 Photograph taken on the existing N4 looking northeast



L7.2 Photograph taken on the existing N4 looking east



Location 8

L8.1 Photograph taken in lands to the right-hand side (western side) of the existing N4



Location 9

L9.1 Photograph taken on the southern side of the waste permitted site looking north



L9.2 Photograph taken on the southern side of the waste permitted site looking north



Location 10

L10.1 Photograph taken in the apartment development looking south



L10.2 Lands to the north of the apartment development that are also within the waste permitted site



Location 11

L11.1 Site of the old gasworks building



L11.2 Photo taken on the R368 facing towards Carrick-on-Shannon. Railway embankment shown in the background. The site of the old gasworks building is on the right of the photograph.



L11.3 Site to the north of the railway embankment



L11.4 The R370 that runs parallel to the Railway embankment.



L11.5 Site on the right-hand side of the R368 to the east of the railway embankment.



Location 12

L12.1 Lands to the south of Killukin River running parallel to the local road that accesses the camping ground. Photograph taken on the local road looking north.



L12.2 Lands to the south of Killukin River running parallel to the local road that accesses the camping ground. Photograph taken on the local road looking west.



L12.3 Lands to the south of Killukin River running parallel to the local road that accesses the camping ground. Photograph taken on the local road looking northeast.



Location 13

L13.1 Photograph taken on the western bank of the River Shannon at Carrick Camping looking east.



L13.2 Photograph taken on the western bank of the River Shannon at Carrick Camping looking southeast at the lands floodplain adjacent to Carrick Camping.



L13.2 Photograph taken on the western bank of the River Shannon at Carrick Camping looking east towards Glas na hAbhainn residential estate.



Location 14

L14.1 Photograph taken looking north from the riverside end of the Glas na hAbhainn estate on the eastern side of the River Shannon.



L14.2 Photograph taken looking west at the riverside end of Glas na hAbhainn estate.



Location 15

L15.1 Photograph taken from the road on the N4 embankment on the left hand side of the road (eastern side) looking towards Carrick-on-Shannon.



L15.2 Existing N4 embankment looking towards Aghamore on the left-hand side of the road (eastern side)



L15.3 Existing N4 embankment looking towards Aghamore on the left hand side of the road (eastern side)



L15.4 Existing N4 embankment looking towards Aghamore on the right-hand side of the road (western side)



Location 16

L16.1 Photograph taken on the existing N4 looking towards Carrick-on-Shannon on the right-hand side of the road (northern side)



L16.2 Photograph taken on the existing N4 looking towards Carrick-on-Shannon on the left-hand side of the road (southern side)



Location 17

Access to this site was not possible at the time the survey was undertaken so photographs were not taken as it was not safe to park on the side of the N4. The site was observed from the car.

Location 18

Access to this site was not possible at the time the survey was undertaken so photographs were not taken as it was not safe to park on the side of the N4. The site was observed from the car.

Location 19

L19.1 Photograph taken looking south. No obvious evidence of a historic pit or quarry at this location.



Location 20

L20.1 Photograph was taken on the southern side of Drumgilra Lough looking northeast.



L20.2 Photograph was taken on the southern side of Drumgilra Lough looking northeast. This photograph was taken closer to the existing N4 than the photograph in L20.1.



Location 21

L21.1 Photograph taken looking northwest from Annaduff National School



L21.1 Photograph taken looking northwest from St Marys Church, Annaduff



Location 22

This location was observed from the car as it was not safe to park on the road side.

Location 23

Finnalaughta Quarry is surrounded by vegetation so the quarry itself could not be photographed from afar. Aerial photographs are sufficient to look at this site.

L23.1 Taken looking west towards the eastern side of the quarry.



Location 24

This location was not visible from the existing N4 so this photograph was taken from east of Bog Lough.

L24.1: Photograph taken looking west

