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9 Soils and Geology

9.1 Introduction

This chapter of the EIAR consists of an appraisal of the proposed N6 Galway City Ring Road, hereafter referred to as the proposed road development, under the heading of soils and geology.

This chapter sets out the methodology (**Section 9.2**), describes the receiving environment (**Section 9.3**) and summarises the main characteristics of the proposed road development which are of relevance for soils and geology (**Section 9.4**). The likely significant impacts of the proposed road development on soils and geology are described (**Section 9.5**). Measures are proposed to mitigate likely significant impacts (**Section 9.6**) and residual impacts are described (**Section 9.7)**. The chapter concludes with a summary (**Section 9.8**) and reference section (**Section 9.9**).

This chapter has utilised the information gathered during the previous phases of the proposed road development to inform the soils and geology impact appraisal. **Sections 4.4**, **6.5.2** and **7.6.2** of the **Route Selection Report** considered the soils and geology constraints within the scheme study area and compared the potential soils and geology impacts of the proposed route options respectively. These sections of the Route Selection Report contributed to the design of the proposed road development which this chapter appraises.

9.2 Methodology

9.2.1 Introduction

The following section outlines the legislation and guidelines considered and the adopted methodology for the preparing this chapter.

9.2.2 Guidelines

The main guidelines used in preparing this chapter are:

- Draft EPA Guidelines on the information to be contained in an EIS (EPA, 2015)
- Draft Advice Notes on preparing an EIS (EPA 2015)
- Transport Infrastructure Ireland (TII, the operational name of the National Roads Authority) guidelines on procedures for assessment and treatment of geology, hydrology and hydrogeology for National Road Schemes (TII, 2009), referred to as the TII Guidelines within this chapter
- EPA Guidelines on Information to be contained in EISs (EPA, 2002)
- EPA Advice Notes on current practice in preparation of an EIS (EPA, 2003)
- TII Environmental Impact Assessment of National Road Schemes – A Practical Guide (TII, 2008)

- Institute of Geologists of Ireland (IGI) Guidelines for the Preparation of Soils, Geology and Hydrogeology Chapters of EISs (IGI, 2013)
- Draft Guidelines on the Information to be contained in Environmental Impact Assessment Reports (EPA, 2017)

9.2.3 Study Area

The study area for the proposed road development extends 250m beyond the proposed development boundary. This is in accordance with the TII Guidelines. Where appropriate, the study area has been extended to include nearby geological features which may be impacted as a result of the construction and operation of the proposed road development. The study area is presented on the soils and geology suite of figures, **Figures 9.1.001** to **9.8.012**.

9.2.4 Baseline Data Collection

9.2.4.1 Introduction

In order to identify and quantify the potential impact of the construction and operation of the proposed road development, it is first necessary to undertake a detailed study of the existing (baseline) geological environment along the route of the proposed road development. This requires the collation and evaluation of available regional and local information and more site-specific data obtained from walkover surveys and both historic and commissioned ground investigations.

The information presented in this chapter is based on information obtained from two main data collections:

- Regional and local baseline desk study from:
  - Desk Study Information
  - Historic Ground Investigations
  - Consultations
- Project specific information from:
  - Ground Investigations
  - Field Surveys and Walkovers

9.2.4.2 Regional and local baseline desk study

Desk Study Information

The following sources of information were reviewed[1] in order to evaluate the soils and geological environment in the vicinity of the proposed road development:

- Current and historical Ordnance Survey maps available for the study area (1:2,500 and 1:10,560 scales), 2017

[1] The latest review of all available information sources was conducted in June 2017

- Aerial photography (2012 and 2016) of the study area, supplemented with a sectional drone survey in April 2016
- Aerial imagery from Google (imagery from 2001 to 2015) and Bing accessed in 2017
- Geological maps of the site area produced by the Geological Survey of Ireland (GSI) (www.dccae.gov.ie)
- MacDermot, C.V., McConnell, B. and Pracht, M. (2003) Geology of Galway Bay 1:100,000 scale Bedrock Geology Map Series, Sheet 14, Galway Bay, Geological Survey of Ireland
- Pracht, M., Lees, A., Leake, B., Feely, M., Long, B., Morris, J., McConnell, B. (2004) Geology of Galway Bay: A geological description to accompany the Bedrock Geology 1: 100,000 Scale Map Series, Sheet 14, Galway Bay. Geological Survey of Ireland
- Teagasc and the Environmental Protection Agency Irish Soil Information System (http://gis.teagasc.ie/soils/index.php)
- Flood, P. and Eising, J. (1987). The use of vertical band drains in the construction of the Galway Eastern Approach Road. Proceedings of the 9th European Conference on Soil Mechanics and Foundation Engineering, Dublin, Ireland
- Gannon, M.J. (year unknown) Corrib Quincentenary Bridge, Paper presented to Engineers Ireland
- Lidar elevation data commissioned by OPW
- Results from karst field surveys reported in the June 2016 karst report, Appendix A.9.2
- Constraints reports from the previous N6 Galway City Outer Bypass Scheme (2006 GCOB):
- Galway City Outer Bypass R336 Western Approach Constraints Study Report 2000
- N6 Galway City Outer Bypass Constraints Study Report (2000)
- N6 Galway City Outer Bypass R336 Western Approach Link Route Selection Report (2001)
- N6 Galway City Outer Bypass East Route Selection Report (2001)
- N6 Galway City Outer Bypass Environmental Impact Statement Volume 2 (2006)

Historic Ground Investigations

Ground investigation reports held by the Geological Survey of Ireland for the study area were sourced and details are as follows:

- R1340 Galway County Council Eastern Approach Road Galway (N6) (Ballybane – Doughiska), 1993

- R1365 Thos. Garland and Partners Digital Limited, Galway Industrial Estate, 1983
- R3176 Dermot Rooney and Associates I.D.A Business Park, Dangan, Galway, 1997
- R5906 Irish Linen Proposed Irish Linen Factory, Rahoon, Galway, 2005
- R6136 Galway County Council Residential Development, Headford Road, Galway, 2006
- R6898 Storm Technology Office Block Development, Dangan, Galway, 2006

In addition, ground investigation reports made available within the study area were also sourced and include the following:

- SSE Renewables Ireland, Galway Wind Park 110kV River Corrib Crossing, Menlough, Galway, 2013
- Galway County Council Galway City Outer Bypass Preliminary Ground Investigation, 2006

Consultations

Consultation was carried out with the relevant bodies as detailed below:

- Geological Survey of Ireland (GSI)
- Department of Housing, Planning and Local Government[2]
- Mineral Exploration & Mining Division of the Department of Communications, Climate Action and Environment3
- Teagasc
- Office of Public Works (OPW)
- Galway County Council
- Galway City Council
- Environmental Protection Agency (EPA)
- Landowners

Consultation with these relevant bodies, along with the other specialists on the project team, is ongoing since 2014.

9.2.4.3 Project-Specific Information

Site-specific data was obtained from the following sources:

- Historic Ground investigations (extracts from baseline data collection outlined in **Section 9.2.4.2**)
- Project Specific Ground investigations

[2] Please note that department names have changed during the development of this chapter and consultation may be addressed to a previous superseded name. The names which these departments are referred to currently are provided.

- Field Surveys and Walkovers

The scope of the ground investigations within the study area include:

- Shell and auger boreholes
- Rotary core boreholes
- Trial pits
- Window samples[3]
- Geophysical surveys
- Groundwater level monitoring
- Geotechnical and environmental testing on soil and groundwater samples

Commissioned Ground Investigations

Preliminary ground investigations (GI) were commissioned for the EIAR and details of these are as follows:

- N6 GCTP Phase II Ground Investigation Contract I, November 2015
- N6 GCTP Phase III Ground Investigation Contract I, April 2016
- N6 GCTP Phase III Ground Investigation Contract II, December 2015
- N6 GCTP Phase III Ground Investigation Contract III, December 2016

The ground investigation factual reports for each of these GI is include in **Appendix A.9.1**. A summary of the project specific ground investigation has also been provided in **Table 9.1**. The ground investigation locations are presented on **Figures 9.8.001** to **9.8.012**, **9.9.001** and **9.9.002**.

Table 9.1: Summary of Project Specific Ground Investigations

Project Specific Ground Investigation						
Ground Investigation Activity	**Unit**	**Phase 1 C1**	**Phase 2 C1**	**Phase 3 C1**	**Phase 3 C2**	**Phase 3 C3**
Cable Percussive Boreholes	no.	-	-	29	-	1
Rotary Holes	no.	2	4	40	5	3
Rotary Percussive Holes	no.	-	5	-	-	1
Trial Pits	no.	-	-	38	-	4
Soakaway Testing	no.	-	-	2	-	17
Window Samples	no.	-	-	4	-	
Multi Analysis Surface Wave	m	1726	-	-	-	

[3] A window sample is used to bore shallow boreholes, usually up to 5mbgl depending on the soil type, to obtain soil samples for assessment.

Project Specific Ground Investigation						
Ground Investigation Activity	**Unit**	**Phase 1 C1**	**Phase 2 C1**	**Phase 3 C1**	**Phase 3 C2**	**Phase 3 C3**
Seismic Refraction	m	1726	1285	8496	-	2175
2D Resistivity Survey	m	-	973	6027	-	2175
Electrical Resistivity Tomography	m	-	-	-	1897	
Microgravity	stations	-	-	-	118	

Walkover Surveys

Walkover surveys were conducted while scoping the ground investigation in September and October 2015 and throughout the duration of the ground investigation fieldwork which was conducted between January to May 2016 and December 2016. See also **Chapter 10, Hydrogeology** for a description of karst[4] field surveys.

9.2.4.4 Technical Limitations

The data included in the geological assessment includes existing data from earlier investigations into the region as well as dedicated field surveys and walk overs commissioned for the proposed road development. The data collected provides a comprehensive geological dataset along the route of the propose road development.

The data points provide valuable information on the soils and geology environment at point locations. Between each point the data is assessed by conservative interpretation. While soils and geology can vary the exploratory locations have been selected following the completion of the comprehensive baseline data collection. This review was completed by studying local geological maps, aerial photography, historic ground investigation and completing site walkovers to provide an understanding of the soils and geology. The location and the spacing of the exploratory locations was chosen in order to gain an understanding of the ground conditions. The ground investigation findings for the majority of cases compared favourably with the baseline data collection desk study. In instances where it did not, supplementary ground investigation was undertaken, these locations were:

- Peat areas, additional window samples were undertaken to the establish the peat extent
- Adjacent to the River Corrib, to establish the transition from granite to limestone and the extent of karst

[4] Karst refers to a distinctive terrain that evolves through dissolution of the bedrock and development of efficient underground drainage. The special landforms of karst include sinkholes, dry valleys, pavements, cave systems and associated springs (Waltham *et al.* 2005)

- Coolough, for Lackagh Tunnel to establish rockhead and extent of palaeokarst fill due to an unexpected buried valley feature which was encountered
- Briarhill, to investigate the water table due to unexpected groundwater conditions which were encountered (refer to **Chapter 10, Hydrogeology**)

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

9.2.5 Impact Evaluation Methodology

Having defined the extent and form of the proposed road development, an evaluation is made of its potential likely significant impacts on the soils and geology environments. Mitigation measures are identified to mitigate any significant adverse impacts, where feasible.

This impact evaluation methodology is in accordance with the guidance outlined in Section 5.4 of the TII Guidelines (NRA, 2009) and in accordance with this guidance, all potential impacts of the proposed road development must be identified and assessed as per the conditions provided in **Table 9.2**.

Table 9.2: Identification of Impacts (Section 5.4.2 of TII Guidelines (NRA, 2009))

Condition	Classification	Description
Category of Impact	Direct Impact	Existing geological environment along or in close proximity to the proposed road development is altered, in whole or in part, as a consequence of road construction and/or operation
	Indirect Impact	Geological environment beyond the proposed road development is altered by activities related to road construction and/or operation
	No Predicted Impact	The proposed road development has neither a negative nor a positive impact on the geological environment
Effect of Impact	Positive	The proposed road development enhances a geological exposure
	Neutral	The proposed road development neither has a negative nor a positive impact on the geological environment
	Negative	The proposed road development results in a loss of a geological feature
Likelihood of Impact	Certain	Consideration should be given to such impacts in accordance with TII guidance (NRA, 2009)
	Likely	
	Possible	Consideration not required to such impacts in accordance with TII guidance (NRA, 2009)
	Unlikely	
Duration of Impact	Temporary	Construction related and lasting less than one year
	Short Term	Lasting one to 7 years
	Medium Term	Lasting between 7 to 15 years
	Long Term	Lasting 15 to 60 years

Condition	Classification	Description
	Permanent	Lasting over 60 years
Type / Nature of Impact	**Cumulative**	Combination of many minor impacts create one, larger, more significant impact
	Potential	Impact of the proposed development before mitigation measures are fully established
	Worst – Case	Impact of the proposed development should mitigation measures substantially fail to fulfil their intended function
	Residual	Final or designed impact which results after proposed mitigation measures have been fully established

In accordance with Section 5.4.3 of the TII Guidelines, the rating criteria for assessing the importance of geological features within the study area are outlined in **Table 9.4** and the rating criterion for quantifying the magnitude of impacts is outlined in **Table 9.5**. The rating of potential environmental impacts on the soils and geology environment are based on the matrix presented in **Table 9.6** below which takes account of both the importance of an attribute and the magnitude of the potential environmental impacts of the proposed road development on it.

The magnitude of impacts should be defined in accordance with the criteria provided in the EPA Guidelines. This is outlined in **Table 9.3**.

Table 9.3: Definition of Magnitude of Impact (Table 5.1 (NRA, 2009))

Magnitude of Impact	Description
Imperceptible	An impact capable of measurement but without noticeable consequences
Slight	An impact that alters the character of the environment without affecting its sensitivities
Moderate	An impact that alters the character of the environment in a manner that is consistence with existing or emerging trends
Significant	An impact which by its character, magnitude, duration or intensity alters a sensitive aspect of the environment
Profound	An impact which obliterates all previous sensitive characteristics

These impact ratings are in accordance with impact assessment criteria provided in the aforementioned EPA Guidelines. The criteria apply to potential impacts during both the construction and operational phases.

Table 9.4: Criteria for rating the importance of identified geological features (Table C2 (IGI, 2013) and Box 4.1 (NRA, 2009))

Importance	Criteria	Typical Example
Very High	Attribute has a high quality, significance or value on a regional or national scale. Degree or extent of soil contamination is significant on a national or regional scale. Volume of peat and / or soft organic soil underlying route is significant on a national or regional scale.	Geological feature rare on a regional or national scale (NHA) Large existing quarry or pit Proven economically extractable mineral resource
High	Attribute has a high quality, significance or value on a local scale. Degree or extent of soil contamination is significant on a local scale. Volume of peat and / or soft organic soil underlying route is significant on a local scale.	Contaminated soil on site with previous heavy industrial usage Large recent landfill site for mixed wastes Geological feature of high value on a local scale (County Geological Site) Well drained and / or highly fertility soils
Medium	Attribute has a medium quality, significance or value on a local scale. Degree or extent of soil contamination is moderate on a local scale. Volume of peat and / or soft organic soil underlying route is moderate on a local scale.	Contaminated soil on site with previous light industrial usage Small recent landfill site for mixed wastes Moderately drained and / or moderate fertility soils Small existing quarry or pit
Low	Attribute has a low quality, significance or value on a local scale. Degree or extent of soil contamination is minor on a local scale. Volume of peat and / or soft organic soil underlying route is small on a local scale*.	Large historical and / or recent site for construction and demolition wastes Small historical and / or recent landfill site for construction and demolition wastes Poorly drained and / or low fertility soils. Uneconomically extractable mineral resource

Note: * relative to the total volume of inert soil disposed of and/or recovered

Table 9.5: Criteria for Rating Soil and Geology Impact Significance and Magnitude at EIS Stage (Table C4 (IGI, 2013) and Box 5.1 (NRA, 2009))

Magnitude of Impact	Criteria	Typical Examples
Large Adverse	Results in loss of attribute	Loss of high proportion of future quarry or pit reserves Irreversible loss of high proportion of local high fertility soils Removal of entirety of geological heritage feature Requirement to excavate / remediate entire waste site Requirement to excavate and replace high proportion of peat, organic soils and / or soft mineral soils beneath alignment
Moderate Adverse	Results in impact on integrity of attribute or loss of part of attribute	Loss of moderate proportion of future quarry or pit reserves Removal of part of geological heritage feature Irreversible loss of moderate proportion of local high fertility soils Requirement to excavate / remediate significant proportion of waste site Requirement to excavate and replace moderate proportion of peat, organic soils and / or soft mineral soils beneath alignment
Small Adverse	Results in minor impact on integrity of attribute or loss of small part of attribute	Loss of small proportion of future quarry or pit reserves Removal of small part of geological heritage feature Irreversible loss of small proportion of local high fertility soils and / or high proportion of local low fertility soils Requirement to excavate / remediate small proportion of waste site Requirement to excavate and replace small proportion of peat, organic soils and/or soft mineral soils beneath alignment
Negligible	Results in an impact on attribute but of insufficient magnitude to affect either use or integrity	No measurable changes in attributes
Minor Beneficial	Results in minor improvement of attribute quality	Minor enhancement of geological heritage feature
Moderate Beneficial	Results in moderate improvement of attribute quality	Moderate enhancement of geological heritage feature
Major Beneficial	Results in major improvement of attribute quality	Major enhancement of geological heritage feature

Table 9.6: Rating of Significant Environmental Impacts at EIS Stage (Table C6 (IGI, 2013) and Box 5.4 (NRA, 2009))

		Magnitude of Impact			
		Negligible	Small	Moderate	Large
Importance of Attribute	**Extremely High**	Imperceptible	Significant	Profound	Profound
	Very High	Imperceptible	Significant / Moderate	Profound / Significant	Profound
	High	Imperceptible	Moderate / Slight	Significant / Moderate	Severe / Significant
	Medium	Imperceptible	Slight	Moderate	Significant
	Low	Imperceptible	Imperceptible	Slight	Slight / Moderate

The appraisal of the potential likely significant impacts of the proposed road development on soils and geology will consider the following specific topics in accordance with the TII Guidelines (TII, 2009):

- Soils (range of agricultural uses, fertility and drainage characteristics)
- Requirements for treatment and/or handling of soft, unstable or contaminated soils, subsoils or other geological materials
- Requirements for excavation, disposal and / or recovery of soils, subsoils or other geological materials which may be unsuitable for re-use in construction of earth structures or present a risk to human health and/or the environment
- Environmental impact of engineering works on, in or over karst features (buried open / infilled cavities, slope and pavement stability)
- Impact on Economic Geology (mines, pits and quarries) either currently being extracted or potentially developable in the future
- Geological Heritage
- Requirements for blasting in cuttings which may impact on existing structures or infrastructure nearby (noise and vibration)
- Requirements for transportation and truck movements of excavated material and disposal of waste material (traffic, noise and vibration)
- Requirements for pile driving at bridge structures which may impact on existing structures or infrastructure nearby (noise and vibration)
- Requirements for tunnel construction which may impact on existing structures or infrastructure nearby (noise and vibration, settlement and instability)

An analysis of the potential impacts of the proposed road development on soils and geology during construction and operation is presented in **Section 9.5**.

Through the evolution of the design of the proposed road development measures were included in the design to reduce or avoid specific impacts where possible.

Following the evaluation of potential impacts as a result of the design, specific mitigation measures have been developed to avoid, prevent, reduce and, if possible, remedy any significant adverse impacts on the soils and geology. These are described in **Section 9.6** below. Residual impacts which are the final impacts which result after mitigation measures have been fully established are described in **Section 9.7 Table 9.19** and **Table 9.20**.

9.3 Receiving Environment

9.3.1 Introduction

This section describes the soils and geology within the study area. A regional overview is provided in terms of the geomorphology, topography, soils and solid geology of the local area followed by sub sections identifying the feature importance ranking of the agricultural soils, superficial deposits, bedrock geology, soft and unstable ground, contaminated land, karst solution features, mineral and aggregate resources and geological heritage sites within the study area.

When examining the receiving environment of the study area, the proposed road development has been divided into four sections for ease of presentation and due to the volume of information available. For consistency, these sub-divisions are also applied in **Chapter 10, Hydrogeology**. The four sections are as follows:

- Section 1: Chainage 0+000 to 8+500 (R336 to the N59 Moycullen Road)
- Section 2: Chainage 8+500 to 9+400 (N59 Moycullen Road to the River Corrib)
- Section 3: Chainage 9+400 to 14+000 (River Corrib to the N83 Tuam Road)
- Section 4: Chainage 14+000 to 17+500 (N83 Tuam Road to the existing N6 at Coolagh)

These four sections of the proposed road development are discussed in **Sections 9.3.2** to **9.3.12**.

The description of the regional overview is sub-divided and discussed in terms of the western and eastern areas, which are separated by the River Corrib. Section 1 and 2 of the study area covers the western area and the eastern area covers Sections 3 and 4.

The receiving environment is presented on **Figures 9.1.001** to **9.8.012**.

In **Section 9.2.18** a conceptual site model is presented on **Figures 9.8.001** to **9.8.0012** and summarised in **Table 9.16**. The conceptual model plots the factual ground investigation data within the study area along the existing ground level against the proposed road level, earthworks areas and chainage of the proposed road development. **Table 9.16** presents additional information for each earthworks area.

9.3.2 Regional Overview

The proposed road development traverses from west to east of Galway on the northern side of Galway City. This section will discuss the following aspects of the region surrounding the proposed road development:

- Regional Geomorphology and Topography
- Regional Soils and Bedrock Geology

9.3.2.1 Regional Geomorphology and Topography

The general geomorphology of the western area consists of gently undulating to hummocky[5] topography in areas overlying granite. The ground level is lowest at the shores of Lough Corrib and along the coast (10m OD) and rises to the high points at Gortacleva / Tonabrocky (111m OD), Derry Crih (96m OD) and Corcullen (90m OD). The GSI maps indicate ridge lines exist at Tonabrocky and Derry Crih which run northwest-southeast.

The proposed road development crosses the River Corrib near Menlo Castle on the eastern bank and on the western side it passes through National University of Ireland Galway (NUIG) Sporting Campus at Dangan. On crossing the River Corrib, the topography to the eastern area is less undulating than in the western area. The area around the River Corrib is relatively flat and rises to the east. The highest point is at Coolough (65m OD). This is also directly beside the disused Lackagh Quarry in Coolough. From this point the ground surface gently slopes towards Ballindooley Lough and rises again towards Twomileditch (60m OD). The Geological Survey of Ireland (GSI) have produced Quaternary Geology [6] mapping for Ireland. A presentation of the mapping is provided in **Figures 9.1.001** to **9.1.002** and **Figure 9.1.101** to **9.1.114**.

The Galway Granite Batholith is recorded as an indicator erratic or a known source area, with path direction or known erratic train to the south of Ireland. Glacial erracatics are evident east of the River Corrib.

Striation[7] is rather non-uniform to the west of the River Corrib. However the majority of striae direction and drumlins face in a north to northeast direction. The striae direction, streamlined bedrock and drumlin direction in the east of the River Corrib is provided as a northeast direction.

The Lower Carboniferous Visean Limestone is known to contain karst solution feature including surface features such as springs, turloughs and swallow holes which are present east of the River Corrib. Limestone pavement is also common throughout the study area, east of River Corrib and is located both outside and

[5] Hummocky terrain is defined as uneven or undulating surface which contains subdued and rolling landforms.
[6] The Quaternary mapping consists of unconsolidated sediments, the distribution and outline of the main geomorphological features and ice direction indicators.
[7] This refers to glacial striation or scratches, gouges cut into bedrock by glacial abrasion during movement of the glacier.

within the Lough Corrib cSAC, refer to **Chapter 8, Biodiversity** for the ecological assessment of Limestone pavement.

The proposed road development intercepts several watercourses, predominately to the west of the River Corrib. To the east of the River Corrib, due to the highly karstic nature of the terrain, there is a very sparse network of watercourse features. Lake features include Coolagh Lakes and Ballindooley Lough which are located east of the River Corrib. For further details refer to **Chapter 11, Hydrology**. Blanket peat is widespread on the west of the River Corrib but reduces toward the river. Some isolated areas of cutover peat also exist on the eastern side of the River Corrib.

9.3.2.2 Regional Soils and Bedrock Geology

Generally the western area consists of a mix of peaty podzols, blanket peat, lithosols / regosols and surface water gleys, overlying predominantly granular glacial till over early-middle Devonian granite intrusions known as the Galway Granite Batholith and other igneous intrusive rocks. The lowest ground level is at the shores of Lough Corrib where alluvial deposits and fen peat are encountered. The land in the western area is predominantly used as agricultural land with the lands closer to the River Corrib becoming more urban with many residential, commercial and University areas.

The soils in the east consists predominantly of grey brown podzolics, lithosols peat and renzinas / lithosols, overlying cohesive glacial till derived from the underlying bedrock consisting of overly karstified Carboniferous Visean Limestone. Pracht 2013 refer to these limestone as the Burren Formation. Palaeolandscape features (and likely palaeokarst) were identified which comprise of features of significantly deep infilled buried valleys. The land in the eastern area is predominantly used as agricultural land with the area between Ballybrit and Briarhill as an urban environment. Within this area there is an active and disused limestone quarry located in Twomileditch and Coolough, Menlough respectively.

9.3.3 Agricultural Soils

Soil within the study area was assessed based on agricultural usage, fertility and drainage characteristics. Teagasc developed a national indicative soil map, which classifies the soils of Ireland into simplified categories. The Teagasc Soil Mapping has been reproduced in **Figure 9.2.001** to **Figure 9.2.002** and **Figure 9.2.101** to **9.2.114**. Cognisance was taken of the CORINE (Co-Ordinated Information on the Environment) dataseries, established by the European Community (EC) and nationally coordinated by the EPA, when interpreting the Teagasc Soil maps. This section looks at the agriculture soil only. Potential agriculture impacts are assessed in **Chapter 14, Material Assets Agriculture**.

A summary of the agricultural soils present along the proposed road development and their associated feature importance is provided in **Table 9.7**.

Section 1: Chainage 0+000 to 8+500

The soil from Na Foraí Maola to Aille is typically described as poorly drained shallow deposits with peaty topsoil. From Aille to Dangan, the soil description changes to become a shallow to deep, well drained, non-calcareous deposit. These areas are typically described as agricultural lands with arable land and pastures. Some vegetation typical of peatlands exists in both An Chloch Scoilte and Aille.

Section 2: Chainage 8+500 to 9+400

Soil in the central part of the study area, in the vicinity of the River Corrib, is primarily described as made ground with alluvial deposits indicated along the river catchment. This area has no agricultural soil value as it is part of the urban fabric.

Section 3: Chainage 9+400 to 14+000 and Section 4: Chainage 14+000 to 17+500

To the east of the River Corrib, the majority of the land is described as well drained, with a high percentage of agricultural, fertile land, mixed with small clusters of residential and industrial facilities.

Land is predominantly natural however the potential for contaminated ground is further discussed in **Section 9.3.8**.

Table 9.7: Geological Feature Importance of Soil within Study Area

Soil Type	Description	Location / General Extent	Feature Importance Ranking
Teagasc Soils			
AminSRPT	Shallow, lithosolic or podzolic type soils potentially with peaty topsoil. Predominantly shallow soils derived from non-calcareous (granite) rock or gravels with / without peaty surface horizon	Generally from Na Foraí Maola to An Chloch Scoilte	Low
BktPt	Blanket Peat	An Chloch Scoilte	Low
AminSW	Shallow well drained mineral. Derived from mainly non-calcareous (granite) parent materials	Generally from An Chloch Scoilte to Ballard	High
AminDW	Deep well drained mineral soils derived from mainly non-calcareous (granite) parent materials	Aille to Cappagh and Ballyburke to Dangan	High
AminPD	Deep poorly drained mineral derived from mainly non-calcareous (granite) parent materials	Various locations along the western section of the study area	Low
Made	Made Ground	Dangan to Menlough and Ballybrit	Low
AlluvMIN	Mineral Alluvium	Menlough	Low

Soil Type	Description	Location / General Extent	Feature Importance Ranking
BminSW	Shallow well drained mineral. Derived from mainly calcareous (limestone) parent materials	Generally from Menlough to Ballindooley	High
BminSRPT	Shallow, lithosolic or podzolic type soils potentially with peaty topsoil. Predominantly shallow soils derived from calcareous (limestone) rock or gravels with / without peaty surface horizon	Lackagh and Ballybrit	Low
Cut	Cutover Peat	River Corrib and Ballindooley Lough	Low
BminDW	Deep well drained mineral. Derived from mainly calcareous (limestone) parent minerals	Generally from Ballindooley to Coolagh	High
BminPD	Deep poorly drained mineral. Derived from mainly calcareous parent minerals	Various locations along the eastern section of the study area	Low
BminPDPT	Poorly drained mineral soils with peaty topsoil. Derived from mainly calcareous (limestone) parent materials	Various locations along the eastern section of the study area	Low

9.3.4 Superficial Deposits

Superficial deposits refer to geological deposits associated with the youngest geological deposits formed during the most recent period of geological time, the Quaternary, which extends back about 2.6 million years from the present (http://www.bgs.ac.uk/products/digitalmaps/digmapgb_drift.html).

The Irish Soil Information System [8]project has developed a national association soil map for Ireland, providing information on soil types and properties across Ireland.

Superficial deposits were established based on the Irish National Soil Map 1:250,000, the Teagasc Subsoil Map and relevant ground investigation information along the proposed road development.

A reproduction of the Irish National Soil map 1:250,000, as provided by Teagasc and Cranfield University, has been provided in **Figure 9.3.001** to **Figure 9.3.002** and **Figure 9.3.101** to **Figure 9.3.114**. The Teagasc Subsoil Map, produced by Teagasc, EPA and GSI, was also consulted. This map has also been reproduced in **Figure 9.4.001** to **Figure 9.4.002** and **Figure 9.4.101** to **Figure 9.4.114**.

[8] The Irish Soil Information System project has developed a national association soil map for Ireland at a scale of 1:250,000. The project is co-funded by Teagasc and the Environmental Protection Agency (EPA) Science, Technology and Research & Innovation for the Environment (STRIVE) programme (http://gis.teagasc.ie/isis/about.php)

A summary of the superficial deposits are presented in **Table 9.8**.

Section 1: Chainage 0+000 to 8+500

Generally Section 1 consists of peat over a mixture of granular glacial deposits and highly weathered granite.

Section 2: Chainage 8+500 to 9+400

Section 2 is comprised of shallow granular granite derived till over weathered granite, with some instances of peat. This changes to soft to firm sandy gravelly clay over weathered limestone at the intersection of the rock types.

Section 3: Chainage 9+400 to 14+000 and Section 4: Chainage 14+000 to 17+500

East of the River Corrib, the study area typically consists of glacial till derived from limestone, over weathered limestone. Instances of palaeolandscape infilling were uncovered in various low-lying areas within the study area in Menlough, Coolough, Castlegar and Terryland.

Areas of soft and / or unstable ground are discussed further in **Section 9.3.7**.

Table 9.8: Geological Feature Importance of Superficial Deposits within Study Area

Strata[9]	**General Extent / Location**	**Depth to Top of Strata (m BGL)**	**Thickness Range (m)**	**Notes / Description**
Topsoil	Widespread	0.0	0.0 – 0.7	Occasionally peaty in nature
Made Ground	Widespread	0.0 – 0.3	0.0 – 1.9	Occasional fragments of concrete, red brick, ceramic pipe, timber
Peat	Section 1 and 3	0.0 – 0.8	0.0 – 1.3	Occasionally slightly sandy
Glacial Till derived from Granite	Section 1	0.1 – 2.3	0.0 – 3.5	Cohesive and granular mix
Glacial Till derived from Limestone	Section 2 to 4	0.1 – 1.9	0.0 – 21.6	Cohesive and granular mix
Palaeolandscape Fill	Section 2 and 3	13.7 – 101.5	87m (only confirmed thickness)	Described as silt, organic clay, and a transition zone consisting of cobbles and boulders

[9] Strata indicated may not be present at all locations along the proposed road development.

9.3.5 Bedrock Geology

The underlying bedrock geology was determined based on the Bedrock Geology 1:100,000 online mapping (Geological Survey of Ireland), and relevant ground investigation along the route of the proposed road development and is presented in **Figures 9.5.001** to **Figure 9.5.002** and **Figure 9.5.104** to **Figure 9.5.114**.

Section 1: Chainage 0+000 to 8+500

Section 1 is underlain by the Galway Granite Batholith which consists of a number of distinct granite intrusions and is faulted into three main parts by the Shannawona north northeast trending faults and the Bearna northwest trending faults. The Bearna Fault is indicated by the GSI as running approximately through the center of Section 1 at Aille / Ballard. Faulting in the Galway Granite Batholith was not confirmed in intrusive investigation.

To the west of the inferred Bearna Fault, the underlying granite is described as a black, grey, pink, biotite Megacrystic-Porphyritic Granite. The coarse grained, pink, phenocrystic K-feldspar granite known as the Errisbeg Townland Granite occurs to the east of the fault.

Late stage felsite, quartz porphyry and granite porphyry dykes cross almost all of these intrusions.

The white to grey fine grained aphyric felsic Murvey Granite occurs at or near the margins of the batholith and also at the eastern end of Section 1 in Dangan. The Murvey Granite is considered to be the most fractionated of all the granites in the batholith.

Section 2: Chainage 8+500 to 9+400

West of the River Corrib, the study area is typically underlain by Early to Middle Devonian granite intrusions within the Galway Granite Batholith. The Murvey Granite occurs at the outer periphery of the Errisbeg Townland Granite, adjacent to the Lower Carboniferous Visean Limestone known as the Burren Formation.

The area of limestone between the western shore of the River Corrib and the fault bounding the pre-Carboniferous rocks to the west were originally mapped by C.V. MacDermot in the late 1960's and early 1970's. Based on the results of the project specific ground investigation, the rock type change occurs in the vicinity of the unconformity line. Intrusive investigation and geophysical investigation confirmed the high likelihood that the change in rock type occurs at Ch. 8+880. On the limestone side of the indicative chainage, a zone of low resistivity that is up to 40m wide and greater than 20m deep was encountered. This is likely to be a highly weathered zone at the contact zone. East of this zone, the geology sharply reverts to high resistivity, typical of competent limestone. Therefore, this unconformity line / fault is still considered valid and provided in **Figures 9.5.001** to **Figure 9.5.002** and **Figure 9.5.104** to **Figure 9.5.114**.

The rock is described as thick to thinly bedded, however, the majority of intrusive coring indicates that the limestone rockmass is thinly bedded. Average depth to rock is approximately 5.0m below ground level, however intrusive investigation along the River Corrib indicates that rock can drop to 78m below ground level.

Section 3 and 4: Chainage 9+400 to 17+500

The area to the east of the River Corrib is underlain by the Burren Formation (Visean) of the Lower Carboniferous age. There is limited available information on the depositional sequencing of the Burren Formation west and east of Lough Corrib. The exploratory descriptions for the limestones encountered during the site investigation vary widely and therefore no trend or isolated areas of distinct characteristics have been observed. The bedrock topography associated with the palaeolandscape was encountered at depths deeper than elsewhere within the study area.

Some argillaceous (clayey) material was recorded in the coreholes. The nature of the limestone strongly influences its susceptibility to karstification. Purer limestones (>90% calcite) are more susceptible than impure (shaley / argillaceous) limestones.

The average depth to rock across the Sections 3 and 4 (excluding areas of palaeolandscape features) is approximately 2.4m below ground level. Intrusive coring indicates that the rock is massive to thinly bedded.

Karst within the limestone is discussed in **Section 9.3.6**.

A summary of the bedrock formations and associated descriptions is provided in **Table 9.9**.

Table 9.9: Rock Formations within Study Area

Geological Period	Bedrock Unit	Formation	Description	General Extent / Location
Carboniferous	Dinantian Pure Bedded Limestone	Burren Formation (Visean)	Medium to very strong massive to thinly bedded blueish dark grey fine grained slightly weathered	**Section 2, 3** and **4** East of River Corrib, with small section west of river bank
Early-Middle Devonian	Galway Granite Batholith	Porphyritic-Megacrystic Granite	Very strong grey, white, pink, black biotite slightly weathered	**Section 1** Coast Road (R336) to Aille *Principal granite mass west of the Bearna Fault*
		Fine Grained Foliated Granite	Very strong thickly to thinly banded brown pink green medium to coarse grained slightly weathered	**Section 1** Between An Chloch Scoilte and Ballard
		Errisbeg Townland Granite	Very strong thickly to thinly banded brownish purple	**Section 1** and **2** Aille to Dangan

Geological Period	Bedrock Unit	Formation	Description	General Extent / Location
			fine to coarse grained slightly weathered	*Principal granite mass east of Bearna Fault*
		Murvey Granite	Very strong thickly to thinly banded green, white fine coarse grained moderately weathered	**Section 1** and **2** Dangan *Border formation between principal granite and visean limestone*
Ordovician	Other Igneous Intrusive Rocks	Metagrabbo and Orthogneiss Suite (undifferentiated)		**Section 1** and **2** Dangan

9.3.6 Karst Solution Features

From the N59 Moycullen Road at Dangan (Section 1) to the existing N6 at Coolagh, Briarhill (Section 4) the study area is underlain by clean non-argillaceous limestone which is prone to karst. A range of solution features were identified within the study area and presented in **Figure 9.6.001** to **Figure 9.6.002**, **Figure 9.6.101** to **Figure 9.6.114**, **Figure 10.1.001** to **Figure 10.1.002** and **Figure 10.1.101** to **Figure 10.1.114**. These include:

- Limestone pavement
- Epikarst
- Dolines (enclosed depressions)
- Caves
- Estavelles
- Springs
- Superficial Solution Features
- Wells
- Swallow holes
- Turloughs

The solution features have been identified based on the GSI Karst Database and were further assessed in a project specific karst survey, which is available in **Appendix A.9.2**.

Section 1: Chainage 0+000 to 8+500

There is no karst in Section 1 as this area is underlain by granite which is not susceptible to karst.

Section 2, 3 and 4: Chainage 8+500 to 17+500

The Teagasc subsoil mapping indicates that approximately 40% of the landcover over the limestone bedrock is karstified outcrop or subcrop. Site walkovers and ground investigation established that much of Section 3 and 4 is limestone subcrop with a thin / shallow layer of topsoil, glacial till.

Areas of Limestone pavement were uncovered and mapped in Sections 3 and 4. Limestone pavement, which is underlain by limestone bedrock accounts for approximately 10% of the land cover. Limestone pavement occurs within and outside European designated sites. For the purpose of the geological assessment no differentiation has been made between Limestone pavement located within or outside the European designated sites. Refer to **Chapter 8, Biodiversity** for an ecological assessment of Limestone pavement.

Most of the karstification identified along the proposed road development consists of a weak to well-developed zone of epikarst[10], ranging from approximately 0m to 2.7m in thickness[11] (epikarst refers to the zone of partially weathered or weathered limestone which is present between the overburden soils and the underlying unweathered rock).

In a smaller number of areas, more intense karstification has led to deeper weathering (below the epikarst zone) and clay infilling of solutionally enlarged features (typically joints). In some of these, even more intense karstification has occurred, leading to the development of relatively large dissolution features which are typically infilled with sediments. The establishment of the location of these features is achieved through geophysical surveys and intrusive investigation.

Palaeokarst features have been identified with the bedrock formation. These consist of large buried valleys filled with silt and clay.

Various anomalies were encountered in both intrusive investigation and geophysical surveys, which may likely be karst related. These include the following:

- Non intact zones identified in rotary coreholes below bedrock level
- Cavities in rotary coreholes
- Calcite deposits and infilled voids identified in rotary coreholes
- Significant drop in resistivity values recorded during the geophysical survey which do not coincide with typical bedrock resistivity values

[10] Epikarst comprises of highly weathered carbonate bedrock immediately beneath the surface or soil where present.

[11] The values provided are representative of the typical thicknesses observed / recorded. Weathered rock was recorded as 6.4m thick in BH 3/35R conducted during the N6 GCTP Phase 3 Contract 1 Ground Investigation in 2016. However, based on site observations during monitoring of the works and available geophysical data, the material was a mixture of cobbles and boulders with dense granular content. This was an isolated record.

Such anomalies were encountered at various locations across the study area underlain by limestone bedrock. The location of these anomalies are presented in the ground investigation factual data and are not included in

Table 9.10. Refer to **Chapter 10, Hydrogeology** for a full description of both surface karst features and anomalies recorded from the ground investigations.

Table 9.10: Geological Feature Importance of Karst Features within Study Area

ID Code	Karst Feature	Information Source	Location / General Extent	Feature Importance Ranking
Limestone Pavement				
LP	Limestone pavement	Field mapping from Ecologist	Widespread throughout Sections 3 and 4	Very High[12]
Palaeolandscape (Palaeokarst)				
PK	Palaeokarst Valley	Mapping from Hydrogeologist	Menlough, Ballindooley Castlegar	Medium
Surface Karst Solution Features				
K7	Spring	Field Survey	Bushypark	Medium
K10	Enclosed Depression	Field Survey	Bushypark	Medium
K11	Enclosed Depression	Lidar, Bing Maps, Google Maps, Aerial Photography	Bushypark	Medium
K12	Enclosed Depression	Lidar, Bing Maps, Google Maps, Aerial Photography	Bushypark	Medium
K17	Spring	Field Survey	Menlough	Medium
K25	Spring	Lidar, Bing Maps, Google Maps, Aerial Photography, OSI Water Line	Menlough	Medium
K31	Turlough	Scott Cawley Ecologists Surveys	Menlough	Medium
K44	Enclosed Depression	Lidar, Bing Maps, Google Maps, Aerial Photography	Coolagh	Medium
K45	Spring	Lidar, Bing Maps, Google Maps, Aerial Photography, OSI Water Line	Coolagh	Medium
K49	Enclosed Depression	Lidar, Bing Maps, Google Maps, Aerial Photography	Coolagh	Medium

[12] Limestone pavement is ranked based on its soils and geological feature importance not as ecological importance. Refer to **Chapter 8, Biodiversity** for ecological importance rating.

ID Code	Karst Feature	Information Source	Location / General Extent	Feature Importance Ranking
K51	Enclosed Depression	Lidar, Bing Maps, Google Maps, Aerial Photography	Coolagh	Medium
K54	Enclosed Depression	Lidar, Bing Maps, Google Maps, Aerial Photography	Coolagh	Medium
K57	Enclosed Depression	Lidar, Bing Maps, Google Maps, Aerial Photography	Coolagh	Medium
K59	Enclosed Depression	Lidar, Bing Maps, Google Maps, Aerial Photography	Coolagh	Medium
K61	Enclosed Depression	Field Survey	Coolagh	Medium
K62	Enclosed Depression	Field Survey	Coolagh	Medium
K64	Enclosed Depression	Field Survey	Coolagh	Medium
K67	Enclosed Depression	Lidar, Bing Maps, Google Maps, Aerial Photography	Coolagh	Medium
K70	Enclosed Depression	Field Survey	Coolagh	Medium
K71	Enclosed Depression	Field Survey	Coolagh	Medium
K97	Enclosed Depression	Lidar, Bing Maps, Google Maps, Aerial Photography	Castlegar	Medium
K104	Enclosed Depression	Lidar, Bing Maps, Google Maps, Aerial Photography	Castlegar	Medium
K131	Enclosed Depression	Lidar, Bing Maps, Google Maps, Aerial Photography	Parkmore	Medium
K158	Spring	OSI Water Line map	Coolagh	Medium
K161	Spring	GSI Database: Well survey carried out by Bride Naughton GSI 1972	Coolagh	Medium
K166	Spring	GSI Database: Well survey carried out by Bride Naughton GSI 1972	Coolagh	Medium
K172	Enclosed Depression	Lidar, Bing Maps, Google Maps, Aerial Photography	Coolagh	Medium

ID Code	Karst Feature	Information Source	Location / General Extent	Feature Importance Ranking
K175	Enclosed Depression	Field Survey	Coolagh	Medium
K176	Spring	GSI Database: Well survey carried out by Bride Naughton GSI 1972	Coolagh	Medium
K178	Spring	GSI Database: Well survey carried out by Bride Naughton GSI 1972	Coolagh	Medium
K179	Enclosed Depression	Field Survey	Coolagh	Medium
K180	Spring	GSI Database: Well survey carried out by Bride Naughton GSI 1972	Coolagh	Medium
K181	Spring	GSI Database: Well survey carried out by Bride Naughton GSI 1972	Coolagh	Medium
K193	Enclosed Depression	Field Survey	Coolagh	Medium
K328	Enclosed Depression	Bing Maps	Parkmore	Medium

9.3.7 Soft and/or Unstable Ground

Soft deposits consist of peat, alluvium or very soft cohesive material. These soft compressible deposits, which are located within the study area, are presented in **Figure 9.7.001** to **Figure 9.7.002** and **Figure 9.7.101** to **Figure 9.7.114**. Various sources of information were consulted in establishing these areas along the study area namely:

- Teagasc Subsoil map, produced by Teagasc, EPA and GSI
- GSI database of historical landslides
- EPA subsoil mapping
- Ground Investigation data

The Teagasc Subsoil map outlined locations of soft soil within the study area and the GSI database shows no recorded landslide events within the study area.

Areas containing peat and very soft to soft cohesive material identified within the study area were primarily obtained through assessment of intrusive investigation and consultation of the EPA Subsoil mapping. The ground investigation soil log descriptions (soft, very soft) and in-situ strength testing were used to determine the location of soft deposits. In accordance with EN ISO 14688-2:2004, material with an undrained shear strength of 40 kPa is considered a soft deposit.

According to the Teagasc subsoil mapping for the county, less than 1% of the peatland areas in County Galway fall within the study area. Areas containing peat and soft soil are displayed in **Figure 9.7.001** to **Figure 9.7.002** and **Figure 9.7.101** to **Figure 9.7.114** and the conceptual site model as presented in **Figure 9.8.001** to **Figure 9.8.012**.

Section 1: Chainage 0+000 to 8+500

Intrusive investigation indicates the existence of peaty topsoil and shallow deposits of peat throughout Section 1. The evidence and likelihood of this material reduces at Dangan, where the landcover enters the urban fabric. Typically, the depths observed for the peat were less than 1.0m however a number of locations were identified where the peat extended up to thicknesses of 2.0m or soft deposits up to thicknesses of 3.6m, as presented in **Figure 9.8.001** to **Figure 9.8.012**. The soft deposits are typically non-organic, however organic deposits were encountered in Na Foraí Maola and Aille. These are isolated instances only and are likely due to the overlying peat.

Section 2: Chainage 8+500 to 9+400

Peat is recorded in the upper, northern part of the study area within Section 2. Alluvial deposits and highly organic soft deposits were encountered along the bank of the River Corrib.

Section 3: Chainage 9+400 to 14+000

Peat was observed in the valley area at Coolough, Menlough, west of Lackagh Quarry. This is mixed with highly organic soft ground deposits and alluvial deposits as per the intrusive investigation and GSI subsoil mapping. Geophysical surveying during the commissioned site investigation indicates that the likely deposition of these deposits as is associated with infilling of deep buried valleys or palaeovalleys.

A significant palaeokarst feature was uncovered west of Lackagh quarry with palaeokarst fill encountered to 101.5m below ground level (blg) in one exploratory hole. This is significantly deeper than the shallow bedrock in the immediate vicinity which includes Limestone pavement.

Peat was also encountered at Ballindooley Lough, with historic ground investigation showing peat up to 3.7m in thickness. Soft deposits, mixed with peat are expected both west and east of the N84 Headford Road, as the geophysical survey indicate the potential presence of deep buried valleys either side of the N84 Headford Road.

Section 4: Chainage 14+000 to 17+500

Isolated instances of soft ground were encountered in Section 4. A buried valley was uncovered following a geophysical survey, with intrusive investigation confirming the anomaly. Only two isolated instances of peat were encountered in historic and recent intrusive investigations, along with only one instance of slightly organic material.

In determining the feature importance of soft ground, the soil types have been grouped and are ranked in the **Table 9.11**.

Table 9.11: Geological Feature Importance for Geohazards within Study Area

Feature	Description	Feature Importance Ranking
GEOHZ01	Peat	Low
GEOHZ02	Soft Organic[13]	Low
GEOHZ03	Soft Non-Organic	Low

9.3.8 Contaminated Land

Various sources of information were consulted in assessing the study area for locations of potential contaminated land:

- CORINE land cover mapping
- Teagasc Soil map
- EPA
- Ground Investigation data

No known areas of contaminated ground were identified. Industrial sites may be the source of locally contaminated land due to site activities. Approximately 5% of the study area is comprised of Industrial and Commercial Units in accordance with the CORINE land cover mapping. However, these sites operate within the EPA Industrial Emissions (IE) licence framework and due to the regulated nature of their activities, the risk of contamination is low.

There are no sites within the study area that have been granted a waste water discharge licence.

Made ground has been defined as soil which has been altered in some way by human activity (imported and placed in-situ). Made ground has been observed in the form of inclusions of metal, glass, copper piping, ceramic piping. All locations of made ground are presented in the conceptual site model **Figure 9.8.001** to **Figure 9.8.012**. Based on the Teagasc Soil mapping less than 10% of the study area is comprised as made ground with approximately 30% of the study area comprised of artificial surfaces.

In 1996 the EPA began licensing certain activities in the waste sector which include landfills, transfer stations, hazardous waste disposal and other significant waste disposal and recovery activities. It has been determined from consultation with Galway County Council (29 August 2016) that there are no known historical (or legacy) landfills within the study area.

Section 1: Chainage 0+000 to 8+500

No known areas of contaminated ground were identified.

[13] Palaeolandscape fill is anticipated to be organic in nature, particularly due to the highly organic material encountered along the River Corrib and isolated instance at other locations identified to be overlaying palaeolandscape valleys. No organic testing has been conducted in the palaeolandscape fill in the project specific ground investigation.

CORINE and Teagasc subsoil mapping highlight areas of artificial surfaces due to residential dwellings, commercial properties and industrial usage.

One site was identified which previously had a Certificate of Registration for the importation of Construction and Demolition Waste. The certificate expired on the 28 May 2015.

Section 2: Chainage 8+500 to 9+400

No known areas of contaminated ground were identified.

CORINE and Teagasc subsoil mapping highlight areas of artificial surfaces due to residential dwellings, commercial properties, industrial usage and university buildings.

Section 3: Chainage 9+400 to 14+000

No known areas of contaminated ground were identified.

CORINE and Teagasc subsoil mapping highlight areas of artificial surfaces due to residential dwellings, commercial properties and industrial usage.

Section 4: Chainage 14+000 to 17+500

No known areas of contaminated ground were identified.

CORINE and Teagasc subsoil mapping highlight areas of artificial surfaces due to residential dwellings, commercial properties, sport and leisure facilities and industrial usage.

Three licenced IPPC facilities were identified in Section 4. These are tabulated in **Table 9.12** and are provided in in **Figure 9.7.001** to **Figure 9.7.002** and **Figure 9.7.101** to **Figure 9.7.114**.

Table 9.12: Geological Feature Importance for Contaminated Land within Study Area

Feature	Status / Extent in Percentage	Description	Location / General Extent	Feature Importance Ranking
Licensed IPPC Facilities				
IP01	Licensed	Medtronic Vascular Galway Ltd	Parkmore	Low
IP02	Surrendered	Irish Finishing Technologies Ltd	Ballybrit	Low
IP03	Licensed	Boston Scientific Ireland Ltd	Ballybrit	Low

9.3.9 Mineral / Aggregate Resources

Various datasets were consulted in establishing the economic geology of the study area including:

- GSI: aggregate potential mapping
- GSI: mineral localities
- EPA: active mine sites

These datasets are presented in **Figure 9.6.001** to **Figure 9.6.002** and **Figure 9.6.101** to **Figure 9.6.114**.

A detailed description of how the Aggregate Potential Mapping was developed is available in Issue No. 15 of Geology Matters as part of the Newsletter of the Geological Survey of Ireland or on the GSI website[14].

The existence of high or very high potential aggregate within the study area will result in a loss of available aggregate. However, such potential is beneficial during construction as material can be sourced on site removing the need to import suitable / acceptable material during the construction stage in its place.

No active metallic mines exist today in the study area. Over the past 50 years, parts of the area have been extensively prospected by mineral exploration companies for base metals, but no economically viable deposits have been discovered to date. There is no record of underground mining in the area therefore there would be a low risk of underground structure collapse due to underground excavations, and as such this assessment does not consider this feature any further.

Section 1: Chainage 0+000 to 8+500

The majority of Section 1 consists of very high crushed rock aggregate potential derived from granite with instances of high crushed rock aggregate potential at the beginning of Section 1, Na Foraí Maola, in the middle at An Chloch Scoilte and at the eastern end of Section 1 in Letteragh and Ballagh. Two instances of medium crushed rock aggregate potential were identified in Section 1, at An Chloch Scoilte and Dangan.

An area of low sand and gravel aggregate potential was identified in Rahoon.

All of the metallic mineral localities identified in the study area are located at the beginning of Section 1 in Na Foraí Maola.

One non-metallic locality was identified in An Chloch Scoilte which is described as low lying granite pavement. Four historic pits and one historic quarry were identified in the eastern extent of Section 1, between Keeraun and Dangan.

Section 2: Chainage 8+500 to 9+400

The majority of Section 2 consists of very high crushed rock aggregate potential with smaller instances of both high and moderate crushed rock aggregate potential.

[14] The Aggregate Potential Mapping section of the Spring 2014 Newsletter of the Geological Survey of Ireland is available as pdf on the GSI website (https://www.gsi.ie/Newsletters/Aggregate+Potential+Mapping.htm)

The potential crushed rock in the limestone section is predominantly very high potential.

Section 3: Chainage 9+400 to 14+000

Section 3 is ultimately an area of very high crushed limestone rock aggregate potential with some very small, isolated instances of high potential.

One active (Roadstone Quarry at Twomileditch) and one disused quarry (Lackagh Quarry in Coolagh) are located in Section 3.

Section 4: Chainage 14+000 to 17+500

Section 4 is regarded as having very high crushed limestone rock aggregate potential. Two historic quarries and one historical gravel pit are located in Section 4.

Table 9.13: Geological Feature Importance of Mineral / Aggregate Resources within the Study Area

ID	Type	Description	Location / Extent	Feature Importance Ranking
Active Quarries				
Q01	Disused	Lackagh Quarry	Lackagh	Medium
Q02	Active	Roadstone Twomileditch Quarry	Polkeen	Very High
Active and Historic Quarries				
HPQ01	Historic	Sourced from OSI 6inch mapping	Keeraun	Low
HPQ02	Historic	Sourced from OSI 6inch mapping	Keeraun	Low
HPQ03	Historic	Sourced from OSI 6inch mapping	Keeraun	Low
HPQ04	Historic	Sourced from OSI 6inch mapping	Letteragh	Low
HPQ05	Historic	Sourced from OSI 6inch mapping	Ballagh	Low
HPQ06	Historic	Sourced from OSI 6inch mapping	Ballybrit	Low
HPQ07	Historic	Sourced from OSI 6inch mapping	Ballybrit	Low
HPQ08	Historic	Sourced from OSI 6inch mapping	Parkmore	Low
Aggregate Potential				
VHPCR	Crushed Rock	Very high crushed rock aggregate potential	Entire Study Area (89%)	Very High
HPCR	Crushed Rock	High crushed rock aggregate potential	Na Foraí Maola, An Chloch Scoilte,	High

ID	Type	Description	Location / Extent	Feature Importance Ranking
			Rahoon, Letteragh, Dangan (10%)	
MPCR	Crushed Rock	Moderate crushed rock aggregate potential	An Chloch Scoilte, Dangan (1%)	Medium
LPSAGR	Sand and Gravel	Low sand and gravel aggregate potential	Rahoon and Ballybrit	Low
Mineral Localities				
ML01	Metallic	Copper	Na Foraí Maola	Low
ML02	Metallic	Iron	Na Foraí Maola	Low
ML03	Metallic	Molybdenum	Na Foraí Maola	Low
ML04	Metallic	Iron	Na Foraí Maola	Low
ML05	Metallic	Molybdenum	Na Foraí Maola	Low
ML06	Metallic	Copper	Na Foraí Maola	Low
ML07	Metallic	Copper	Na Foraí Maola	Low
ML08	Metallic	Iron	Na Foraí Maola	Low
ML09	Metallic	Molybdenum	Na Foraí Maola	Low
ML10	Metallic	Iron	Na Foraí Maola	Low
ML11	Metallic	Copper	Na Foraí Maola	Low
ML12	Metallic	Copper	Na Foraí Maola	Low
ML13	Metallic	Iron	Na Foraí Maola	Low
ML14	Metallic	Molybdenum	Na Foraí Maola	Low
ML15	Metallic	Copper	Na Foraí Maola	Low
ML16	Metallic	Iron	Na Foraí Maola	Low
ML17	Metallic	Fluorspar	Na Foraí Maola	Low
ML18	Non-Metallic	Low lying Granite pavement	An Chloch Scoilte	Low
ML19	Non-Metallic	Disused Granite Quarry	Letteragh	Low
ML20	Non-Metallic	Disused Granite Quarry	Ballagh	Low
ML21	Non-Metallic	Dimension stone	Lackagh Quarry, Coolagh	Low
ML22	Non-Metallic	Limestone (in general)	Lackagh Quarry, Coolagh	Low
ML23	Non-Metallic	Dimension stone	Roadstone Quarry, Twomileditch	Very High
ML24	Non-Metallic	Limestone (in general)	Roadstone Quarry, Twomileditch	Very High

9.3.10 Geological Heritage Areas

The Irish Geological Heritage Programme is a partnership between the GSI and the National Parks and Wildlife Service (NPWS). The programme was developed to identify, document the geological heritage and protect and conserve it. Consultation was conducted with the GSI in order to identify all geological heritage sites within the study area.

The Galway County Development Plan (2015-2021) states that it is a Natural Heritage and Biodiversity policy (NHB 2) to recognise that nature conservation is not just confined to designated sites and acknowledge the need to protect non-designated habitats and landscapes and also (NHB 5) to protect, conserve and enhance important geological and geo-morphological systems in the county and seek to promote access to such sites where possible.

Consideration was given to Table 4.3 Network of Local Biodiversity Areas and Table 4.4 Other Areas/Features of Local Importance in the City from the Galway City Council Development Plan 2017-2023.

Section 1: Chainage 0+000 to 8+500

Igneous intrusions (GHA06) and observable magma mingling are located at the very beginning of Section 1, on the coastal side of the R336.

Section 2: Chainage 8+500 to 9+400

No geological heritage sites have been identified in Section 2.

Section 3: Chainage 9+400 to 14+000

Roadstone Quarry (GHA01) is located at Twomileditch in Section 3.

Section 4: Chainage 14+000 to 17+500

No geological heritage sites have been identified in Section 4.

Table 9.14: Geological Feature Importance of Heritage Areas within Study Area

ID	Site Name	Principle Characteristic	Feature Importance Ranking
GHA01	Roadstone Quarry on Tuam Road	Heritage / large existing quarry. Limestone quarry producing aggregates, agricultural ground limestone and concrete	Very High
GHA06	Igneous Intrusions	Observable magma mingling	Very High

9.3.11 Summary of Geological Feature Importance

A summary of the geological features with an importance of medium or higher found within the study area, are presented below in **Table 9.15**.

Table 9.15: Summary of Geological Features

ID	Feature Name / ID	Description / Location	Feature Importance Ranking
Agricultural Soils			
AminDW	Deep well drained non-calcareous soil	Deep well drained non-calcareous soil. Widespread in Section 1	High
AminSW	Shallow well drained non-calcareous soil	Shallow well drained non-calcareous soil. Widespread in Section 1	High
BminDW	Deep well drained calcareous soil	Deep well drained calcareous soil. Widespread in Section 3 and 4	High
BminSW	Shallow well drained calcareous soil	Shallow well drained calcareous soil. Widespread in Section 3 and 4	High
Karst Features			
LP	Limestone pavement	Widespread across Section 3 and 4	Very High
PK	Palaeokarst Valley	Menlough, Ballindooley, Castlegar	Medium
K7	Spring	Bushypark	Medium
K10	Enclosed Depression	Bushypark	Medium
K11	Enclosed Depression	Bushypark	Medium
K12	Enclosed Depression	Bushypark	Medium
K17	Spring	Menlough	Medium
K25	Spring	Menlough	Medium
K31	Turlough	Menlough	Medium
K44	Enclosed Depression	Coolagh	Medium
K45	Spring	Coolagh	Medium

ID	Feature Name / ID	Description / Location	Feature Importance Ranking
K49	Enclosed Depression	Coolagh	Medium
K51	Enclosed Depression	Coolagh	Medium
K54	Enclosed Depression	Coolagh	Medium
K57	Enclosed Depression	Coolagh	Medium
K59	Enclosed Depression	Coolagh	Medium
K61	Enclosed Depression	Coolagh	Medium
K62	Enclosed Depression	Coolagh	Medium
K64	Enclosed Depression	Coolagh	Medium
K67	Enclosed Depression	Coolagh	Medium
K70	Enclosed Depression	Coolagh	Medium
K71	Enclosed Depression	Coolagh	Medium
K97	Enclosed Depression	Castlegar	Medium
K104	Enclosed Depression	Castlegar	Medium
K131	Enclosed Depression	Parkmore	Medium
K158	Spring	Coolagh	Medium
K161	Spring	Coolagh	Medium
K166	Spring	Coolagh	Medium
K172	Enclosed Depression	Coolagh	Medium
K175	Enclosed Depression	Coolagh	Medium
K176	Spring	Coolagh	Medium
K178	Spring	Coolagh	Medium
K179	Enclosed Depression	Coolagh	Medium
K180	Spring	Coolagh	Medium
K181	Spring	Coolagh	Medium
K193	Enclosed Depression	Coolagh	Medium

ID	Feature Name / ID	Description / Location	Feature Importance Ranking
K328	Enclosed Depression	Parkmore	Medium
Aggregate / Resource Potential			
Q01	Lackagh Quarry - Disused	Coolagh	Medium
Q02	Roadstone Quarry	Twomileditch	Very High
VHPCR	Crushed Rock	Very high crushed rock aggregate potential. Entire Study Area.	Very High
HPCR	Crushed Rock	High crushed rock aggregate potential. Na Foraí Maola, An Chloch Scoilte, Rahoon, Letteragh, Dangan.	High
MPCR	Crushed Rock	Moderate crushed rock aggregate potential. An Chloch Scoilte, Dangan.	Medium
ML23	Roadstone Dimension Stone	Twomileditch	Very High
ML24	Roadstone Limestone (in general)	Twomileditch	Very High
Geological Heritage			
GHA01	Roadstone Quarry on Tuam Road	Heritage / large existing quarry. Limestone quarry producing aggregates, agricultural ground limestone and concrete	Very High
GHA06	Igneous Intrusions	Observable magma mingling in Bearna	Very High

9.3.12 Conceptual Site Model

A conceptual site model was developed based on the ground investigation data. The model includes the factual data within the study area that was gathered during the ground investigations. The information is presented on **Figure 9.8.001** to **Figure 9.8.012** in plan and profile format with the profile illustrating the existing and proposed ground levels, earthwork sections, local ground investigation logs and geophysical data along the centre-line of the proposed road development. See also **Appendix A.9.1** for all ground investigation data.

The earthworks areas of cut and fill are presented in **Figure 9.8.001** to **Figure 9.8.012** and in **Table 9.16** below. The embankment height (average and maximum, cut height (average and maximum) and the soils and geology at each earthwork areas are presented in **Table 9.16**.

Table 9.16: Earthwork Areas of Cut and Fill

Earthwork Reference	Dominant Earthworks Type	Environment Section	Length (m)	Max Fill (m)	Average Fill (m)	Max Cut (m)	Average Cut (m)	Generalised Overburden and Bedrock Description	Average Depth to Rock (mBGL)
EW01	Cut	Section 1 Na Foraí Maola	460	1.63	0.14	-3.13	-1.06	Peat over granite derived glacial gravels with areas of made ground over granite bedrock	0.50
EW02	Fill	Section 1 Na Foraí Maola to An Chloch Scoilte	2270	5.38	1.65	-3.34	-0.22	Peat over granite derived glacial gravels and some deposits of cohesive glacial till with areas of made ground over granite bedrock	0.60
EW03	Fill	Section 1 Ballard West	280	5.66	2.47	0	0	Peat over granite derived glacial gravels over granite bedrock	0.50
EW04	Cut	Section 1 Ballard	800	3.61	0.06	-6.97	-3.86	Peat over granite derived glacial gravels over granite bedrock	0.50
EW05	Fill	Section 1 Aille	530	6.47	2.41	-2.20	-0.17	Peat over granite derived glacial gravels with isolated instances of made ground and possibly alluvial deposits near stream. Area overlying granite bedrock	0.80
EW06	Fill	Section 1 Cappagh	820	4.31	1.53	-2.45	-0.27	Peat over granite derived glacial gravels over granite bedrock	1.40
EW07	Cut	Section 1 Ballyburke	350	2.66	0.28	-8.91	-2.18	Granite derived glacial gravels over granite bedrock	1.00

Earthwork Reference	Dominant Earthworks Type	Environment Section	Length (m)	Max Fill (m)	Average Fill (m)	Max Cut (m)	Average Cut (m)	Generalised Overburden and Bedrock Description	Average Depth to Rock (mBGL)
EW08	FILL	Section 1 Ballymoneen to Letteragh	1550	11.78	3.40	-6.79	-0.25	Peat over granite derived glacial gravels with areas of made ground over granite bedrock	1.30
EW09	FILl	Section 1 Knocknafroska / Knocknabrona	300	10.12	7.54	0.00	0.00	Peat over granite derived glacial gravels over granite bedrock	2.70
EW10	FILL	Section 1 Knocknafroska / Knocknabrona	300	6.98	2.73	-4.28	-0.84	Peat over granite derived glacial gravels over granite bedrock	4.50
EW11	CUT	Section 1 Knocknafroska / Knocknabrona	400	0.00	0.00	-14.89	-8.49	Peat over granite derived glacial gravels over granite bedrock	2.60
EW12	CUT	Section 1 Upper Dangan	150	1.62	0.17	-6.89	-3.05	Granite derived glacial gravels over granite bedrock	2.20
EW13	FILL	Section 1 and 2 Dangan	550	9.70	5.03	-1.35	-0.04	Granite derived glacial gravels with areas of made ground over granite bedrock	3.00
EW14	FILL	Section 2 Dangan to River Corrib	450	16.60	10.65	0.00	0.00	Deposits of limestone derived cohesive glacial till over glacial gravels with areas of made ground over limestone bedrock	5.50

Earthwork Reference	Dominant Earthworks Type	Environment Section	Length (m)	Max Fill (m)	Average Fill (m)	Max Cut (m)	Average Cut (m)	Generalised Overburden and Bedrock Description	Average Depth to Rock (mBGL)
EW15	RIVER CORRIB STRUCTURE	Section 2 River Corrib	200	No Cut / Fill due to existence of structure				Deposits of limestone derived cohesive glacial till over glacial gravels with some isolated alluvial deposits present along the River Corrib	n/a[15]
EW16	FILL	Section 3 Menlough	600	19.37	10.01	0.00	0.00	Peat over limestone derived cohesive glacial till with isolated instances of made ground and alluvial deposits. Identified location of palaeokarst valleys Area overlying limestone bedrock	2.30
EW17	MENLOUGH VIADUCT	Section 3 Menlough	330	No Cut / Fill due to existence of structure				Deposits of limestone derived cohesive glacial till over glacial gravels with some alluvial deposits over limestone bedrock	0.00[16]
EW18	FILL	Section 3 Menlough	380	10.01	3.73	-4.09	-0.12	Deposits of limestone derived cohesive glacial till over glacial gravels mixed with Limestone pavement Identified location of palaeokarst valleys Area overlying limestone bedrock	1.80
EW19	CUT	Section 3 Coolagh	330	4.76	0.34	-15.46	-6.45	Deposits of limestone derived cohesive glacial till over glacial gravels Identified location of palaeokarst valleys Area overlying limestone bedrock	55.00[17]

[15] Depth to rockhead is unavailable over the extent of the River Corrib as no intrusive investigation was conducted.

[16] Some overburden including topsoil exists along the extents of the structure. However, the majority of the area consists of outcropping Limestone pavement. Therefore, the average depth has been provided as 0m to reflect the typically shallow rock.

[17] The change in rockhead, based on intrusive and geophysical ground investigation, is quite significant in this area, with the maximum depth recorded of 109m below ground level. However, this maximum depth is quite isolated with the rockhead typically quite shallow.

Earthwork Reference	Dominant Earthworks Type	Environment Section	Length (m)	Max Fill (m)	Average Fill (m)	Max Cut (m)	Average Cut (m)	Generalised Overburden and Bedrock Description	Average Depth to Rock (mBGL)
EW20	LACKAGH TUNNEL	Section 3 Coolagh	280	No Cut / Fill due to existence of structure				Shallow deposits of limestone cohesive glacial till mixed with Limestone pavement Identified location of palaeokast valleys. Area overlying limestone bedrock	0.00[18]
EW21	FILL	Section 3 Coolagh	300	10.67	4.98	-7.49	-0.55	Deposits of limestone derived cohesive glacial till with areas of made ground over limestone bedrock	0.00[19]
EW22	CUT	Section 3 Ballindooley	200	11.82	4.06	-24.64	-8.60	Deposits of limestone derived cohesive glacial till over glacial gravels over limestone bedrock	3.50
EW23	FILL	Section 3 Ballindooley	270	9.47	3.72	-7.97	-0.75	Limestone derived cohesive glacial till / glacial gravels with areas of made ground Identified location of palaeokarst valleys Area overlying limestone bedrock	10.50
EW24	FILL	Section 3 Ballindooley	310	16.28	10.94	0.00	0.00	Peat over limestone derived cohesive glacial till / glacial gravels Identified location of palaeokarst valleys Area overlying limestone bedrock	7.00
EW25	CUT	Section 3 Castlegar	420	9.49	0.70	-7.61	-4.03	Deposits of limestone derived cohesive glacial till. Identified location of palaeokarst valleys Area overlying limestone bedrock	2.80

[18] While topsoil exists in some of the extent of this earthwork area, the majority consists of outcropping Limestone pavement. This gave rise to the construction of a tunnel through the rock. Therefore, the average depth to rockhead has been indicated as 0m in order to reflect this environment.

[19] This earthworks area extends along the floor of the disused Lackagh Quarry. Therefore, the depth to rockhead has been provided as zero.

Earthwork Reference	Dominant Earthworks Type	Environment Section	Length (m)	Max Fill (m)	Average Fill (m)	Max Cut (m)	Average Cut (m)	Generalised Overburden and Bedrock Description	Average Depth to Rock (mBGL)
EW26	FILL	Section 3 Castlegar	130	8.17	2.79	-4.35	-0.70	Deposits of limestone derived cohesive glacial till with areas of made ground Identified location of palaeokarst valleys Area overlying limestone bedrock	14.30
EW27	CUT	Section 3 Castlegar	600	7.85	0.26	-12.65	-7.58	Deposits of limestone derived cohesive glacial till with areas of made ground Identified location of palaeokarst valleys Area overlying limestone bedrock	5.90
EW28	FILL	Section 3 and 4 N83 Tuam Road	500	12.65	7.52	-3.70	-0.12	Deposits of limestone derived cohesive glacial till with areas of made ground Identified location of palaeokarst valleys Area overlying limestone bedrock	17.80
EW29	CUT	Ballybrit	300	5.66	0.32	-12.84	-8.85	Deposits of limestone derived cohesive glacial till over limestone bedrock	2.70
EW30	CUT	Ballybrit	500	0.00	0.00	-11.20	-8.85	Deposits of limestone derived cohesive glacial till with areas of made ground over limestone bedrock	7.50
EW31	GALWAY RACECOURSE TUNNEL	Galway Racecourse	240	0.00	0.00	-9.52	-8.63	Deposits of limestone derived cohesive glacial till with areas of made ground over limestone bedrock	6.30
EW32	CUT	Ballybrit	310	1.73	0.11	-9.52	-4.64	Deposits of limestone derived cohesive glacial till over limestone bedrock	4.60

Earthwork Reference	Dominant Earthworks Type	Environment Section	Length (m)	Max Fill (m)	Average Fill (m)	Max Cut (m)	Average Cut (m)	Generalised Overburden and Bedrock Description	Average Depth to Rock (mBGL)
EW33	FILL	Briarhill	700	8.43	5.08	-0.98	-0.03	Deposits of limestone derived cohesive glacial till with areas of made ground over limestone bedrock	2.40
EW34	CUT	Briarhill	700	2.82	0.22	-7.44	-2.46	Deposits of limestone derived cohesive glacial till over limestone bedrock	1.90
EW35	CUT	Ardaun, Coolagh	640	1.34	0.11	-9.48	-2.35	Deposits of limestone derived cohesive glacial till with areas of made ground over limestone bedrock	2.00
N59 LINK	CUT/FILL	Letteragh	2170	8.77	0.91	-12.99	-2.25	Peat over granite derived glacial gravels with areas of made ground over limestone bedrock	2.10

9.4 Characteristics of the Proposed Road Development

A detailed description of the proposed road development and construction activities are provided in **Chapter 5, Description of Proposed Road Development** and **Chapter 7, Construction Activities**.

This section of the report outlines the key design features and the construction and operational characteristics and activities of the proposed road development of relevance to soils and geology. The potential impacts related to such construction activities are provided in **Section 9.5**.

9.4.1 Key Design Features

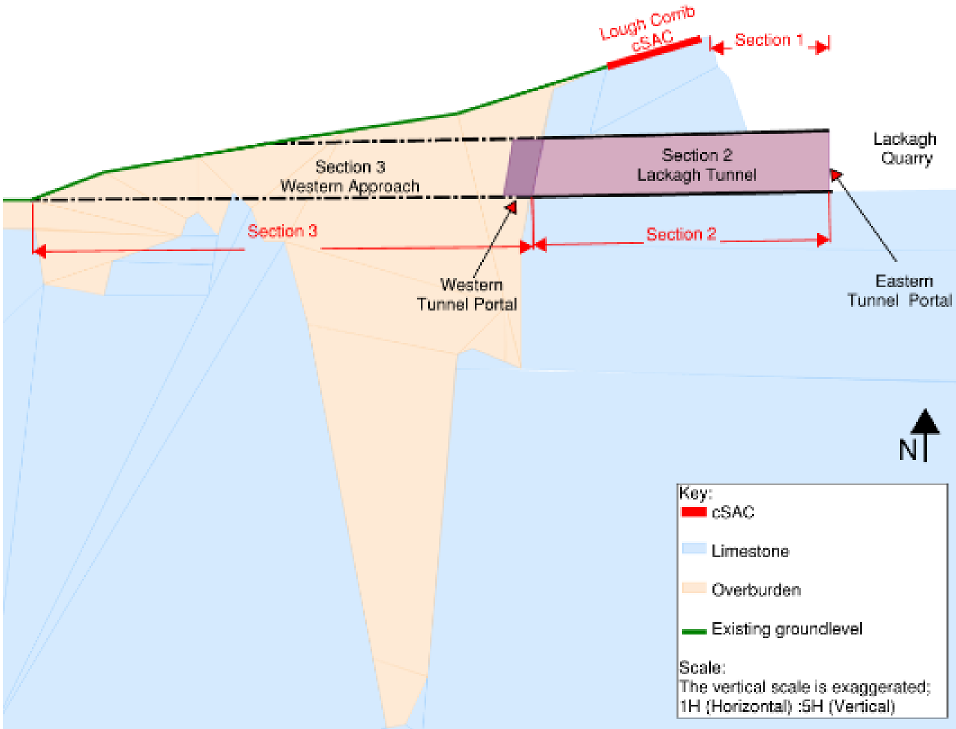
The key design measures of relevance to avoid or reduce impact to soils and geology features, in particular Limestone pavement, are:

- Lackagh Tunnel and the Western Approach
- Menlough Viaduct and Culvert
- Reinforced / retained slopes

9.4.1.1 Lackagh Tunnel and the Western Approach

Lackagh Tunnel comprises of three sections between Ch. 10+775 to Ch. 11+420 of the proposed road development namely Section 1 Lackagh Quarry Face, Section 2 Lackagh Tunnel and Section 3 Western Approach, refer to **Plate 9.1**.

Plate 9.1: Schematic cross section of Sections 1-3 at Lackagh Tunnel



Lough Corrib cSAC which includes Limestone pavement is located immediately west of Section 1. Section 2, Lackagh Tunnel (ST11/01) is a drill and blast mined twin bored tunnel approximately 270m long, from Ch. 11+150 to Ch. 11+420. Section 2 tunnels beneath Lough Corrib cSAC, including Limestone pavement, between approximately Ch. 11+240 and Ch. 11+350. Section 3 lies partially within the Lough Corrib cSAC and traverses between areas of Limestone pavement which is located north and south of the proposed road development.

Given the presence of Limestone pavement, the potential geological impacts of Lackagh Tunnel and its immediate approaches on limestone pavement include:

- Rock mass instability and slope instability in Sections 1 and 3 resulting in potential encroachment onto Limestone pavement within Lough Corrib cSAC, due to its proximity to the proposed road development
- Blasting activities required for the construction of Sections 2 and 3 resulting in potential impact on the structural integrity of the Limestone pavement
- Collapse of the tunnel and ground settlement from the tunnel bore in Section 2 resulting in potential impact on the Limestone pavement within Lough Corrib cSAC

To avoid these geological impacts the following measures are included in the design of Lackagh Tunnel and its approaches (Sections 1, 2 and 3) along with a conservative design approach:

- In Section 1, stabilisation of Lackagh Quarry face will be carried out around the eastern tunnel portal in order to prevent rock mass instability and slope instability. The conservative design approach requires that stabilisation of the Lackagh Quarry face (western face of the quarry) around the eastern tunnel portal will be completed in advance of tunnelling works for Section 2 (Lackagh Tunnel). These stabilisation works include a composite support system of rock bolts, rock dowels, steel mesh and sprayed concrete

- Section 2 is a mined twin bore tunnel in rock constructed using a drill and blast methodology. This method of construction is commonly used for tunnels of this length through hard rock. The conservative design approach of Section 2 requires the following the tunnel design elements to ensure that collapse of the tunnel and ground settlement does not arise:
  - At least 8.0m of clear bedrock is required above the crown of the tunnel bore to the top of the Limestone pavement ground surface in order to maintain the bore stability. This design requirement is achieved in the Lackagh Tunnel design with the proposed alignment providing bedrock cover ranging from ~10m to 14.5m above the crown of the tunnel to the Limestone pavement ground surface
  - A 7m wide separation pillar is required between the two bores in order to maintain the twin bore stability. This design requirement has also been achieved in the Lackagh Tunnel design with the proposed alignment allowing for a rock pillar of 7.3m between the two bores
- In Sections 2 and 3, to prevent rock mass instability, rock mapping assessments will be completed by a geotechnical expert following each tunnel blast in Section 2, rock blast in Section 3 and during the excavation of the Section 3. The outcome of these assessments will govern which rock stability design solution and tunnel design support measure to be employed
- In Section 3, retaining systems will be implemented at pinch points along the Western Approach to support the cut face between existing ground level and the proposed road level preventing slope instability and encroachment onto Limestone pavement. The conservative design approach includes the following retaining systems:

  i. Rock bolts, rock dowels, steel mesh, and sprayed concrete in areas of rock only

  ii. Piled retaining walls, supported with ground anchors in areas of overburden only and in areas with a combination of overburden and rock that will be monitored during construction and compared with the design

- In all sections blast design limitations, these include a maximum vibration limit of 25mm/sec, a construction target vibration limit of 20mm/sec which is less than the maximum vibration limit and a monitored trial blast undertaken in the same bedrock formation by the blasting contractor in a controlled location that will pose no risk to sensitive receptors. The trial blast will not exceed the vibration limitations of the local sensitive receptors. The information obtained from the trial blast will calibrate and refine the blast design to a site specific design.

The tunnel construction activity is outlined in **Section 9.4.2.5**, potential construction and operational impacts are outlined in **Section 9.5.3.4** and **9.5.4** with mitigation measures presented in **Section 9.6**. Refer to **Chapter 8, Biodiversity** for the ecological assessment and **Chapter 10, Hydrogeology** for the hydrogeology assessment.

Further details on Lackagh Tunnel can be found in **Appendix A.7.1**.

9.4.1.2 Menlough Viaduct and Culvert

The design includes a viaduct structure, Menlough Viaduct (ST10/01) from Ch. 10+100 to Ch. 10+420. The total length of the viaduct is governed by the area of Limestone pavement and a Turlough (karst feature ID code K31), which are both located outside of the Lough Corrib cSAC. The viaduct has a total length of approximately 320m, and the proposed road development is on embankment on both approaches to it. The viaduct contains eight spans of a similar 40m span length. The span lengths have been adjusted to minimise the substructure and foundation footprint on the Limestone pavement and avoid the extent of the Turlough.

There is a culvert in Menlough that is also included in the design from approximately Ch. 10+025 to Ch. 10+050. This structure spans Limestone pavement surface (outside of the Lough Corrib cSAC) avoiding the removal of the feature at this location.

9.4.1.3 Reinforced Slopes

The retaining wall in the Menlough area (between Ch. 9+850 and Ch. 10+050) is located adjacent to the Lough Corrib cSAC. This structure will be constructed to retain the embankment of the proposed road development from encroachment on the Annex I habitat of the Lough Corrib cSAC including Limestone pavement. The construction of the retaining wall will be undertaken within the proposed development boundary and outside the areas of Annex I habitat.

9.4.2 Construction activities

As discussed in **Chapter 7, Construction Activities**, it is envisaged that an east to west build will be adopted for the construction of the proposed road development and it may be completed in two concurrent phases or a single overall contract. The two phases are:

- Phase 1 – N6 Coolagh to N59 Letteragh Junction – 9.9km (Including the N59 Link Road North and South)
- Phase 2 – N59 Letteragh Junction – R336 West of Bearna 7.5km

The construction activities involved in the proposed road development relevant to soils and geology are listed below and further discussed in the following sub-sections, **Sections 9.4.2.1** to **9.4.2.10**. The construction activities relevant to soils and geology include:

- Embankment construction
- Excavation of cuts
- Soil and rock slopes

- Reuse and processing of site material
- Importation, exportation and disposal of materials
- Tunnelling
- Construction of foundations for structures
- Contaminated ground
- Soft Soil
- Karst features
- Dewatering

A Construction Environmental Management Plan (CEMP) is provided in **Appendix A.7.5**.

9.4.2.1 Embankment construction

As outlined in the conceptual site model in **Figures 9.8.001** to **9.8.012** and **Table 9.16**, certain areas along the proposed road development will require the placement of fill material to achieve the proposed alignment level. These embankment sections will be formed using imported fill or site won[20] material. The imported fill will be transported on site access roads using trucks and on routes outlined in **Chapter 7, Construction Activities**.

For embankments less than 3.0m in height, topsoil will require removal from beneath the embankment footprint. For areas identified as medium and high karst risk, topsoil will require removal in order to proof roll the underlying material. Topsoil will be excavated, transported and stored at a designated stockpile on site and reused for landscaping across the proposed road development.

Material evaluated to be soft beneath the footprint of the embankment will be removed in order to provide a more suitable founding strata. Bituminous or hard standing material will also be removed.

The potential impact from this construction activity are discussed in **Section 9.5.3.1.**

9.4.2.2 Excavation of cuts

Where the proposed road level is below the existing ground level, existing material will require excavation and removal. As outlined in **Table 9.16**, these cut areas along the proposed road development will require the removal of overburden (fertile soil, soft soils, made ground, superficial deposits) and bedrock (granite and limestone).

Based on the factual ground investigation information available, for cuts in rock, hard ripping using a hydraulic hammer or blasting of the bedrock will be required.

[20] Material which has been recovered as part of the construction excavation activities. If purposed for use in embankment construction, the material must comply with material properties and constituents outlined in the TII Series 600 Earthworks Specification.

See **Appendix A.9.1** for ground investigation data. All other excavation, and removal of broken or blast rock, will be completed using an excavator and transported to other areas of the site or to a designated disposal site. Topsoil will be excavated, transported, stored at a designated stockpile on site and reused for landscaping across the proposed road development. See details in relation to waste in **Chapter 7, Construction Activities**.

As part of the blast design assessment monitored trial blasts in the same bedrock formation as the proposed blast locations at locations of proposed blasting will be conducted. These trial blasts will calibrate the blast design to site specific designs and will refine and validate the blast design properties. Trial blasts will not exceed the limitations of the local sensitive receptors.

Excavations are typically undertaken in a 'dry' environment, therefore cuts that intercept the groundwater table may require temporary dewatering, if permitted. These locations are outlined and assessed in **Chapter 10, Hydrogeology**.

The potential impacts related to this activity are further discussed in **Section 9.5.3.1**.

9.4.2.3 Reuse and processing of site material

Site won material, obtained from cuttings, will where possible be reused as fill for the construction of embankments and other elements along the proposed road development. Crushing and processing of suitable material obtained on site during the earthworks for re-use will be employed insofar as is possible.

The potential impacts related to this activity are discussed in **Section 9.5.3.2**.

9.4.2.4 Importation, exportation and disposal of materials

Earthworks quantities along the proposed road development are subdivided into a number of earthworks sections based upon natural physical boundaries such as rivers and existing roads. The estimated quantities of imported and exported fill within these areas are outlined in **Chapter 7, Construction Activities**.

The construction of Phase 1 will result in a surplus of material however in the unlikely event that the construction of Phase 2 is first this will result in a deficit of acceptable material.

The deficit of aggregate will require the importation of suitable material. Material shall be sourced from quarries which are listed on the register maintained by the local authority. Designated haulage routes and access routes have been identified and are further discussed in **Chapter 7, Construction Activities**.

In line with the principles of sustainable development, the proposed road development will minimise the amount of materials brought into the construction site. This will be achieved by re-using as much of the materials generated during construction as possible subject to further testing to determine if materials meet the specific engineering standards for their proposed end-use.

Where the excavation contains a combination of acceptable and non-acceptable material for reuse, the excavation will be conducted so that acceptable material is excavated separately without contamination by the unacceptable material.

Any hazardous material, as evaluated from appropriate environmental testing, will result in the necessity for off-site disposal to designated disposal sites in accordance with all relevant legislation. This is further discussed in **Chapter 7, Construction Activities**.

The potential impacts related to this activity are further discussed in **Section 9.5.3.3**.

9.4.2.5 Tunnelling

Two tunnels are proposed along the proposed road development as follows:

- Mined Tunnel at Coolough, Menlough (Lackagh Tunnel– Approximately 270m tunnel through limestone bedrock and overburden)
- Cut and Cover at Ballybrit (Galway Racecourse Tunnel – Approximately 230m tunnel in limestone bedrock)

Mined Tunnel

The proposed mined tunnel, Lackagh Tunnel, comprises two bores for the eastbound and westbound carriageways of the proposed road development. Each bore comprises an approximately 15m wide span tunnel with water tight concrete arch lining with the internal elements (road, walkways, lighting, ventilation etc.) placed within this shell. The proposed alignment for Lackagh Tunnel provides bedrock cover ranging from approximately 10m to 14.5m above the tunnel crown below the Limestone pavement surface.

The tunnel excavation, in Menlough, will be a mined tunnel (drill and blast), which is commonly used for tunnels through hard rock. The tunnel commences in Lackagh Quarry at the tunnel portals using drill and blast methods. Excavation progresses for the tunnel in a cyclic manner with drilling, blasting, rock face mapping, mucking out, installation of support measures and then preparing for the next advance of the tunnel.

Further details on Lackagh Tunnel can be found in **Appendix A.7.3**.

Cut and Cover Tunnel

The cut and cover tunnel, Galway Racecourse Tunnel, will consist of 230m twin box construction, with a maximum depth of approximately 11m below ground level, with all elements constructed using cast in-situ reinforced concrete or precast concrete box units, which are assembled longitudinally and transversely from discrete precast elements.

The tunnel excavation will be undertaken from ground level. The overburden will be excavated, followed by blasting of the bedrock in order to break it prior to excavation. Rock excavation will progress in a cyclic manner with drilling blast holes, blasting, rock face mapping and mucking out.

The potential impacts related to tunnelling are further discussed in **Section 9.5.3.4**.

9.4.2.6 Construction of Structures

The proposed road development requires the construction of a number of structures. The proposed structures are discussed in **Chapter 5, Description of Proposed Development**.

In general, foundations are likely to require shallow solutions which require a limited, shallow excavation at the footing locations. However, depending on the structure and the ground conditions encountered, some areas will require a more robust solution, which may include:

- Pile foundation in areas of poor, soft ground or in areas of high karst risk
- Earth retaining structures in areas where soil must be restrained at unnatural slopes
- Excavate and replace at footing locations due to karst risk, to expose rock surface in areas underlain by limestone

From existing ground information, the structures identified in **Table 9.17** will likely require deep or a specialised foundation solution due to ground conditions or karst risk.

The potential impacts related to this activity are further discussed in **Section 9.5.3.5**.

Table 9.17: Structures requiring specialised foundation solutions

Reference	Assessment Section	Name / Function	Approx. Chainage
S08/04	2	River Corrib Bridge Structure	9+300
C09/01	3	Culvert	9+520
C09/02	3	Culvert	9+560
C09/03	3	Culvert	9+580
C09/04	3	Culvert	9+590
C09/05	3	Culvert	9+600
S09/03	3	Accommodation Underpass S09/03	9+910
C10/01	3	Local access Underpass	10+060
S10/01	3	Menlough Viaduct	10+110
S12/01	3	N84 Headford Road Underbridge	12+150
C12/02	3	Culvert	12+350
C12/03	3	Culvert	12+390
C12/04	3	Culvert	12+450
C13/01	3	Mammal Underpass	12+980
C13/02	3	Mammal Underpass	13+700
S13/02	3 / 4	N83 Tuam Road Underbridge (WB merge)	13+925
S13/03	3 / 4	N83 Tuam Road Underbridge (Mainline and EB diverge)	13+975
S15/02	4	Briarhill Business Park Underbridge	15+725

Reference	Assessment Section	Name / Function	Approx. Chainage
S15/03	4	Monivea Road R339 Underbridge	15+880

9.4.2.7 Contaminated ground

Ground investigation information along with the current and historical site activities indicated the potential locations of contamination. These included areas adjacent to existing road networks, infrastructure networks, man-made drainage systems and general built construction.

No areas of contamination were identified during the investigations. See conceptual site model in **Figure 9.8.001** to **Figure 9.8.012**. While areas of contamination are unlikely, out of an abundance of caution, all potential locations will be further investigated during construction and the makeup of the ground evaluated. Any shallow made ground deposits will be excavated and replaced.

Hazardous material removed as part of the excavation may require specialist disposal to designated disposal sites. This is further discussed in **Chapter 7, Construction Activities**.

The potential impacts related to this activity are further discussed in **Section 9.5.3.6**.

9.4.2.8 Soft soil

Soft soil, which includes both peat and soft organic clay / silt, exist across the study area. Typically, peat is present in the western section, underlain by granite, while the limestone area has soft organic and alluvial material. Soft ground areas have been identified and are indicated in **Figure 9.7.001** to **Figure 9.7.002** and **Figure 9.7.101** to **Figure 9.7.114**.

Areas of shallow deposits will likely be excavated and removed. Deeper soft soil deposits may require excavation or in-situ ground improvement.

The potential impacts related to this activity are further discussed in **Section 9.5.3.7**.

9.4.2.9 Karst Features

In Sections 2, 3 and 4, from the N59 Moycullen Road at Dangan to the existing N6 at Coolagh, Briarhill the proposed road development overlies Visean Limestone which is prone to karst. The proposed road development subsequently crosses numerous karst features. Identified surface karst features are presented in **Table 9.10**.

Certain anomalies were encountered during the ground investigation in the area underlain by karstified limestone, refer to **Appendix A.9.1** for all ground investigation data and **Figures 9.8.001** to **9.8.012**.

The hydrogeology of karst features is dealt with in **Chapter 10, Hydrogeology**.

9.4.2.10 Dewatering

The ground investigation data suggests that groundwater will be encountered in some areas of cut and for a number of foundation excavations, refer to **Chapter 7, Construction Activities**. Dewatering is required where significant ingress of water will occur during construction.

The potential impacts of this dewatering and dewatering limitations are assessed and presented in **Chapter 10, Hydrogeology**.

9.4.3 Operational activities

The proposed road development will require periodic maintenance of the development, embankment slopes, cut slopes, tunnels and drainage channels.

9.5 Evaluation of Impacts

9.5.1 Introduction

An appraisal of the potential impacts to geological features and of construction activities was undertaken in accordance with the TII Guidelines (NRA, 2009) considerations as presented in **Section 9.2.5** of this chapter. The evaluation and corresponding impact significance for geological features are presented and summarised in **Table 9.19** for the Construction Phase and **Table 9.20** for the Operational Phase. **Section 9.5.3** and **9.5.4** describes the potential construction and operational activity impacts respectively on soils and geology pre-mitigation.

9.5.2 Do-Nothing Scenario

In the case where the proposed road development was not to be developed there would be no resulting impacts on the soils or geology along the route of the proposed road development. The impact would therefore be *neutral*.

9.5.3 Construction Phase Impacts

The potential soils and geology impacts during the construction phase for each construction activity described in **Section 9.4** are presented in this section, along with their impact significance. These potential impacts also relate to and interact with other environmental factors which are described within the EIAR. Specific interactions are outlined below, with further detail provided in the relevant chapters.

9.5.3.1 Earthworks construction

The soils and geology at each earthworks area are identified in **Table 9.16**. This section relates to potential impacts associated with embankment construction and cutting excavation as discussed in **Section 9.4.2.1** and **Section 9.4.2.2** respectively.

The potential impacts of earthworks construction are listed and described below:

- Compression of Substrata
- Loss of Agricultural Land
- Loss of Solid Geology
- Loss of Future Quarry Reserves
- Introduction of Material derived from a different Lithology
- Flood Barrier
- Earthworks Haulage
- Washout of Fines / Sediment Runoff
- Effect on Surrounding Ground

Compression of Substrata

This impact applies to embankments only.

The construction of an embankment over in-situ virgin ground will cause compression of the sub-strata thus affecting the current characteristics of the ground. The magnitude of such an impact, as per **Table 9.5**, however is deemed to be insignificant due to the small footprint of the embankment areas relative to the local environment.

The significance, as per **Table 9.6** of the potential impact is imperceptible.

Loss of Agricultural Land

The construction of embankments or the excavation of cuts in areas of arable or agricultural land will result in the loss of said resource. The area lost or removed would encapsulate the width of the embankment or cut plus the footprint required for such a construction.

Refer also to **Chapter 14, Material Assets – Agricultural**.

The significance of the potential impact is moderate / slight.

Loss of Solid Geology

This impact applies to cuttings in rock only.

In accordance with the aggregate potential mapping undertaken as part of the National Development Plan 2007-2013, the study area is predominately classified as a very high aggregate potential. The construction of the proposed road development would result in the loss of the aggregate resource.

The type of bedrock that will be excavated is widely available, and as per the TII Guidelines, the portion to be removed will be small adverse in comparison to the volumes retained.

The significance of the potential impact is significant / moderate.

Loss of Future Quarry Reserves

This impact applies to Lackagh Quarry (disused quarry) and Roadstone Quarry (active quarry).

Lackagh Quarry (disused) intersects the proposed road development, impacting future quarry reserves at this location. With appropriate planning permission, the potential for future quarry reserves at Lackagh Quarry, are located beneath the disused quarry footprint and along the east and southern boundaries. Given the presence of a European designated site along the north and western boundaries of Lackagh Quarry expansion in these directions is highly unlikely. The magnitude of impact for loss of a moderate proportion of future reserves is moderate adverse.

The significance of the potential impact is moderate.

The proposed road development is located south of the active Roadstone Quarry in Twomileditch and does not directly impact the quarry. The magnitude of the impact is considered negligible, as the impact to the active quarry is of insufficient magnitude to affect the use or future quarry reserves.

The significance of the potential impact is imperceptible.

Introduction of Material derived from a different Lithology

This impact applies in granite bedrock areas.

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

If limestone derived material is placed over granite bedrock, surface water run-off or groundwater movements through the material have the potential to impact local areas of peatland habitats by changing the pH of the groundwater.

This is further discussed in **Chapter 8, Biodiversity**, **Chapter 10, Hydrogeology** and **Chapter 11, Hydrology**.

The significance of the potential impact is significant / moderate.

Refer also **Chapter 7, Construction Activities**.

Flood Barrier

This impact applies to embankments only.

There are no significant encroachment of any significant floodplains. Embankment constructed in areas prone to flooding have the potential to erode, resulting in a change in the local environment and potential ground movement at the base of the embankment slope. Potential for flooding is discussed further in **Chapter 11, Hydrology**.

The significance of the potential impact is significant / moderate.

Earthworks Haulage

During earthworks construction, heavily loaded large earthmoving vehicles will travel through the site, causing ground vibrations, unwanted compaction and disturbance of natural ground of unfinished road surfaces.

See also **Chapter 7, Construction Activities**, **Chapter 16, Air Quality and Climate** and **Chapter 17, Noise and Vibration**.

The significance of the potential impact is slight.

Washout of Fines / Sediment Runoff

During or following heavy rainfall events, surface water run-off from embankments comprising of fine material (silt and clay) or exposed cuttings could have a high percentage of suspended solids and result in accumulation of unwanted material in adjacent lands.

See also **Chapter 10, Hydrogeology** and **Chapter 11, Hydrology**.

The significance of the potential impact is slight.

Effect on Surrounding Ground

Soil and rock excavation has the potential to induce movement and settlement of surrounding ground. The breaking or blasting of the bedrock could result in ground vibrations and destabilisation of existing slopes, existing rock slopes, with affects felt in the immediate vicinity of the works.

See also **Chapter 7, Construction Activities**, **Chapter 8, Biodiversity**, **Chapter 16, Air Quality and Climate** and **Chapter 17, Noise and Vibration**.

The significance of the potential impact is moderate / slight.

9.5.3.2 Re-use and processing of site material

The impacts associated with the introduction of material derived from a different lithology and earthworks haulage are applicable for the re-use and processing of site material. As mentioned in **Section 9.5.3.1** the potential impacts include:

- in the granite bedrock area, where limestone derived material is placed over granite bedrock there is potential to impact the local areas of peatland habitats by changing the pH of the groundwater. The significance of this potential impact is significant / moderate.
- ground vibrations, unwanted compaction and disturbance of natural ground of unfinished road surfaces as a result of haulage during the earthworks construction where heavily loaded large earthmoving vehicles will travel through the site. The significance of this potential impact is slight.

See also **Chapter 7, Construction Activities**, **Chapter 16, Air Quality and Climate** and **Chapter 17, Noise and Vibration**.

9.5.3.3 Importation, exportation and disposal of materials

The impacts associated with the introduction of material derived from a different lithology and earthworks haulage are applicable for the importation, exportation and disposal of materials, the impacts are mentioned above in **Section 9.5.3.2**.

See also **Chapter 7, Construction Activities**, **Chapter 16, Air Quality and Climate** and **Chapter 17, Noise and Vibration**.

9.5.3.4 Tunnelling

This section outlines the associated impacts for the construction of the mined tunnel at Coolough, Menlough (Lackagh Tunnel) and the cut and cover tunnel at Ballybrit (Galway Racecourse Tunnel).

A summary of the potential impacts for the proposed tunnel construction at each of the tunnel locations are provided below:

Potential Impact on Limestone Pavement

This potential geological impact applies to Lackagh Tunnel only.

Potential geological impacts on the integrity of the geological attribute (Limestone pavement), due to the mined tunnel, include such impacts as ground settlement, and rock mass instability. The potential geological impacts from the mining activities could include blast damage due to ground vibration and air blast vibrations. See also **Chapter 8, Biodiversity** and **Chapter 10, Hydrogeology**.

Considering the key design features presented in **Section 9.4.1** and the conservative design approach the magnitude of the potential geological impact is considered to be negligible, as the potential geological impact would result in impact on attribute but of insufficient magnitude to affect either use or integrity, as per **Table 9.5**. Further details on the proposed Lackagh Tunnel are provided in **Appendix A.7.3**.

The significance, as per **Table 9.6**, of the potential geological impact is imperceptible.

Other potential geological impacts to Limestone pavement are discussed in **Section 9.5.3.5** where Limestone pavement occurs under structures and in **Section 9.5.3.8** where it occurs within the study area.

Loss of Feature

The tunnel bores are to advance through Visean limestone, resulting in the loss of the intact rock. The cut and cover tunnel in Ballybrit will require the excavation of Visean limestone, which will also result in the loss of intact rock.

The impacts associated with the loss of solid geology are applicable for loss of feature. As mentioned in **Section 9.5.3.1** the potential impact which applies to cuttings in rock only will result in the loss of the aggregate resource. The significance of this potential impact is significant / moderate.

Ground Settlement

The impacts associated with the effects to surrounding ground are applicable for ground settlement. As mentioned in **Section 9.5.3.1** soils and rock excavations, including the breaking or blasting of the bedrock, could result in ground vibrations and destabilisation of existing slopes, existing rock slopes and has the potential to impact the surrounding ground by inducing movement. The significance of this potential impact is moderate / slight.

Potential Impact due to Blasting

The impacts associated with the effects to surrounding ground are also applicable for potential impact due to blasting and are outlined above.

Other potential construction impacts from Lackagh Tunnel and Galway Racecourse Tunnel are discussed in **Chapter 7, Construction Activities**, **Chapter 8, Biodiversity**, **Chapter 10, Hydrogeology**, **Chapter 11, Hydrology**, **Chapter 16, Air Quality and Climate**, **Chapter 17, Noise and Vibration** where the potential impacts of construction traffic, dewatering, dust and noise and vibration from blasting bedrock are described in detail.

9.5.3.5 Construction of Structures

The construction activities for structures presented in **Chapter 5, Description of Proposed Development** may impose some of the following impacts, dependant on the geology encountered at the location of the structure footings:

- Ground Settlement
- Noise and vibration
- Material disposal i.e. bored pile installation

See also **Chapter 7, Construction Activities**, **Chapter 16, Air Quality and Climate** and **Chapter 17, Noise and Vibration**.

The significance of the potential impact is slight.

Potential Impact on Limestone Pavement

Two structures along the proposed road development traverse Limestone pavement in Menlough. It should be noted, at both of these locations the Limestone pavement is outside the Lough Corrib cSAC, refer to **Chapter 8, Biodiversity** for the ecological assessment.

The proposed road development includes the construction viaduct in Menlough. The proposed Menlough Viaduct will result in the minor loss (circa $500m^2$) of a small part of the attribute (Limestone pavement).

The magnitude of the potential geological impact, as per **Table 9.5** is considered small adverse, as the potential geological impact would result in loss of small part of the attribute[21].

The significance of the potential geological impact, as per **Table 9.6**, is significant / moderate.

A culvert is located in an area of Limestone pavement in Menlough. The magnitude of the potential geological impact is negligible, as the structural integrity of the Limestone pavement is maintained. The significance of the potential geological impact is imperceptible.

Other potential geological impacts to Limestone pavement are discussed in **Section 9.5.3.4** for Lackagh Tunnel and in **Section 9.5.3.8** where Limestone pavement occurs within the study area.

9.5.3.6 Contaminated Ground

No known areas of contaminated ground were located within the study area. Exposure of locations of contamination and excavation of contaminated soil may potentially lead to a risk to the surrounding environment or underlying soil if not dealt with in an appropriate manner in accordance with the Environmental Protection Agency guidance on Land Contamination.

The underlying soil could be impacted from the exposure of previous buried hazardous material, in an unlicensed dumping site for example, or from the discharge of wash water from concrete operations.

The potential impacts could also include the potential for leakage or spillage of construction related materials, contaminating the subsoils present.

For example, raw or uncured concrete and grouts, washed down water from exposed aggregate surfaces, cast-in-place concrete from concrete trucks, fuels, lubricants and hydraulic fluids for equipment used on the development site, bitumen and sealants used for waterproofing concrete surfaces can all potentially impact on soils and groundwater during construction stage.

The significance of the potential impact is moderate / slight.

9.5.3.7 Soft soil

The potential impacts associated with soft ground removal are discussed under Effects of Surrounding Ground in **Section 9.5.3.1**.

As mentioned in **Section 9.5.3.1** soil excavations could result in destabilisation of existing slopes and has the potential to impact the surrounding ground by inducing movement.

The significance of this potential impact is moderate / slight

[21] Box 5.1: Criteria for rating impact significance at EIA stage. A magnitude of impact of small adverse is one where there is a "minor impact on integrity of attribute or loss of small part of attribute" (NRA, 2009)

The potential impact associated with the presence of soft ground at structure locations is ground settlement as discussed **Section 9.5.3.5**.

9.5.3.8 Karst features

The study area contains the following karst features (which have a geological feature importance of medium or higher):

- Limestone pavement
- Turlough
- Springs

See also **Chapter 10, Hydrogeology**.

Potential Impact on Limestone Pavement

The proposed road development traverses six locations of limestone pavement in Sections 3 and 4. These locations include:

- One location at Lackagh Tunnel, which passes under an area of Limestone pavement, within Lough Corrib cSAC, refer to **Section 9.5.3.4**. The significance of this potential geological impact is imperceptible
- Two locations of Limestone pavement are under structures in Menlough, located outside Lough Corrib cSAC, refer to **Section 9.5.3.5**. The significance of this potential geological impact at these locations is considered significant / moderate and imperceptible
- Three other locations, all outside the Lough Corrib cSAC, are under the proposed road development and discussed below.

At these three locations the Limestone pavement is encapsulated under the proposed road development. Two of these locations are in Menlough and one location is in Coolagh, at these locations the proposed road development results in loss of small part of the Limestone pavement.

The significance of the potential geological impact for areas of Limestone pavement lost under the proposed road development is significant / moderate.

All other Limestone pavement areas within the study area are not directly impacted by the proposed road development.

The significance of the potential geological impact for areas of Limestone pavement within the study area but outside of the proposed road development is imperceptible.

Refer to **Chapter 8, Biodiversity** for the potential ecological impacts to Limestone pavement.

Surface Karst Solution Features

The proposed road development will result in the loss of part of the enclosed depression (K12), the enclosed depression (K97) and the spring (K193).

The significance of the potential impact for these attributes is moderate.

Additional individual karst features have been identified in the study area, as presented in
Table 9.10, however these additional ones, excluding K12, K97 and K193, will not be directly affected by the proposed road development as they exist outside the fence line.

In such situations, the significance of the potential impact is imperceptible.

9.5.4 Operational Phase

The significance rating on the soils and geology from the operational phase of the proposed road development will generally be Imperceptible according to the TII Guidelines criteria (TII, 2009). Overall there is neutral long term impact on the soils and geology along the route of the proposed road development. The potential geological impacts on the environment have been provided below for the operational phase:

Contamination

Maintenance works could lead to occasional accidental leakage of oil, petrol or diesel, allowing contamination of the surrounding environment. However, the magnitude of the impact is negligible as spills will be contained and materials will be disposed of appropriately using a fully licensed waste contractor with the appropriate permits. The significance of the potential impact is imperceptible.

Ground Movement

The mined tunnel in Coolough, Menlough, Lackagh Tunnel, may experience minimal long term ground movement (settlement) of the local environment. With the support measures as outlined in the design phase, **Section 9.4.1.1**, and monitoring during the construction phase the magnitude of the potential impact is negligible.

The significance of the potential impact is imperceptible.

9.6 Mitigation Measures

9.6.1 Introduction

This section describes the mitigation measures to reduce or avoid potential impacts where possible, for both the construction (**Section 9.5.2**) and operational phases (**Section 9.5.3**) of the proposed road development.

The mitigation measures for potential impacts to geological features are presented and summarised in **Table 9.19** for the Construction Phase and **Table 9.20** for the Operational Phase.

9.6.2 Construction Phase

The mitigation measures for the potential construction impacts are provided below.

9.6.2.1 Earthworks construction

Construction techniques that comply with the requirements of statutory bodies in terms of noise, vibration, soil and groundwater contamination and disposal of contaminated material for both soil and rock cuttings will be adopted.

Loss of Agricultural Land and Solid Geology

All excavated material, excluding a small potential volume of hazardous material, will be re-used as construction fill and material deposition areas minimising the loss of the feature. The Contractor will ensure acceptability of the material for re-use within the proposed road development with appropriate handling, processing and segregation of the material.

Introduction of Material derived from a different Lithology

A construction earthworks programme will be implemented as part of the CEMP, which is finalised by the contractor, for the proposed road development which categorises the source of material for each fill section. During the finalisation of this programme, the fill limitations outlined below will be incorporated.

To prevent impact to the local peatland habitats, described in **Chapter 8, Biodiversity**, the following fill limitations will be incorporated at the locations identified **Table 9.18**.

- Only pavement and capping layers protected from surface water runoff and groundwater movements are permitted to be derived from non-native material
- All other acceptable fill material will be derived from native material or other pH compatible material

Table 9.18: Fill Limitation Areas

Location	Annex I Habitat / Fossitt (2000) ID Codes*	Fill Limitation Chainage area	
		From	To
1	4030 mosaic	0+620	0+775
2	4010	1+300	1+450
3	4010	1+830	2+065
4	4010	2+875	3+090
5	4010	3+440	3+550
6	4030/4010 and 4010	3+595	3+890
7	4030 mosaic and 4010	4+800	5+150
8	PF2	7+850	7+900

*Refer to **Chapter 8, Biodiversity** for details

Flood Barrier

A drainage layer or starter layer, in accordance with the TII publication CC-SCD-00606, will be implemented for the construction of embankments in areas prone to flooding. The introduction of a drainage layer will ensure hydraulic conductivity exists across the flood plain and removes the risk of the embankment acting as a flood barrier.

Earthworks Haulage

Earthworks haulage will be along predetermined routes within and outside the proposed development boundary as shown on **Figures 7.101** to **7.123**.

The identified haulage routes are along existing national, regional and local routes or within the proposed development boundary.

Where compaction occurs due to truck movements and other construction activities on unfinished surfaces, remediation works will be undertaken to reinstate the ground to its original condition. Where practicable, compaction of any soil or subsoil which is to remain in-situ along the proposed road development will be avoided.

Washout of Fines / Sediment Runoff

The use of granular fill material in embankment construction will remove the likelihood of the washout of fines. However, in the event the embankment will be constructed of local material, the introduction of a drainage layer or starter layer (as discussed in Flood Barrier section above) will reduce the likelihood of run-off of fine material.

Alternatively, the introduction of a geotextile separator will reduce the potential impact in areas. A composite system, combining a drainage layer and a geotextile separator will be implemented in embankments constructed with cohesive fill material.

Sediment control methods are outlined in the CEMP in **Appendix A.7.5** and in **Chapters 10, Hydrology** and **11, Hydrogeology**.

Effect on Surrounding Ground

Ground settlement, horizontal movement and vibration monitoring will be implemented during construction activities to ensure that the construction does not exceed the design limitations.

In situations where the site specific blast design has determined that blasting is not feasible in a particular location due to excessive ground vibrations, alternative extraction methods such as hydraulic breaking, hydraulic splitting, chemical splitting and electrical disintegration may be implemented and monitored. Monitoring will be implemented during blasting, during excavation of cuts, for overburden slopes steeper than 1V:2H (V= vertical slope, H = horizontal slope) and rock slopes steeper than 1V:1.5H.

A geotechnical expert will be appointed by the contractor and will be present to monitor the surrounding ground vibrations near sensitive receptors during blasting works. In the unlikely event that the blast vibration limit at the surface is exceeded, blasting works will cease on site until it is understood the basis for the increased vibration. The blast design will then be recalibrated and blasting works will proceed with continued monitoring.

Allowable distances for the various construction methods are outlined in **Chapter 17, Noise and Vibration**.

9.6.2.2 Reuse and processing of site material

A construction earthworks programme will be implemented for the proposed road development which categorises the source of material for each fill section. During the finalisation of this programme the fill limitations outlined in **Section 9.6.2.1** will be incorporated at the locations presented in **Table 9.18**.

9.6.2.3 Importation, exportation and disposal of materials

Importation of materials from outside the site will be minimised by ensuring that materials arising within the site area are used to the greatest extent possible. Any surplus material remaining which cannot be incorporated into the construction fill activities shall be placed in material deposition areas within the proposed road development. This will significantly reduce the deposition of material off-site.

Hazardous material will be transported off site for disposal or recovery at appropriately licence or permitted sites as outline in **Chapter 7, Construction Activities**.

9.6.2.4 Tunnelling

The adopted construction techniques will comply with the requirements of statutory bodies in terms of noise, vibration, soil and groundwater contamination and disposal of contaminated material.

During the construction of Lackagh Tunnel the supported rock face of Lackagh Quarry Face and retaining walls for the Western approach will be monitored for movement. A geotechnical expert will be appointed, by the contractor and will be present to monitor the rock mass stability during their construction period. In the unlikely event that instability within the rock mass is observed, additional support measures will be installed to ensure that there is no impact to the surface above. The additional rock support measures comprise ground anchors, rock bolts, rock dowels, rock mesh, shotcrete or a combination of these measures, designed to the relevant design standards and best practice guidance documents. However, based on the conservative design approach it is considered that the risk of instability will be avoided and additional support measures will not be required.

A geotechnical expert will be appointed by the contractor and will be present to monitor the vibrations at the surface, including the areas of Limestone pavement, during blasting works for the construction of Lackagh Tunnel and the Western Approach. The blast target vibration limit is defined as 20% more conservative than the conservative design approach vibration limit of 25mm/sec at the ground surface which includes areas of Limestone pavement, which provides an added factor of safety to the construction works to ensure that blasting will not impact the structural integrity of the Limestone pavement. In the unlikely event that the blast target vibration limit at the surface is exceeded, blasting works will cease on site until it is understood the basis for the increased vibration. The blast design will then be recalibrated and blasting works will proceed with continued monitoring.

For further information on Lackagh Tunnel is presented in **Appendix A.7.3**.

9.6.2.5 Construction of Structures

Construction of structures will be completed in accordance with the Construction Environmental Management Plan (CEMP) in **Appendix A.7.5** and as described in the following:

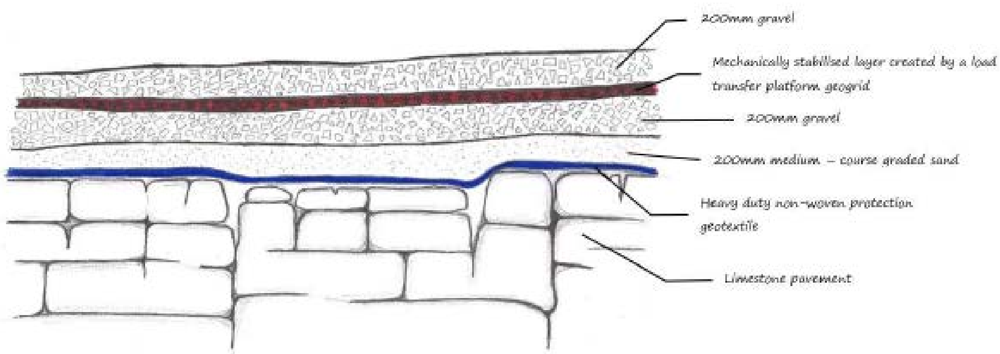
- River Corrib Bridge Constructability Examination **Appendix A.7.1**
- Menlough Viaduct Constructability Examination **Appendix A.7.2**
- Lackagh Tunnel Geotechnical and Hydrogeological Appraisal **Appendix A.7.3**
- Galway Racecourse Tunnel Constructability Report **Appendix A.7.4**

Ground settlements will be controlled through selection of the foundation type and method of construction which are suitable for the particular ground conditions.

To minimise soil movements due to pile operations in the vicinity of sensitive receptors, each pile shall be constructed sequentially in a direction away from the sensitive receptor. Previously installed piles act as a shield as soil movements are greater in a direction away from the stiffer zone i.e. away from the piles and sensitive receptors.

During construction, the Limestone pavement at Menlough Viaduct will be protected and will not be impacted by implementing a protection system comprising of geogrid, protection geotextile and layers of material, as per **Plate 9.2**. This will be removed once construction is complete. Refer to Menlough Viaduct Constructability Report in **Appendix A.7.2** for further details.

Plate 9.2: Limestone pavement protection system



9.6.2.6 Contaminated ground

No known areas of contaminated ground were located within the study area. Samples of ground suspected of contamination will be tested for contamination during the detailed investigation and ground excavated from these areas will be disposed of to a suitably licence or permitted sites in accordance with the current Irish Waste Management legislation.

Good housekeeping (daily site clean-ups, use of disposal bins, etc.) on the site, and the proper use, storage and disposal of these substances and their containers will prevent soil contamination.

For all activities involving the use of potential pollutants or hazardous materials, material such as concrete, fuels, lubricants and hydraulic fluids will be carefully handled and stored to avoid spillages. Potential pollutants shall also be adequately secured against vandalism and will be provided with proper containment according to codes of practice. Any spillages will be immediately contained and contaminated soil removed from the site and disposed of to an appropriately permitted or licenced site according to the current Irish Waste Management Legislation by the contractor.

The contractor is required to make provision for removal of any concrete wash water. Concrete trucks will be directed back to their batching plant for washout. The arrangement for concrete deliveries to the site will be discussed with suppliers before commencement of work, outlining the agreed assessed routes, prohibiting on site washout and discussing emergency procedures.

9.6.2.7 Karst features

As a minimum, the carriageway drainage network will be sealed in areas where the proposed road development crosses rock particularly prone to karstification. Through the use of engineered solutions, including an impermeable barrier, cement slurry or grout, direct run-off from the paved surface of the proposed road development will be prevented from entering into the rock along the proposed alignment, as this could cause further deterioration and instability of the rock mass. Individual mitigation measures will be assessed on a case by case basis, determined by the extent of karst and make up of the proposed road development as outlined in the karst protocol which is part of the CEMP (**Appendix A.7.5**). Inspections of karst features will be undertaken by a hydrogeologist and/or geotechnical expert in order to determine the appropriate remediation measure. These remedial measures include but are not limited to the removal of all loose, soft, weak or voided soil material, backfilling voids with an agreed combination of boulders cobbles / chunk rock / cement slurry and installation of a high strength geosynthetic to form a competent, safe foundation platform.

Mitigation measures for the protection of karst features are further outlined in **Chapter 10, Hydrogeology** and included in the Construction Environmental Management Plan (CEMP) as part of the karst protocol.

9.6.3 Operational Phase

During the operational phase, monitoring of the rock mass stability will continue. The rock and overburden retaining systems in Lackagh Quarry and Western Approach will continue to be monitored as part of the TII (Transport Infrastructure Ireland) maintenance schedule. In the extremely unlikely event that instability within the rock mass is observed additional support measures outlined above in **Sections 9.4.1.1** and **9.6.2.4**, for the construction phase will be installed to ensure that there is no impact to the structural integrity of the Limestone pavement. However, based on the conservative design approach, (the installed composite support system and monitoring during construction) it is considered that the risk of instability will be avoided and additional support measures will not be required.

Operation mitigations measures for Lackagh Tunnel are further discussed in **Appendix A.7.3**.

The implementation of the design, construction methodology control measures and mitigations measures results in no other operational phase mitigation measures for avoiding potential direct and indirect impact to the soils and geology environment for the proposed road development.

9.7 Residual Impacts

9.7.1 Construction and Operation Residual Impacts

Implementing the outlined mitigation measures will result in a number of significant residual negative impacts on the soil and geological at the construction phase. These impacts occur where the construction of the proposed road development will result in a small loss of Limestone pavement (all outside European designated sites).

Implementation of the outlined mitigation measures will result in imperceptible residual negative impacts on the soil and geological at the operation phase.

The residual impacts are shown in **Table 9.19**: Predicted Residual Impacts for Geological Features and Activities during Construction Phase and **Table 9.20**: Predicted Residual Impacts for Geological Features and Activities during Operational Phase.

Table 9.19: Predicted Residual Impacts for Geological Features and Activities during Construction Phase

Feature / Construction Activity				Impact Assessment				
Name	**Importance**	**Assessment Section**	**Location**	**Magnitude of Impact**	**Criteria for Impact Assessment**	**Significance of Impact**	**Mitigation Measure**	**Residual Impact**
Limestone pavement [22]– Menlough Viaduct (outside European designated sites)	Very High	3	Menlough	Small Adverse	Results in loss of small part of attribute	Significant / Moderate	The magnitude of the loss of the attribute was minimised during the design stage where the number of piers and size of the pier footings was kept to a minimum. During construction of the viaduct, the Limestone pavement will be protected using a protection system, comprising of geogrid, protection geotextile and layers of material. This will be removed once construction is complete.	Significant / Moderate

[22] This table presents the geological assessment of Limestone pavement, refer to **Chapter 8, Biodiversity** for an ecological assessment.

Feature / Construction Activity				Impact Assessment				
Name	**Importance**	**Assessment Section**	**Location**	**Magnitude of Impact**	**Criteria for Impact Assessment**	**Significance of Impact**	**Mitigation Measure**	**Residual Impact**
Limestone pavement – Covered by the proposed road development (outside European designated sites)	Very High	3 and 4	Menlough and Coolagh	Small Adverse	Results in loss of small part of attribute	Significant / Moderate	No mitigation available	Significant / Moderate
Limestone pavement – Lackagh Tunnel (within European designated sites)	Very High	3	Coolagh	Negligible	Results in an impact on attribute but of insufficient magnitude to affect integrity	Imperceptible	The engineered design solutions to reduce the impact of the integrity of the geological feature will be monitored on site during construction. These solutions include sufficient rock above the tunnel bores, a suitable pillar between the bores to protect the tunnel from collapse and suitable blasting sequences. The site control measures include probing ahead of the tunnel and	Imperceptible

Feature / Construction Activity				Impact Assessment				
Name	**Importance**	**Assessment Section**	**Location**	**Magnitude of Impact**	**Criteria for Impact Assessment**	**Significance of Impact**	**Mitigation Measure**	**Residual Impact**
							mapping of the tunnel blast face and monitoring of the blast. Where required the introduction of stability measures will be implemented including rock bolts, and a robust steel tunnel lining.	
Limestone pavement – All other areas (Both within and outside European designated sites)	Very High	3 and 4	Menlough to Castlegar	Negligible	Results in an impact on attribute but of insufficient magnitude to affect integrity	Imperceptible	Not required	None
Palaeokarst	Medium	2, 3 and 4	Menlough, Ballindooley, Castlegar	Small Adverse	Proposed construction will result in the loss of small part of the attribute	Slight	No mitigation available	Slight
Karst: K7 - Spring	Medium	2	Bushypark	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K10 – Enclosed Depression	Medium	2	Bushypark	Negligible	No measurable change to attribute	Imperceptible	Not required	None

Feature / Construction Activity				**Impact Assessment**				
Name	**Importance**	**Assessment Section**	**Location**	**Magnitude of Impact**	**Criteria for Impact Assessment**	**Significance of Impact**	**Mitigation Measure**	**Residual Impact**
Karst: K11 – Enclosed Depression	Medium	2	Bushypark	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K12 – Enclosed Depression	Medium	2	Bushypark	Moderate Adverse	Proposed construction will result in the loss of part of the attribute	Moderate	No mitigation available	Moderate
Karst: K17 - Spring	Medium	3	Menlough	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K25 - Spring	Medium	3	Menlough	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K31 - Turlough	Medium	3	Menlough	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K44 - Enclosed Depression	Medium	3	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K45 - Spring	Medium	3	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K49 - Enclosed Depression	Medium	3	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None

Feature / Construction Activity				**Impact Assessment**				
Name	**Importance**	**Assessment Section**	**Location**	**Magnitude of Impact**	**Criteria for Impact Assessment**	**Significance of Impact**	**Mitigation Measure**	**Residual Impact**
Karst: K51 - Enclosed Depression	Medium	3	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K54 - Enclosed Depression	Medium	3	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K57 - Enclosed Depression	Medium	3	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K59 - Enclosed Depression	Medium	3	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K61 - Enclosed Depression	Medium	3	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K62 - Enclosed Depression	Medium	3	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K64 - Enclosed Depression	Medium	3	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K67 - Enclosed Depression	Medium	3	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K70 - Enclosed Depression	Medium	3	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None

Feature / Construction Activity				Impact Assessment				
Name	**Importance**	**Assessment Section**	**Location**	**Magnitude of Impact**	**Criteria for Impact Assessment**	**Significance of Impact**	**Mitigation Measure**	**Residual Impact**
Karst: K71 - Enclosed Depression	Medium	3	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K97 - Enclosed Depression	Medium	3	Castlegar	Moderate Adverse	Proposed construction will result in the loss of part of the attribute	Moderate	No mitigation available	Moderate
Karst: K104 - Enclosed Depression	Medium	3	Castlegar	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K131 - Enclosed Depression	Medium	3	Parkmore	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K158 - Spring	Medium	4	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K161 - Spring	Medium	4	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K172 - Enclosed Depression	Medium	4	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K175 - Enclosed Depression	Medium	4	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None

Feature / Construction Activity				**Impact Assessment**				
Name	**Importance**	**Assessment Section**	**Location**	**Magnitude of Impact**	**Criteria for Impact Assessment**	**Significance of Impact**	**Mitigation Measure**	**Residual Impact**
Karst: K176 - Spring	Medium	4	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K179 - Enclosed Depression	Medium	4	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K181 - Spring	Medium	4	Coolagh	Negligible	No measurable change to attribute	Imperceptible	Not required	None
Karst: K193 - Spring	Medium	4	Coolagh	Moderate Adverse	Proposed construction will result in the loss of part of the attribute	Moderate	No mitigation available	Moderate
Geological Heritage Site (GHA06): Igneous Intrusions	Very High	1	Bearna	Negligible	Feature is located within study area but will undergo no measurable change during construction	Imperceptible	Not required	-
Geological Heritage Site (GHA01): Roadstone Quarry	Very High	3	Twomileditch	Negligible	Feature is located within study area but will undergo no measurable change during construction	Imperceptible	Not required	-
Agricultural Soil AminDW:	High	1 and 2	Widespread across western portion of study area	Small Adverse	Irreversible loss of small proportion of	Moderate / Slight	All excavated agricultural soil shall be used as	Moderate / Slight

Feature / Construction Activity				Impact Assessment				
Name	**Importance**	**Assessment Section**	**Location**	**Magnitude of Impact**	**Criteria for Impact Assessment**	**Significance of Impact**	**Mitigation Measure**	**Residual Impact**
Deep well drained non-calcareous soil					local high fertility soils and / or high proportion of local low fertility soils		construction fill or placed in deposition areas and will contribute to the construction material requirements for the proposed road development.	
Agricultural Soil AminSW: Shallow well drained non-calcareous soil	High	1 and 2	Widespread across western portion of study area	Small Adverse	Irreversible loss of small proportion of local high fertility soils and / or high proportion of local low fertility soils	Moderate / Slight	All excavated agricultural soil shall be used as construction fill or placed in deposition areas and will contribute to the construction material requirements for the proposed road development.	Moderate / Slight
Agricultural Soil BminDW: Deep well drained calcareous soil	High	2, 3 and 4	Widespread across eastern portion of study area	Small Adverse	Irreversible loss of small proportion of local high fertility soils and / or high proportion of local low fertility soils	Moderate / Slight	All excavated agricultural soil shall be used as construction fill or placed in deposition areas and will contribute to the construction material requirements for	Moderate / Slight

Feature / Construction Activity				**Impact Assessment**				
Name	**Importance**	**Assessment Section**	**Location**	**Magnitude of Impact**	**Criteria for Impact Assessment**	**Significance of Impact**	**Mitigation Measure**	**Residual Impact**
							the proposed road development.	
Agricultural Soil BminSW: Shallow well drained calcareous soil	High	2, 3 and 4	Widespread across eastern portion of study area	Small Adverse	Irreversible loss of small proportion of local high fertility soils and / or high proportion of local low fertility soils	Moderate / Slight	All excavated agricultural soil shall be used as construction fill or placed in deposition areas and will contribute to the construction material requirements for the proposed road development.	Moderate / Slight
Quarry Q01: Lackagh Quarry - Disused	Medium	3	Lackagh / Coolagh	Moderate Adverse	Loss of moderate portion of future quarry or pit reserves	Moderate	No mitigation available	Moderate
Quarry Q02: Roadstone Quarry	Very High	3	Twomileditch	Negligible	The proposed road development is located south of Roadstone Quarry. Impact to the active quarry is of insufficient magnitude to affect the use or	Imperceptible	Not available	-

Feature / Construction Activity				Impact Assessment				
Name	**Importance**	**Assessment Section**	**Location**	**Magnitude of Impact**	**Criteria for Impact Assessment**	**Significance of Impact**	**Mitigation Measure**	**Residual Impact**
					future quarry reserves.			
Mineral ML23: Roadstone Dimension Stone	Very High	3	Twomileditch	Negligible	Feature is located within study area but will undergo no measurable change during construction	Imperceptible	Not required	-
Mineral ML24: Roadstone Limestone (in general)	Very High	3	Twomileditch	Negligible	Feature is located within study area but will undergo no measurable change during construction	Imperceptible	Not required	-
Crushed Rock Aggregate Potential: Very High Potential	Very High	1, 2, 3 and 4	Entire Study Area	Small Adverse	Loss of small proportion of future quarry or pit reserves or potential aggregate	Significant / Moderate	All excavated crushed rock shall be used as construction fill or placed in deposition areas and will contribute to the construction material requirements for the proposed road development.	Moderate / Slight
Crushed Rock Aggregate	High	1, 2 and 3	Na Foraí Maola,	Negligible	No measurable change to attribute	Imperceptible	Not required	-

Feature / Construction Activity				**Impact Assessment**				
Name	**Importance**	**Assessment Section**	**Location**	**Magnitude of Impact**	**Criteria for Impact Assessment**	**Significance of Impact**	**Mitigation Measure**	**Residual Impact**
Potential: High Potential			An Chloch Scoilte, Rahoon, Letteragh, Dangan					
Crushed Rock Aggregate Potential: Moderate Potential	Medium	1 and 2	An Chloch Scoilte, Dangan	Negligible	No measurable change to attribute	Imperceptible	Not required	-
Sub-Embankment Compression: Compression of founding material on the underside of the embankment	Medium	1, 2, 3 and 4	All fill areas	Negligible	Results in an impact on attribute but of insufficient magnitude to affect integrity	Imperceptible	Not required	-
Introduction of Material derived from a different Lithology	High	1, 2, 3 and 4	All fill areas	Moderate Adverse	Results in impact on integrity of attribute	Significant / Moderate	Detailed construction earthworks programme outlining use of all cut material, haulage routes, plans and continuous monitoring of earthwork movement. Limitations will be implemented in eight locations in the granite region. The restrictions in	Imperceptible

Feature / Construction Activity				Impact Assessment				
Name	**Importance**	**Assessment Section**	**Location**	**Magnitude of Impact**	**Criteria for Impact Assessment**	**Significance of Impact**	**Mitigation Measure**	**Residual Impact**
							these locations are only pavement and capping layers protected from surface water runoff and groundwater movements are permitted to be derived from non-native material and all other acceptable fill material will be derived from native material or other pH compatible material	
<u>Embankment Flood Barrier:</u> Blockade of water due to embankment	High	-	All fill areas in floodplains	Moderate Adverse	Results in impact on integrity of attribute	Significant / Moderate	Introduction of a drainage / starter layer within the embankment makeup to provide hydraulic conductivity.	Moderate / Slight
<u>Haulage of Material:</u> Unwanted compaction or disturbance	Medium	1, 2, 3 and 4	Widespread	Small Adverse	Results in minor impact on integrity of attribute	Slight	No mitigation available	Slight

Feature / Construction Activity				**Impact Assessment**				
Name	**Importance**	**Assessment Section**	**Location**	**Magnitude of Impact**	**Criteria for Impact Assessment**	**Significance of Impact**	**Mitigation Measure**	**Residual Impact**
Washout of Fines: Risk of deposition of sediment on agricultural land	Medium	1, 2, 3 and 4	Widespread	Small Adverse	Results in minor impact on integrity of attribute	Slight	In embankments, drainage layers incorporating geotextile separators will be utilised. The use of granular fill will also remove the risk of washout of fines	Imperceptible
Settlement, Movement from Cutting	High	1, 3 and 4	All cut areas	Small Adverse	Results in impact on integrity of attribute	Moderate / Slight	Ground settlement and vibration monitoring during excavation activities will be implemented to ensure that the works do not exceed the design limitations. Where blasting is not viable, alternative methods of rock fracturing such as hydraulic breaking shall be implemented. This will result in protection to attributes but an	Moderate / Slight

Feature / Construction Activity				Impact Assessment				
Name	**Importance**	**Assessment Section**	**Location**	**Magnitude of Impact**	**Criteria for Impact Assessment**	**Significance of Impact**	**Mitigation Measure**	**Residual Impact**
							extended construction timeline.	
<u>Foundation Construction:</u> Ground settlement, noise and vibration caused from foundation construction	Medium	1, 2, 3 and 4	Widespread	Small Adverse	Results in loss of small part of attribute and integrity of attribute	Slight	No mitigation available	Slight
<u>Construction Contamination:</u> Chemical spillage, material accumulation, or concrete activities	High	1, 2, 3 and 4	Widespread	Small Adverse	Results in minor impact on integrity of attribute and requirement to excavate waste material	Moderate / Slight	A requirement is to be introduced where all contaminants are carefully handled and stored to avoid spillages. Potential pollutants will be adequately secured against vandalism and should be provided proper containment according to code of practice.	Imperceptible

Table 9.20: Predicted Residual Impacts for Geological Features and Activities during Operational Phase

Feature / Operational Activity				Impact Assessment				
Name	**Importance**	**Assessment Section**	**Location**	**Magnitude of Impact**	**Criteria for Impact Assessment**	**Significance of Impact**	**Mitigation Measure**	**Residual Risk**
Limestone pavement – Menlough Viaduct	Very High	3	Menlough	Negligible	Results in impact on attribute but of insufficient magnitude	Imperceptible	Continuous monitoring should be conducted in sensitive zones.	Imperceptible
Limestone pavement - Menlough	Very High	3	Menlough	Negligible	Results in impact on attribute but of insufficient magnitude	Imperceptible	No mitigation available	Imperceptible
Limestone pavement – Lackagh Tunnel	Very High	3	Coolagh	Negligible	Results in impact on attribute but of insufficient magnitude	Imperceptible	No mitigation available	Imperceptible
Limestone pavement – All other areas	Very High	3 and 4	Menlough to Castlegar	Negligible	Results in impact on attribute but of insufficient magnitude	Imperceptible	No mitigation available	Imperceptible
Geological Heritage Site: Igneous Intrusions	Very High	1	Bearna	Negligible	No measurable change to the attribute	Imperceptible	Not required	-
Geological Heritage Site: Roadstone Quarry	Very High	3	Twomileditch	Negligible	No measurable change to the attribute	Imperceptible	Not required	-
Agricultural Soil AminDW: Deep well drained non-calcareous soil	High	1 and 2	Widespread across western portion of study area	Negligible	Results in an impact on attribute but of insufficient magnitude to affect either use or integrity	Imperceptible	No mitigation available	Imperceptible
Agricultural Soil AminSW: Shallow well	High	1 and 2	Widespread across western	Negligible	Results in an impact on attribute but of insufficient magnitude	Imperceptible	No mitigation available	Imperceptible

Feature / Operational Activity				Impact Assessment				
Name	**Importance**	**Assessment Section**	**Location**	**Magnitude of Impact**	**Criteria for Impact Assessment**	**Significance of Impact**	**Mitigation Measure**	**Residual Risk**
drained non-calcareous soil			portion of study area		to affect either use or integrity			
Agricultural Soil BminDW: Deep well drained calcareous soil	High	2, 3 and 4	Widespread across eastern portion of study area	Negligible	Results in an impact on attribute but of insufficient magnitude to affect either use or integrity	Imperceptible	No mitigation available	Imperceptible
Agricultural Soil BminSW: Shallow well drained calcareous soil	High	2, 3 and 4	Widespread across eastern portion of study area	Negligible	Results in an impact on attribute but of insufficient magnitude to affect either use or integrity	Imperceptible	No mitigation available	Imperceptible
Quarry Q02: Roadstone Quarry	Very High	3	Twomileditch	Negligible	Results in an impact on attribute but of insufficient magnitude to affect either use or integrity	Imperceptible	No mitigation available	Imperceptible
Mineral ML23: Roadstone Dimension Stone	Very High	3	Twomileditch	Negligible	No measurable change to the attribute	Imperceptible	Not required	-
Mineral ML24: Roadstone Limestone (in general)	Very High	3	Twomileditch	Negligible	No measurable change to the attribute	Imperceptible	Not required	-
Crushed Rock Aggregate Potential: Very High Potential	Very High	1, 2, 3 and 4	Entire Study Area	Negligible	No measurable change to the attribute	Imperceptible	Not required	-

Feature / Operational Activity				Impact Assessment				
Name	**Importance**	**Assessment Section**	**Location**	**Magnitude of Impact**	**Criteria for Impact Assessment**	**Significance of Impact**	**Mitigation Measure**	**Residual Risk**
Crushed Rock Aggregate Potential: High Potential	High	1, 2 and 3	Na Foraí Maola, An Chloch Scoilte, Rahoon, Letteragh, Dangan	Negligible	No measurable change to the attribute	Imperceptible	Not required	-
Crushed Rock Aggregate Potential: Moderate Potential	Medium	1 and 2	An Chloch Scoilte, Dangan	Negligible	No measurable change to the attribute	Imperceptible	Not required	-
Maintenance Works - Contamination: Contamination possible from machinery used	High	1, 2, 3 and 4	Widespread	Negligible	Results in an impact on attribute but of insufficient magnitude to affect either use or integrity	Imperceptible	No mitigation available	Imperceptible
Maintenance Works - Trafficking: Settlement, disturbance due to trafficking	High	1, 2, 3 and 4	Widespread	Negligible	Results in an impact on attribute but of insufficient magnitude to affect either use or integrity	Imperceptible	No mitigation available	Imperceptible
Rock Stability: Stability of quarry face	Very High	3	Coolagh	Negligible	No measurable change to the attribute	Imperceptible	Continuous monitoring should be conducted in sensitive zones.	Imperceptible
Long term Ground Movements: Ground movement, settlement due to tunnel construction	High	3 and 4	Menlough, Ballybrit	Negligible	Results in an impact on attribute but of insufficient magnitude to affect either use or integrity	Imperceptible	Continuous monitoring should be conducted in sensitive zones.	Imperceptible

9.7.2 Cumulative Impacts

The cumulative residual construction and operational impacts of the proposed road development and the following projects and plans have been assessed:

- The N59 Oughterard to Maam Cross
- M17 / N18 Gort to Tuam PPP Scheme
- Galway Harbour Port Extension
- Galway Transport Strategy (GTS), which includes the following:
    - Investigate prospective sites to the east of the city for Park and Ride
    - Bearna Greenway
    - Tuam Road Bus Corridor Scheme
    - Expansion of Public Bike Hire Scheme
- Galway City Development Plan 2017–2023
- Galway County Development Plan 2015–2021

Cumulative soils and geology impacts can occur when other projects in the locality have similar soils and geology potential impacts as the proposed road development. Cumulative impacts are assessed based on the residual impact[23] of these impacts on the proposed projects.

The following feature / construction activity impacts are identified in the projects and plans, listed above, and are also present in the proposed road development:

- Peat Removal / Disposal
- Impact to Geological Heritage Sites
- Contaminated Ground
- Loss of agricultural land and solid geology
- Haulage of material

As part of the environmental evaluation of the proposed road development the residual impact from peat removal/disposal, of geological heritage sites and contaminated ground is imperceptible. Due to the mitigation measures considered in the other project, the residual impact of those projects is also considered imperceptible. Therefore, the cumulative impact of these impacts is imperceptible.

The cumulative impact for:

- peat removal /disposal is considered to be imperceptible as peat is intended to remain within the proposed development boundary for each respective project
- geological heritage sites is considered to be imperceptible as none of the projects indicate that a geological heritage sites or county geological sites will

[23] This infers that mitigation measures have been implemented and the cumulative impact is assessed against the residual risk.

be impacted. The Galway Transport Strategy specifically outlines that it will seek to protect such sites from any inappropriate measures

- contaminated ground is considered to be imperceptible as the Galway City Development Plan (2017-23) waste management policy contains policy to ensure that proposals on contaminated lands include appropriate remediation measures

Loss of agricultural land and solid geology and haulage of material, whether imported or sourced from site, are activities that are also considered on other projects. Mitigation measures for other projects include the reduction and minimisation of removal or disposal of material off-site and the reuse of such material whether in construction fill or in designated material deposition areas. Consideration has been given to the extent of material which will be imported, exported or disposed and their combined impact. The cumulative impact is considered to remain unchanged as the combination of the impact will not increase the magnitude of the impact from small adverse.

The significance of the impact of the proposed road development operational activities is imperceptible and is considered not to change in combination with the other projects.

Therefore, there are no other plans or projects that are likely to result in a significant effect on soils and geology cumulatively with the proposed road development.

9.7.3 Residual Impacts Summary

The construction and operational residual impacts for the proposed road development are presented in **Table 9.19** and **9.20** respectively. After consideration of the other projects in the locality, the cumulative residual impact for the construction and operational stage is as per **Table 9.19** and **9.20** for the proposed road development and there are no cumulative soils and geology impacts.

9.8 Summary

The soils and geology environment will be impacted by the proposed road development.

Certain geological features will be impacted in all earthwork sections and these are highlighted in **Section 9.8.1**, loss of attributes.

Potential impacts due to construction or operational activities have the potential to occur, but the significance of the impact will be reduced, where possible, with implementation of mitigation measures. The potential residual impacts are presented in **Section 9.8.2** and **Section 9.8.3** respectively.

A summary review of the four sections of the proposed road development is presented in **Section 9.8.4** to **Section 9.8.7**.

Construction will be completed in accordance with the Construction Environmental Management Plan in **Appendix A.7.5**.

9.8.1 Loss of Attributes

A proportion of well drained fertile soil and crushed rock aggregate potential will be lost within the footprint of the proposed road development. The significance of such a loss is considered a moderate / slight impact in the case of agricultural soil and significant / moderate in the case of the crushed rock aggregate potential. While no mitigation measure can be implemented to reduce the impact on the agricultural soil, all excavated material will be used as construction fill or placed in deposition areas, thus contributing to the construction material requirements for the proposed road development. The re-use of the crushed rock aggregate potential is considered to be a reduction in impact to future quarry reserves, thus reducing the impact to a residual impact of moderate / slight.

The loss of part of three karst features will result from the proposed road development, enclosed depression (K12), enclosed depression (K97) and spring (K193). The significance of the potential impact for these attributes is moderate.

The proposed road development traverses locations of Limestone pavement in Sections 3 and 4 that is located both within and outside European designated sites. The geological assessment (importance and impact) has not differentiated between Limestone pavement located within or outside the European designated sites. Refer to **Chapter 8, Biodiversity** for an ecological assessment of Limestone pavement.

Lackagh Tunnel passes under an area of Limestone pavement that is within a European designated site resulting in minimal to no impact on the feature from a geological perspective. Menlough Viaduct and a culvert in Menlough pass over Limestone pavement (both outside European designated sites), resulting in a loss of a small part of the attribute under the viaduct piers and no impact on the feature under the culvert. There are three locations where the proposed road development traverses and covers Limestone pavement (all outside European designated sites): two locations in Menlough and one location in Coolagh. At these locations it will result in loss of a small part of the Limestone pavement, it should be noted that both of these locations are outside of the European designated sites.

The geological significance of loss of Limestone pavement was assessed at each location with the results ranging from imperceptible where there is no impact to significant/ moderate where loss of small part of the attribute occurs.

The proposed road development will result in the loss of part of the palaeolandscape in the east of the city. These features are known to be located in Menlough, Ballindooley and Castlegar. The significance of the loss of these features is slight.

The proposed road development will also result in the moderate loss of future reserves, with appropriate planning, at Lackagh Quarry (disused quarry). The significance of the loss of future reserves is considered moderate.

9.8.2 Residual Impacts due to Construction

Introduction of material derived from a different lithology, washout of fines, spread of contamination, construction induced flooding or unwanted disturbance of environment are all potential construction impacts on the receiving environment. Development and implementation of mitigation measures reduce such impacts to a moderate / slight or imperceptible residual impact on the soils and geology environment.

9.8.3 Residual Impacts due to Operation

All operational activities of the proposed road development are deemed to produce imperceptible impacts to the surrounding geological environment.

9.8.4 Section 1: Chainage 0+000 to 8+500 (R336 to the N59 Moycullen Road)

Section 1 contains the least number of potential impacts out of all four sections. All unique impacts applicable to Section 1 are presented in this section.

Settlement or movement of the surrounding environment can be induced adjacent to large cuttings, such as in Ballard or Letteragh. A clear understanding of the soil /rock behaviour, following detailed ground investigation, will contribute to the development of the detailed design and construction methodology in order to reduce or completely remove construction induced movement.

Blasting will be required for deep cuttings in rock, such as the characteristics anticipated for the cut sections in Ballard and Letteragh. Data obtained from trial blasts will calibrate the blast design to site specific designs and will refine the blast design properties. Where blasting is not viable, rock breaking will be conducted by hydraulic breaking/splitting or other industry methods.

In this granite region to prevent impact to the local peatland habitats**,** the following fill limitations will be incorporated at the locations identified **Table 9.18** of this chapter.

- Only pavement and capping layers protected from surface water runoff and groundwater movements are permitted to be derived from non-native material
- All other acceptable fill material will be derived from native material or other pH compatible material

This will be included in the construction earthworks programme which categorises the source of material for each fill section.

9.8.5 Section 2: Chainage 8+500 to 9+400 (N59 Moycullen Road to the River Corrib)

Section 2 is completely in fill and contains the second least number of potential impacts of all sections. The section is also the shortest length at only 900m. All unique impacts applicable to Section 2 are presented in this section.

The bedrock changes from granite to limestone in Section 2 at the N59 Moycullen Road, with the overlying materials having different chemical compositions. As such at the locations identified in **Table 9.18** in the granite region the following fill limitations will be incorporated:

- Only pavement and capping layers protected from surface water runoff and groundwater movements are permitted to be derived from non-native material
- All other acceptable fill material will be derived from native material or other pH compatible material

River Corrib Bridge will require a specialised foundation solution due to the soft ground anticipated and karst risk in the area. The foundation solution will require the installation of piles which could induce ground settlement in the surrounding environment and cause noise and vibrations from the installation works.

9.8.6 Section 3: Chainage 9+400 to 14+000 (River Corrib to the N83 Tuam Road)

Section 3 contains the largest number of impacts out of all four sections. All unique impacts applicable to Section 3 are presented in this section.

Sixteen structures located in Section 3 will potentially require specialised foundation solutions. The location and name of these structures are presented in **Table 9.17**. Two of the structures are located on the boundary between Section 3 and 4.

The proposed road development traverses locations of Limestone pavement located within and outside European designated sites in Sections 3. These locations are:

- Menlough Viaduct and a culvert structure traverse over areas of Limestone pavement both outside European designated sites resulting in loss of a small part of Limestone pavement at the viaduct
- There are two other locations in Menlough which will result in loss of part of the Limestone pavement that is located outside European designated sites through encapsulation
- Lackagh Tunnel traverses beneath Limestone pavement that is located within European designated sites and will emerge into Lackagh Quarry. A conservative design approach has been adopted for Lackagh Tunnel including ground anchors, rock bolts, rock dowels, steel mesh and shotcrete controlling rock stability and tunnel design features. As an additional control measure, a geotechnical expert will be appointed to monitor the rock mass stability at construction and operation stages. In the extremely unlikely event, due to the adopted conservative design approach, that instability within the rock mass is observed additional support measures such as ground anchors, rock bolts, rock dowels will be installed to ensure that there is no impact to the Limestone pavement. Based on the conservative design approach, it is considered that the risk of instability will be avoided and additional support measures will not be required. The residual risk is considered imperceptible to the Limestone pavement. Further details in relation to this can be found in **Appendix A.7.3**.

The remaining structures in **Table 9.17** are likely to require a robust foundation solution due to soft ground or karst which is present throughout section 3. The foundation solutions will require either the installation of piles or an excavation and replace of soft ground, which could induce ground settlement in the surrounding environment and cause noise and vibrations from the works.

Settlement or movement of the surrounding environment can be induced adjacent to large cuttings. The implemented design and selected construction methodology, will reduce or completely remove construction induced movement.

Blasting will be required for the tunnel construction and for deep cuttings in rock. Blasting may not be viable at all locations as a result of the local receptors limitations. Where blasting is not viable, alternative rock breaking methods will be implemented such as hydraulic breaking/splitting or other industry methods. As part of the blast design assessment monitored trial blasts in the same bedrock formation as the proposed blast locations at locations of proposed blasting will be conducted. These trial blasts will calibrate the blast design to site specific designs and will refine the blast design properties. Trial blasts will not exceed the limitations of the local sensitive receptors.

The proposed road development intersects a disused Lackagh Quarry and is located south of an active Roadstone Quarry in Twomileditch. Considering the proposed road development, the quarry location, proximity and status the potential impact of future reserves was assessed. The proposed road development will result in the loss of moderate proportion of future quarry reserves at Lackagh Quarry. The magnitude of such an impact is considered moderate adverse. No mitigation measure can be implemented to reduce this impact. The significance of the impact is moderate for the disused Lackagh Quarry. At Roadstone Quarry the proposed road development does not directly impact the quarry. The magnitude of the impact is considered negligible, as the impact to the active quarry is of insufficient magnitude to affect the use or future quarry reserves. The significance of the potential impact is imperceptible for the active Roadstone Quarry.

9.8.7 Section 4: Chainage 14+000 to 17+500 (N83 Tuam Road to the existing N6 at Ardaun, Coolagh)

All unique impacts applicable to Section 4 are presented in this section.

Two structures in Section 4 will potentially require specialised foundation solutions. The location and name of these structures are presented in **Table 9.17**. The foundation solution may require the installation of piles, which could induce ground settlement in the surrounding environment and cause noise and vibrations from the piling works.

Settlement or movement of the surrounding environment can be induced adjacent to large cuttings. The implemented design and selected construction methodology, will reduce or completely remove construction induced movement. Tolerances will be set for cuttings adjacent to properties.

The proposed road development traverses one location of Limestone pavement, which is located outside the European designated sites, in Sections 4 in Coolagh resulting in the loss of small part of the Limestone pavement.

Blasting will be required for the construction of the Galway Racecourse cut and cover tunnel. As part of the blast design data obtained from trial blasts will calibrate the blast design to site specific designs and will refine and validate the blast design properties. Where blasting is not viable, rock breaking will be conducted by hydraulic breaking/splitting or other industry methods.

9.9 References

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