Appendix A

Hydrogeology Assessment Report

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Galway County Council

N6 Galway City Ring Road

NIS - Hydrogeological Assessment

GCOB-4.04-021.2

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Contents

1 Introduction

This report has been prepared to document the potential impacts on groundwater bodies as they relate to European sites due to the proposed N6 Galway City Ring Road, hereafter referred to as the proposed road development.

This report details the data sources and baseline data collection used (**Section 2**), identifies the designated European sites supported by the groundwater bodies traversed by the proposed road development (**Section 3**) and describes the hydrogeological regime of the receiving environment (**Section 4**). The likely significant groundwater impacts from the proposed road development as they relate to European sites are assessed (**Section 5**) and measures to mitigate against theses impacts as outlined (**Section 6**). A conclusion is presented (**Section 7)** with references (**Section 8**).

2 Methodology

A conceptual groundwater model has been developed based on available hydrogeology data for the study area of the proposed road development. Based on this conceptual model the regional hydrogeology has been characterised into aquifer type and divided into a series of discrete groundwater bodies, each of which have their own surface catchment and flow paths that transfer groundwater from recharge to discharge.

Due to the coastal location all groundwater in the study area contributes to the Atlantic Ocean at Galway Bay either by discharges to coastal or transitional waters or from groundwater contributions to the surface watercourses that flow to Galway Bay.

This report assesses the potential for hydrogeological impact from the proposed road development to those groundwater bodies that support groundwater dependant ecosystems within European sites, whether coastal, transitional (estuary) or terrestrial. In terms of hydrogeology the term terrestrial refers to all onshore ecosystems (including fresh water ecosystems).

The data used to develop the conceptual model comprises of historic data, a 2015 desk study and ground investigation data collected during 2015 - 2017 for the project. The data sources for each of these are detailed below.

2.1 Desk Study

The following sources of information were reviewed in order to evaluate the hydrogeology of the proposed road development:

- Current and historical Ordnance Survey maps available for the study area (1:2,500 and 1:10,560 scales)
- Aerial photography (2012) of the study area

- Aerial imagery from Google (imagery from 2001 to 2016) and Bing accessed in 2016
- Geological and hydrogeological maps of the site area produced by the Geological Survey of Ireland (GSI) (www.dcenr.gov.ie, accessed November 2016)
- MacDermot, C.V., McConnell, B. and Pracht, M. (2003) *Geology of Galway Bay 1:100,000 scale Bedrock Geology Map Series*, Sheet 14, Galway Bay, Geological Survey of Ireland
- Pracht, M. and Somerville I.D., 2015. A Revised Mississippian lithostratigraphy of County Galway (western Ireland) with analyses of Carbonate lithofacies, biostratigraphy, depositional environments and paleogeography reconstructions utilising new borehole data. Journal of paleogeography. Volume 4, Issue 1, January 2015, Pages 1-26
- Teagasc and the Environmental Protection Agency Irish Soil Information System (http://gis.teagasc.ie/soils/index.php, accessed November 2016)
- Ground investigation reports held by the Geological Survey of Ireland for the study area
- Ground investigation reports held by Arup for the study area
- Flood, P. and Eising, J. (1987). *The use of vertical band drains in the construction of the Galway Eastern Approach Road*. Proceedings of the 9th European Conference on Soil Mechanics and Foundation Engineering, Dublin, Ireland
- Lidar elevation data commissioned by OPW
- N6 Galway City Outer Bypass Scheme (2006 GCOB):
  - Galway City Outer Bypass R336 Western Approach Constraints Study Report 2000
  - N6 Galway City Outer Bypass Constraints Study Report (2000)
  - Galway County Council Galway City Outer Bypass Preliminary Ground Investigation, 2006
  - N6 Galway City Outer Bypass Environmental Impact Statement (2006)
- Data available from the Geological Survey of Ireland:
  - R1340 Galway County Council Eastern Approach Road Galway (N6) (Ballybane – Doughiska), 1993
  - R1365 Thos. Garland and Partners Digital Limited, Galway Industrial Estate, 1983
  - R3176 Dermot Rooney and Associates I.D.A Business Park, Daingean, Galway, 1997
  - R5906 Irish Linen Proposed Irish Linen Factory, Rahoon, Galway, 2005
  - R6136 Galway County Council Residential Development, Headford Road, Galway, 2006
  - R6898 Storm Technology Office Block Development, Daingean, Galway, 2006

2.2 Field Surveys and Ground Investigations

As part of the environmental studies for the proposed road development a number of field surveys and ground investigations were undertaken to assess the hydrogeological environment. These included a survey of pre-existing monitoring wells, a survey of surface karst features and ground investigation including groundwater monitoring installations.

The ground investigations included boreholes, trial pits, window sampling and geophysical surveys. The ground investigations included hydrogeological monitoring and testing. In summary, these investigations comprised:

- 34 No. groundwater monitoring wells
- 16 No. groundwater level monitoring rounds [1]
- 12 No. groundwater quality monitoring rounds
- 15 No. infiltration test
- 16 No. small scale pumping test and variable head permeability tests
- 3 No. Packer tests

All investigation locations were sited based on the design of the proposed road development at that location. Water level, water quality and aquifer testing in particular was focused on locations of cuttings, structures and receptors. An overview on the extent of available data is presented in **Plate 1** below.

[1] Groundwater monitoring was undertaken between February 2015 and April 2017. This included a total of 16 groundwater monitoring rounds. Measurements on individual wells were also taken during commissioning, well testing and spot checks. In total 54 individual wells were regularly measured, which comprised of 34 project specific wells, 16 (2006 GCOB wells and 4 private wells.

Plate 1: Overview of the groundwater monitoring network for the proposed road development

3 Designated European Sites

As part of the hydrogeological studies (which is documented in **Section 4**), the groundwater bodies traversed by the proposed road development have been identified and delineated using all available public information and hydrogeological data collected from ground investigations undertaken for the proposed road development. It is important to recognise that the boundary for a groundwater body marks the catchment within which all recharge and groundwater flow is contained. Recharge and groundwater does not flow across the divide and in this regard, groundwater characteristics, such as water quality and seasonal groundwater level fluctuation, are isolated and specific to a particular groundwater body.

In terms of assessing the potential to impact on the hydrogeological regime of a European site, the focus of the assessment is on delineating and characterising those groundwater bodies (GWB) that the proposed road development is adjacent to (within 500m) or traverses. Divides between groundwater bodies can be hydraulic barriers which isolate interaction between GWB or they may be a groundwater ridge, which can migrate laterally between seasons.

Those groundwater bodies separate from the proposed road development (i.e. not traversed by the road and more than 500m away from it) are not included in the assessment as groundwater impacts from the proposed road development to those groundwater bodies are not possible.

All European sites within 30km of the proposed road development have been considered using the precautionary principle. The European sites beyond 15km do not have a groundwater connection from the proposed road development and are not considered further. A summary of European sites in the region within 15km of those groundwater bodies traversed by the proposed road development are presented below in **Table 1.**

The European sites listed in the table below are individually assessed to determine its potential dependency on a groundwater body traversed by or adjacent (within 500m) to the proposed road development.

Table 1: European sites with groundwater dependant habitat located within 15km of groundwater bodies traversed by the proposed road development

Site Name	NPWS Site code	Proximity	Screening	Result
Black Head-Poulsallagh Complex cSAC	000020	11km	Site lies in separate groundwater body. Screened out.	Not considered further
Moneen Mountain cSAC	000054	13km	Site lies in separate groundwater body. Screened out.	Not considered further
Castletaylor Complex cSAC	000242	14km	Site lies in separate groundwater body. Screened out.	Not considered further

Site Name	NPWS Site code	Proximity	Screening	Result
Galway Bay Complex cSAC	000268	0.14km	Site lies adjacent to groundwater body that the proposed road development traverses.	Impact assessment required
Lough Corrib cSAC	000297	0.0km	Site lies adjacent to groundwater body that the proposed road development traverses.	Impact assessment required
Rahasane Turlough cSAC	001271	13km	Site lies in separate groundwater body. Screened out.	Not considered further
Lough Fingall Complex cSAC	000606	11km	Site lies in separate groundwater body. Screened out.	Not considered further
Gortnandarragh Limestone Pavement cSAC	001312	14km	Site lies in separate groundwater body. Screened out.	Not considered further
Kiltiernan Turlough cSAC	001285	14km	Site lies in separate groundwater body. Screened out.	Not considered further
Ross Lake and Woods cSAC	001271	10km	Site lies in separate groundwater body. Screened out.	Not considered further
East Burren Complex cSAC	001926	13km	Site lies in separate groundwater body. Screened out.	Not considered further
Connemara Bog Complex cSAC	002034	6km	Site lies in separate groundwater body. Screened out.	Not considered further
Ardrahan Grassland cSAC	002034	15km	Site lies in separate groundwater body. Screened out.	Not considered further
Inner Galway Bay SPA	004031	1km	Site lies adjacent to groundwater body that the proposed road development traverses.	Impact assessment required
Lough Corrib SPA	004142	0.0km	Site lies adjacent to groundwater body that the proposed road development traverses.	Impact assessment required
Rahasane Turlough SPA	004089	13km	Site lies in separate groundwater body. Screened out.	Not considered further
Cregganna Marsh SPA	004142	4km	Site lies in separate groundwater body. Screened out.	Not considered further

Site Name	NPWS Site code	Proximity	Screening	Result
Connemara Bog Complex SPA	004181	9km	Site lies in separate groundwater body. Screened out.	Not considered further

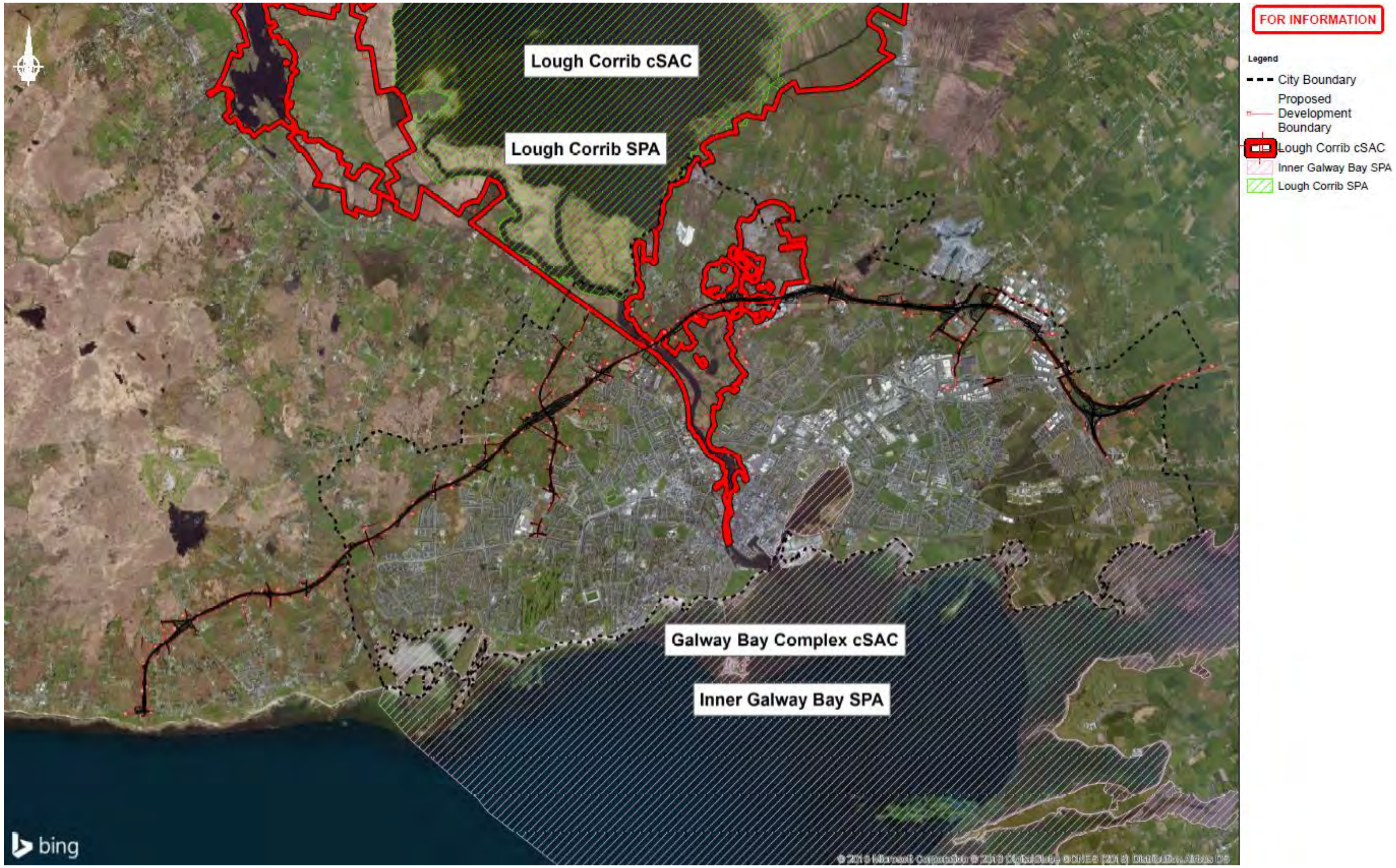
Based on the above regional assessment, there are four European sites that receive groundwater from groundwater bodies that the proposed road development is adjacent to or traverses (**Plate 2**).

These European sites are:

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

The aquifers that the European sites receive groundwater from (and the specific groundwater bodies that make up each aquifer) are presented in the following section (**Section 4 - Receiving Environment**).

Plate 2: Overview showing location of Galway Bay Complex cSAC, Inner Galway Bay SPA, Lough Corrib cSAC and Lough Corrib SPA



4 Receiving Environment

This section provides a characterisation of the hydrogeological receiving environment of the proposed road development. The hydrogeological environment is presented firstly in the regional context using publicly available information and then secondly in detail for the study area based on information obtained specifically for the project.

The hydrogeological study area is divided into two main areas based on the contrasting aquifer properties for the two main geological rock types in the region. The bedrock geology may be divided into:

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

The available data on the hydrogeology of the proposed road development is presented in **Figures 1.01, 1.02, 2.01, 2.02, 3.01, 3.02, 4.01, 4.02, 5.01** and **5.02**. These figures show the bedrock aquifer classifications, location of karst landforms, extent of GSI groundwater bodies, groundwater vulnerability, GSI recharge estimations and location of groundwater receptors.

- **Figures 1.01** and **1.02** Bedrock and karst features
- **Figures 2.01** and **2.02** GSI groundwater bodies
- **Figures 3.01** and **3.02** Groundwater vulnerability
- **Figures 4.01** and **4.02** Groundwater recharge
- **Figures 5.01** and **5.02** Groundwater receptors

The Galway Granite Batholith and the Visean Undifferentiated Limestone have contrasting aquifer properties. The GSI classify the Visean Undifferentiated Limestone as being a regionally important karst aquifer (Rkc) whilst the Galway Granite Batholith is classified as being a Poor Aquifer that is productive in local zones only (Pl).

Groundwater level data has been recorded for the period 2015 - 2017 for both the Galway Granite Batholith and the Visean Undifferentiated Limestone. This data includes peak groundwater level conditions for the winter of 2015/16 and low groundwater level conditions during the summer of 2015/16 and 2016/17. The water level data is presented in **Tables 2** and **3** below.

4.1 Galway Granite Batholith

The GSI descriptions for groundwater bodies in the Galway Granite Batholith describes the aquifer as being poor (**Figure 1.01**) with low storage and short groundwater pathways of up to generally 100m. These short pathways, typically along faults and fractures, are localised and generally only provide small yields. The water level data presented, identifies that the groundwater table remains close to the surface and generally follows the topography. On this basis groundwater contours will generally follow the topography, lowering towards the coast and the River Corrib. The proposed road development either traverses or is adjacent to two groundwater bodies within the GSI database, namely the Spiddal GWB and Maam-Clonbur GWB in the Galway Granite Batholith (**Figure 2.01**). The GSI groundwater bodies within the granite are generally delineated by topography and based on the GI data collected. The groundwater levels show that the groundwater divide matches the topography that forms the watershed between surface water draining to Galway Bay and surface water draining to the River Corrib. On the basis of the GI data collected for this project, the GSI groundwater bodies are confirmed as is and remain unchanged as part of the assessment for the proposed road development.

The overburden overlying the granite is generally less than 3m thick. The soil and subsoil comprises of glacial tills. This data indicates that the permeability of the subsoils is in the low to moderate range. Where overburden is present the groundwater levels are at or near surface. This data is used by the GSI to compile groundwater vulnerability maps (**Figure 3.01**).

Although the Galway Granite Batholith is considered to be a poor aquifer with most rainfall running off to streams and rivers, there will be a small component of groundwater that discharges to Galway Bay (less than 100mm/yr. per unit area based on GSI data **Figure 4.01**). Spiddal GWB contributes to Galway Bay Complex cSAC and Inner Galway Bay SPA. The Maam-Clonbur GWB contributes to Lough Corrib cSAC and Lough Corrib SPA (**Figure 5.01**) and as the River Corrib discharges into Galway Bay it indirectly contributes to Galway Bay Complex cSAC and Inner Galway Bay SPA.

The data collected for the proposed road development correlates with the GSI division of groundwater bodies and on this basis, the extent and naming of these remains unchanged. From the project data, groundwater flow in the Galway Granite Batholith is isolated to weathered zones and fracture zones only. On this basis, groundwater is generally not present except in locations where there are fractures but even in these locations groundwater is restricted to the fracture zone and will only move locally within it. Due to the nature of the bedrock, groundwater flows within these zones will likely flow for only short distances, of the order of 100m.

Table 2: Groundwater levels measured in the Galway Granite Batholith

Monitoring Borehole	Source	East ITM	North ITM	Ground Elevation (mOD)	Groundwater		
					Min (mOD)	Max (mOD)	Range (m)
RC422	N6 GCOB	524196	724742	21.20	19.45	20.75	1.30
RC435	N6 GCOB	524479	725777	59.19	56.13	56.58	0.45
RC451A	N6 GCOB	525153	726691	71.70	69.43	70.04	0.61
RC 548	N6 GCOB	521102	723826	50.84	49.67	50.73	1.06
RC 687	N6 GCOB	522901	725359	69.56	68.78	69.16	0.38
RC 739	N6 GCOB	524763	725951	59.64	58.45	58.86	0.41
BH-3-04R	N6 GCRR	523646	724287	36.82	36.23	36.70	0.47
BH-3-06R	N6 GCRR	524241	724825	23.09	21.87	22.22	0.35
BH-3-08R	N6 GCRR	524621	725069	42.05	39.85	41.39	1.54
BH-3-10R	N6 GCRR	525321	725604	66.51	63.37	64.66	1.29
BH-3-11R	N6 GCRR	525784	725831	54.24	52.83	53.27	0.44
BH-3-13R	N6 GCRR	526079	726036	58.65	52.85	57.12	4.27
BH-3-16R	N6 GCRR	526765	726611	61.66	57.64	58.45	0.81
BH-3-17R	N6 GCRR	527021	726805	65.33	62.46	62.93	0.47
BH-3-18R	N6 GCRR	527254	726894	70.64	68.03	69.11	1.08
BH-3-20R	N6 GCRR	527214	727669	51.63	47.83	48.61	0.78
BH-3-23R	N6 GCRR	527774	727346	26.93	22.32	23.46	1.14
BH-3-24R	N6 GCRR	528036	727521	25.16	20.97	22.77	1.80

Notes:

Includes groundwater level data from project specific monitoring wells

Groundwater levels are measured on site to the nearest centimetre below top of casing. All effort has been made to ensure the accuracy of the data.

4.2 Visean Undifferentiated Limestone

The GSI has classified the Visean Undifferentiated Limestone as a regionally important aquifer that has karst conduit groundwater flow (**Figure 1.02**). The GSI has subdivided this aquifer into six groundwater bodies which are traversed or are adjacent to the proposed road development (**Figure 2.02**). These comprise of:

- Ross Lake
- GWDTE Lough Corrib Fen 1 (Menlough)
- GWDTE Lough Corrib Fen 2
- GWDTE Lough Corrib Fen 3 & 4
- Clarinbridge
- Clare-Corrib

The extents of the groundwater bodies (GWB) as mapped by the GSI are shown on **Figure 2.02**. These GWB, with the exception of the Clarinbridge GWB, contribute directly to Lough Corrib cSAC. Only GWDTE Lough Corrib Fen 2 GWB, GWDTE Lough Corrib Fen 3 & 4 GWB, Ross Lake and Clare-Corrib GWB contribute to the Lough Corrib SPA. As the River Corrib discharges in Galway Bay all the above GWB that contribute to the River Corrib also contribute to Galway Bay Complex cSAC and Inner Galway Bay SPA.

The ground investigation (GI) data and water levels measured along the proposed road development provide significantly more data points for the groundwater table than were available when the GSI mapped the extents of the GWB. Using the additional data, the boundaries for each groundwater body traversed or adjacent to the proposed road development were remapped. The refined GWB (2017) are presented in **Figure 5.01 and 5.02**.

Based on the 2017 data, there are three groundwater divides within the Visean Limestone Undifferentiated that are traversed by the proposed road development and these comprise of the following locations:

- The River Corrib which forms a boundary between the Ross Lake GWB and the Lough Corrib Fen 1 (Menlough) GWB
- A groundwater ridge between Lough Corrib Fen 1 (Menlough) GWB and the Clare Corrib GWB that lies c.200m to the west of Lackagh Quarry
- A deep buried valley along the N83 Tuam Road, which forms the boundary between the Clare-Corrib GWB and the Clarinbridge GWB

Table 3: Groundwater levels measured in the Visean Limestone Undifferentiated aquifer

Monitoring Borehole	Source	Easting ITM	Northing ITM	Ground Elevation (mOD)	Groundwater Level		
					Min mOD	Max mOD	Range m
Western Coolagh Spring	N6 GCRR (SW-2-4)	529045	727934	5.41	5.70	6.37	0.67
Eastern Coolagh Spring	N6 GCRR (SW-2-5)	529900	728162	7.06	7.65	7.78	0.13
MW 01	2006 GCOB	528670	727956	16.14	10.61	13.89	3.28
MW 02	2006 GCOB	528715	728095	13.37	6.15	7.90	1.75
MW 03	2006 GCOB	528920	727970	6.70	5.80	6.46	0.66
BH-3-27R	N6 GCRR	528960	728133	9.10	5.90	6.41	0.51
RC133	2006 GCOB	529325	728185	11.66	5.73	8.16	2.43
BH972	2006 GCOB	529462	728292	12.33	5.70	8.20	2.50
BH-3-29R	N6 GCRR	529489	728334	13.73	Dry (<6.93)	9.23	>2.40
RP-2-05D	N6 GCRR	529701	727145	19.96	5.73	7.78	2.05
RP-2-05S	N6 GCRR	529704	727141	20.22	8.86	12.01	3.15
BH04	N6 GCRR	530151	728400	32.17	8.20	15.74	7.50
BH05	N6 GCRR	530187	728378	34.14	8.08	19.46	11.40
LQ MW6	Private	529919	727971	15.40	12.11	13.20	1.09
LQ MW5	Private	530389	728285	7.40	10.71	19.17	8.46
LQ MW4	Private	530522	728557	16.76	8.71	15.41	6.70
RC 1104	2006 GCOB	531165	728927	9.39	7.24	7.83	0.60
BH-3-31R	N6 GCRR	531274	728424	11.08	9.45	9.78	0.33
RC206	N6 GCRR	531237	729433	28.49	19.29	21.11	1.82
RP-2-03	N6 GCRR	531478	728278	22.44	4.95	9.09	4.14
RP-2-01	N6 GCRR	531726	728689	21.38	7.86	10.28	2.42
RC 1206	N6 GCRR	531986	729388	27.67	17.05	19.45	2.40
BH-3-32R	N6 GCRR	531971	728318	24.43	Dry (<9.43)	10.24	>0.81

Monitoring Borehole	Source	Easting ITM	Northing ITM	Ground Elevation (mOD)	Groundwater Level		
					Min mOD	Max mOD	Range m
RC 1211	N6 GCRR	532454	729601	25.91	20.25	22.03	1.78
BH-3-34R	N6 GCRR	532405	728275	32.57	19.69	25.91	6.22
BH-3-35R	N6 GCRR	532851	728226	17.52	7.91	9.15	1.24
BH-3-47R	N6 GCRR	533062	728286	37.74	27.55	27.74	0.19
BH-3-36R	N6 GCRR	533125	728205	51.78	32.80	34.00	1.28
RC-2-02	N6 GCRR	533685	728102	44.02	44.02	44.61	0.59
BH-3-38R	N6 GCRR	534249	727541	45.17	42.55	43.83	1.28
BH-3-40R	N6 GCRR	534439	727295	42.39	39.30	39.89	0.59
BH-3-48R	N6 GCRR	534397	727197	40.48	39.17	39.32	0.15
BH-3-41R	N6 GCRR	534580	727065	41.49	37.51	38.89	0.59
BH-3-42R	N6 GCRR	534756	726840	32.60	29.50	30.12	0.62

Notes:

1. *Includes groundwater level data from project specific monitoring wells*
2. *Groundwater levels in LQMW4 are the same as LQMW1, 2, 3 and 4.*
3. *It was not possible for IGSL to access to BH-2-32R during May, August, September and November 2016. Water levels for April, June and July are reported. As the groundwater levels recorded during these months are representative of low groundwater levels only 'not representative' (NR) is reported for the maximum groundwater level.*
4. *Monitoring wells LQMW5 and BH05 both straddle a thin black argillaceous limestone that overlies a clay wayboard in the geology sequence, which perches recharge above the main groundwater body. The groundwater levels recorded in LQMW5 and BH05 represent interaction between the main groundwater body and recharge. The water levels in LQMW5 and BH05 are not representative of groundwater levels in the main groundwater body.*
5. *Groundwater levels are measured on site to the nearest centimetre below top of casing. All effort has been made to ensure the accuracy of the data.*

The GSI data shows that the limestone bedrock is generally at or close to surface, but that in a number of locations that deep subsoil is present. The GSI vulnerability data is presented in **Figure 3.02**, which also shows the location of a number of linear buried valleys (also referred to in academic texts as a palaeolandscape) where the bedrock is particularly deeply buried (up to 106m below ground level).

GSI estimations show that where the bedrock is close to surface then recharge will exceed 550mm/yr. (**Figure 4.02**). Where the subsoil is deeper, especially where buried valleys are present, then the recharge will be reduced.

The aquifer classification, karst, recharge estimations and vulnerability data available from the GSI show that the Visean Undifferentiated Limestone has the capacity for groundwater throughput[2] of the order of 550mm/yr per unit area.

The GSI groundwater bodies have been updated based on the GI data obtained as part of the studies for the proposed road development (**Figure 5.02**). In the section below, each groundwater body is described. Schematic sketches are used to present groundwater interactions at potential groundwater dependant terrestrial ecosystems (GWDTE).

4.2.1 Ross Lake Groundwater Body

The Ross Lake GWB encompasses the limestone on the western side of the River Corrib. The Ross Lake GWB as mapped by the GSI is presented in **Figure 2.02.** The extent of the Ross Lake GWB was revised based upon the ground investigation for the proposed road development and the revised extent is presented in **Figure 5.02**.

The GWB receives recharge from rainfall but also runoff from the adjacent granite. There are several drains and ditches that cross from the granite and onto the Ross Lake GWB. As such, the surface catchment for the Ross Lake GWB includes the runoff within the local catchment for the River Corrib.

As the GWB boundary conditions are physical (i.e. bedrock contact and river) they do not fluctuate seasonally.

Groundwater from the Ross Lake GWB contributes directly to the Lough Corrib cSAC, Lough Corrib SPA and indirectly to Galway Bay Complex cSAC and Inner Galway Bay SPA. Lough Corrib SPA extends over the northern part of the Ross Lake GWB **(Figure 5.02**).

4.2.2 GWDTE Lough Corrib Fen 1 (Menlough)[3] Groundwater Body

The GWDTE Lough Corrib Fen 1 (Menlough) GWB extends east from the River Corrib. The eastern extent of the GSI GWDTE Lough Corrib Fen 1 (Menlough) GWB (**Figure 2.02**) has been revised westwards to Coolough to accommodate the groundwater divide identified between it and the Clare-Corrib GWB, which has been refined based on the groundwater monitoring for this project (**Figure 5.02**).

This GWB has been divided into two areas, namely Lough Corrib Fen 1 Menlough and Lough Corrib Fen 1 Lackagh (note that in the revised mapping of the GWB the term GWDTE has not been used in the GWB title), on the basis of the thick silt and clay subsoils (up to 106m deep) that occur in the townland of Coolough. These thick subsoils deposits, which underlie Coolagh Lakes and form a deep valley fill/palaeokarst feature west of Lackagh Quarry, compartmentalise the GWB so that Lough Corrib Fen 1 (Menlough) lies north of Coolagh Lakes and Lough Corrib Fen

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[2] Throughput is the quantity of groundwater passing through an aquifer

[3] Note GSI reference for groundwater body

1 (Lackagh) forms a small GWB (<0.04km^2) between Lough Corrib and Lackagh Quarry.

Groundwater flows westwards within the Lough Corrib Fen 1 (Menlough) from the groundwater divide with the Clare-Corrib GWB to the Coolagh Lakes and the River Corrib. Western Coolagh Spring (K25) is a karst spring and forms part of the Lough Corrib Fen 1 (Menlough) GWB. Western Coolagh Spring (K25) provides groundwater flow to the upper lake of Coolagh Lakes as evidenced by Ground Investigations (GI) and explained further in **Plates 3** and **4** below.

During the site workover, a pond with a ditch outfalling to the Upper Coolagh Lake was identified as being a potential spring and this is referred to as the Eastern Coolagh Spring (K45). However, this spring is not a karst spring because it sits on clay subsoil as evidenced by GI. Monitoring of the water level between 2014 and 2018 at the Eastern Coolagh Spring showed the water level is static and failed to identify a correlation with groundwater in bedrock. There is no bedrock exposed at the Eastern Coolagh Spring and due to the thick cover of clayey subsoil it is unlikely there is any direct discharge from the limestone aquifer to the Eastern Coolagh Spring.

Due to the compartmentalisation of the aquifer by buried valleys/palaeokarst, the groundwater in Lough Corrib Fen 1 (Lackagh) GWB is largely contained. Due to the thick clay subsoil there are no observed discharges from the limestone bedrock to the Eastern Coolagh Spring and the compartmentalisation prevents discharge to Western Coolagh Spring. Instead, groundwater flow from Lough Corrib Fen 1 (Lackagh) is likely to flow eastwards to Lackagh Quarry during peak groundwater levels. There is a potential for seepage from the limestone aquifer through the clayey subsoil to the Eastern Coolagh Spring but due to the low permeability and thickness of the clayey subsoil, these potential seepages are of a very low flow rate. If present, seepages from the subsoil to the Eastern Coolagh Spring would represent a very small fraction of the groundwater contribution to Coolagh Lakes compared to the karst inflow at Western Coolagh Spring (K25), which provides the main groundwater contribution flow to Coolagh Lakes. This hydrogeological assessment however is based on the precautionary principle and assumes that these seepages occur even though they were not observed.

Coolagh Lakes lie in a low-lying area that are shown by GSI data as well as records from 2006 GCOB GI and observations from the site walkover to be underlain by thickness of low permeability overburden and that the overburden adjacent to Upper Coolagh Lake comprises of silt and clay. On this basis groundwater inflow through the base of the lakes is unlikely and the only significant groundwater input is via the karst spring identified, namely Western Coolagh Spring. Groundwater contribution to Coolagh Lakes from the Eastern Coolagh Spring and any other potential seepages (such as from the margin of the Clare-Corrib GWB) are very limited due to the thick clay subsoil that fills the buried valley and forms a very low permeability barrier to the limestone aquifer.

Plates 3 and **4** below show the interactions between Western Coolagh Spring and the Coolagh Lakes and the groundwater at high and low groundwater levels. During high groundwater levels groundwater contributes flow to the lakes, while during the summer the groundwater level lowers to just above the lake level and the springs have minimal flow. **Plate 5** below, shows the relationship between groundwater levels and surface water levels in the springs that feed Coolagh Upper Lake.

Plate 3: Schematic north south cross-section through Coolagh Lakes (groundwater high)

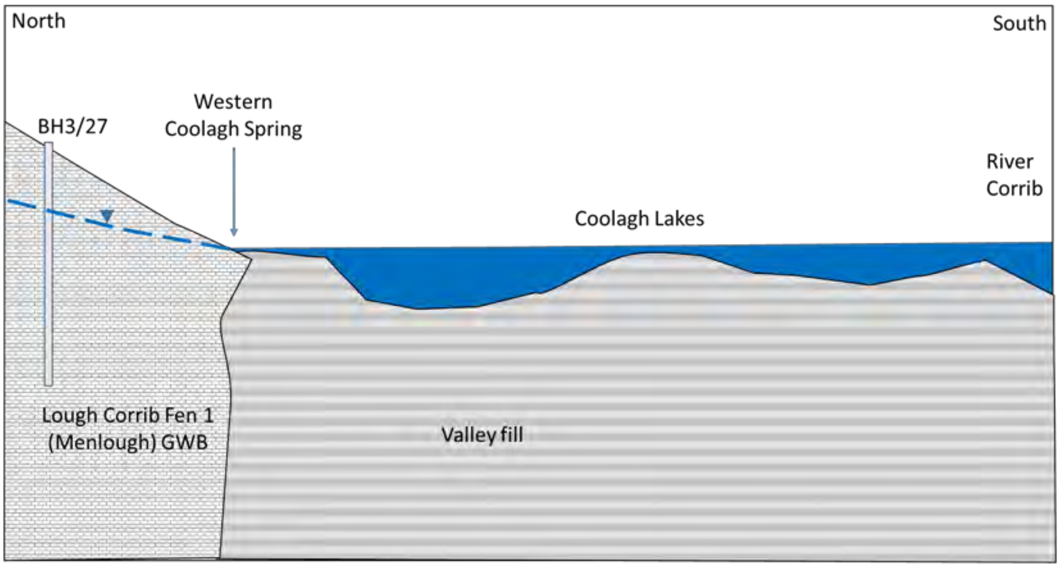
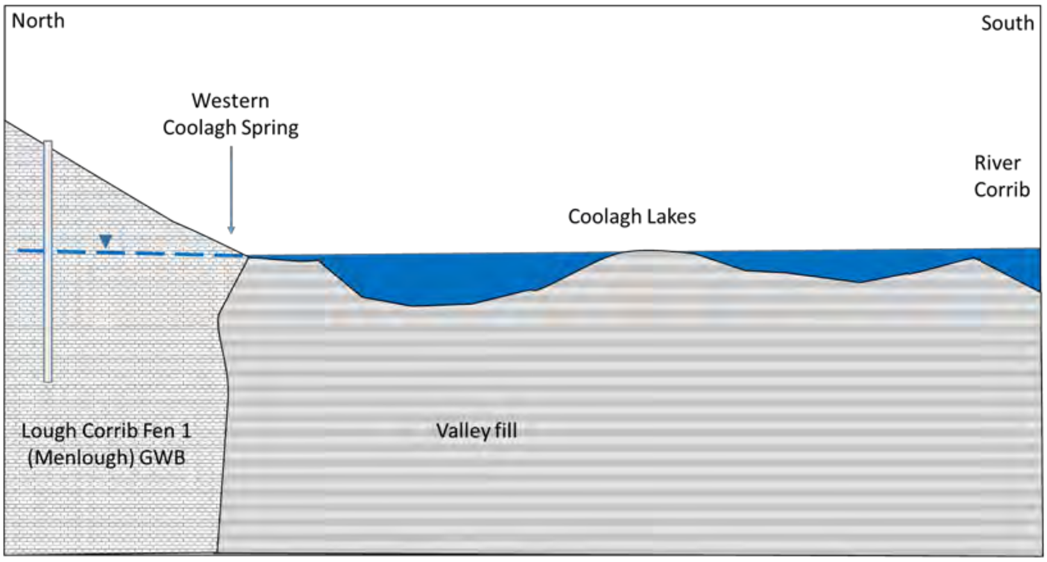


Plate 4: Schematic north south cross-section through Coolagh Lakes (groundwater low)

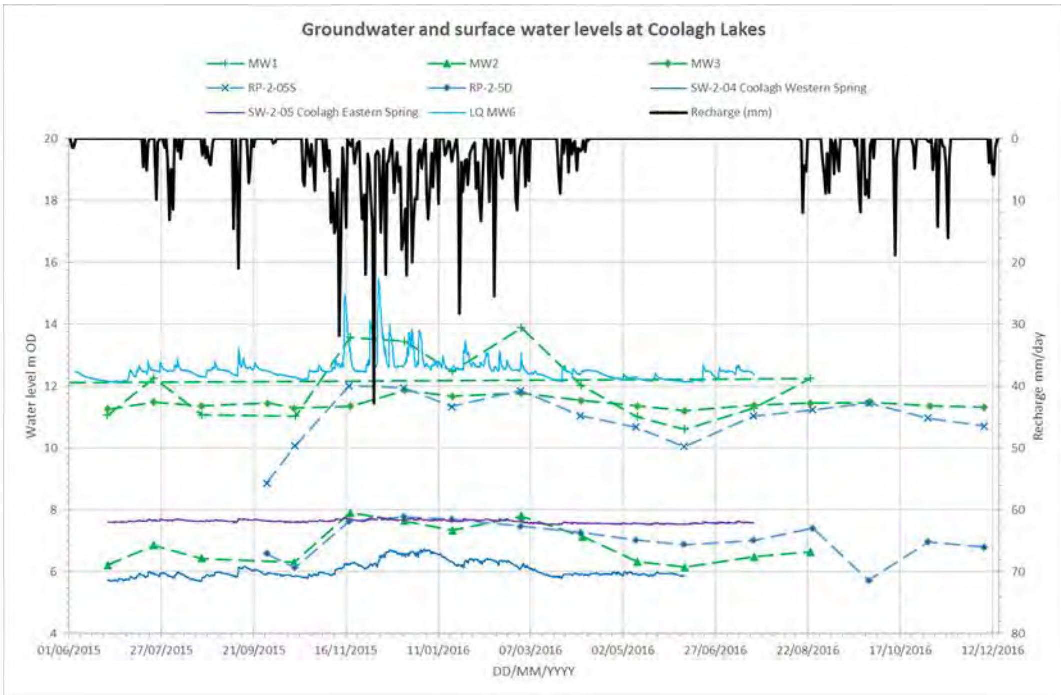


Groundwater hydrographs for the Menlough area are presented below (**Plate 5**), and show the groundwater responses in the aquifer locally as well as levels at the Western Coolagh Spring, Eastern Coolagh Spring as well as Upper and Lower Coolagh Lakes. Eastern Coolagh Spring, which is elevated higher than Western Coolagh Spring remains above the local groundwater table during all but peak groundwater levels. This shows that Western Coolagh Spring is the main contributor of groundwater to the Upper Coolagh Lake.

The hydrograph for the Menlough area (**Plate 5**) shows that groundwater levels remain above both Upper and Lower Coolagh Lakes. On this basis groundwater contributes to the Coolagh Lakes throughout the year, although in the summertime the contribution is slight and during extended dry periods the groundwater contribution is very slight.

As the western boundary of the GWB is a river, there is no seasonal variance in this boundary as it is physically bound. However, as the eastern boundary is formed by a groundwater divide, the seasonal fluctuation in groundwater levels has the potential to cause the divide to shift laterally. Based on the maximum and minimum groundwater levels data (**Table 3**) the groundwater divide remains at BH04 throughout the seasonal fluctuation.

Plate 5. Groundwater and surface water levels at Coolagh Lakes



On the basis of the above descriptions, the Lough Corrib Fen 1 (Menlough) GWB is the sole significant groundwater contributor (via Western Coolagh Spring) to Coolagh Lakes. Coolagh Lakes are part of the Lough Corrib cSAC. The Coolagh Lakes discharge to the River Corrib and as the River Corrib discharges into Galway Bay this GWB also contributes (indirectly) to Galway Bay Complex cSAC and Inner Galway Bay SPA.

4.2.3 GWDTE Lough Corrib Fen 2 Groundwater Body

The GSI mapping of the extents of GWDTE Lough Corrib Fen 2 is shown in **Figure 2.02**. Based on the groundwater level data collected for the proposed road development the southern boundary of the GWDTE Lough Corrib Fen 2 GWB on the GSI GWB map is set 0.3km too far south. Based on the water level data for the proposed road development the GWB extent has been updated and is shown in **Figure 5.02**.

The extent of the GWB overlaps with part of the Lough Corrib cSAC as shown in **Figure 5.02**.

Although the proposed road development does not extend into this GWB (**Figure 5.02)** the divide between it and the adjacent GWDTE Lough Corrib Fen 1 GWB lies in close proximity to it. On this basis this GWB is considered as one of the GWB traversed by the proposed road development.

The seasonal fluctuation in the GWB is of the order of 2.5m (RC133) as shown in **Table 3.** Based upon the mapping of the groundwater levels the groundwater divide remains static and does not migrate seasonally.

GWDTE Lough Corrib Fen 2 GWB contributes directly to Lough Corrib cSAC and Lough Corrib SPA. As the River Corrib discharges into Galway Bay this GWB also contributes (indirectly) to Galway Bay Complex cSAC and Inner Galway Bay SPA.

4.2.4 GWTDE Lough Corrib Fen 3 and 4 Groundwater Body

Based on groundwater level data collected for the proposed road development, the southern extent of the GSI GWDTE Lough Corrib Fen 3 and 4 GWB has been reduced and been moved north by over 2km. As such, the proposed road development does not cross nor is adjacent to the Lough Corrib Fen 3 and 4 GWB.

Lough Corrib Fen 3 and 4 GWB contributes to Lough Corrib cSAC and Lough Corrib SPA, however, the GWB does not have the potential to be impacted by the proposed road development as it is up gradient and 2km distant of the proposed road development.

4.2.5 Clare-Corrib Groundwater Body

The GSI mapping of the GWB is shown in **Figure 2.02**. Based on the groundwater level data collected for the proposed road development, the extent of the Clare-Corrib GWB has been revised with its boundary extending further west, as far as the townland of Coolough, near Menlough, and further east to the N83 Tuam Road **(Figure 5.02)**.

One European site, Lough Corrib cSAC, extends onto the western extents of the GWB (**Figure 5.02**). Ballindooley Lough is located within the GWB and although it is not designated as a European site, it supports wintering bird species listed as Special Conservation Interests (SCIs) of both Lough Corrib SPA and Inner Galway Bay SPA (which may be linked to the SPA populations), and as such is also considered in this section.

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

Analysis of the groundwater data shows that the groundwater at Ballindooley Lough lies up gradient of the proposed road development. The data also shows the lough to be perched during the summer when groundwater levels drop below the lake water level (**Plate 6** and **7**). On this basis, during low groundwater levels the perched water in Ballindooley Lough and the groundwater in the aquifer form separate and distinct water bodies. Based on groundwater levels the Clare Corrib GWB may be divided into sub catchments, west and east of Ballindooley Lough as well as the area between the River Corrib and Terryland River as shown on **Figure 5.02**.

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

Ballindooley Lough from the proposed road development could only arise when groundwater levels are high during winter.

Bathymetry of Ballindooley Lough shows that the lake has a max depth of 10m

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

Plate 6: Schematic east west cross-section through Ballindooley Lough showing the interaction of groundwater with the lake during high groundwater levels

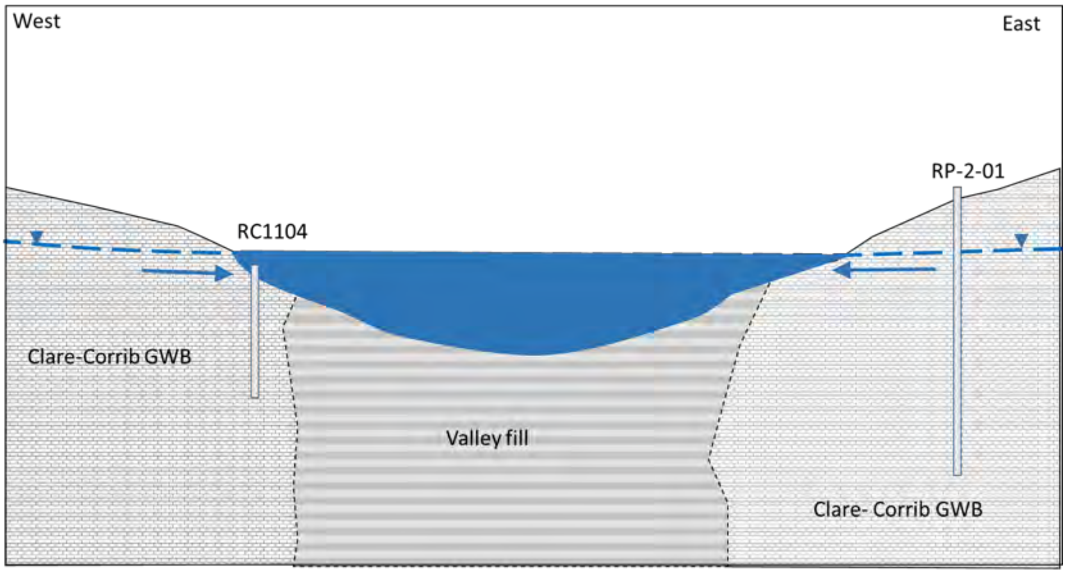
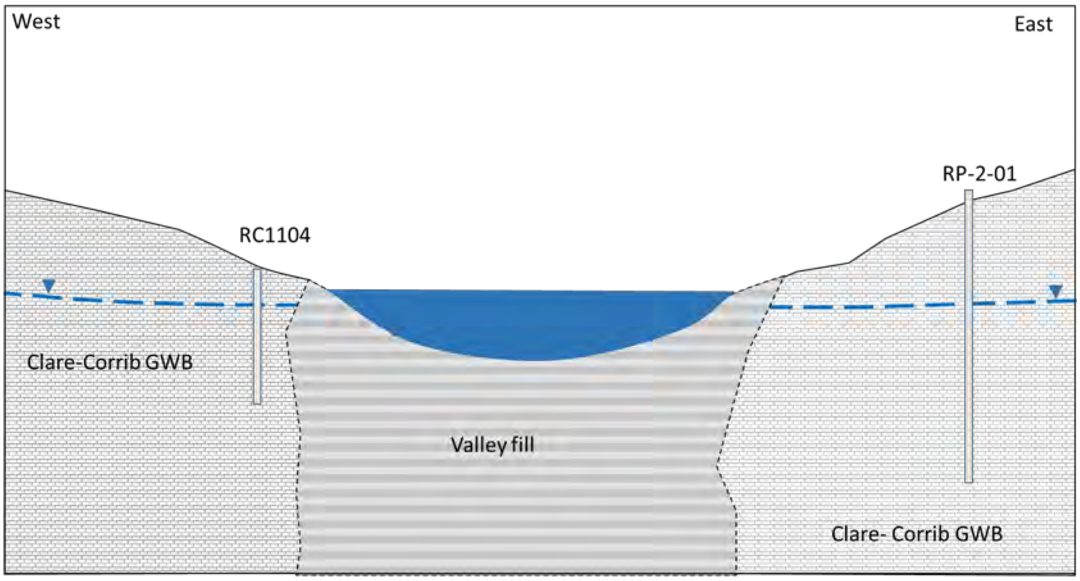
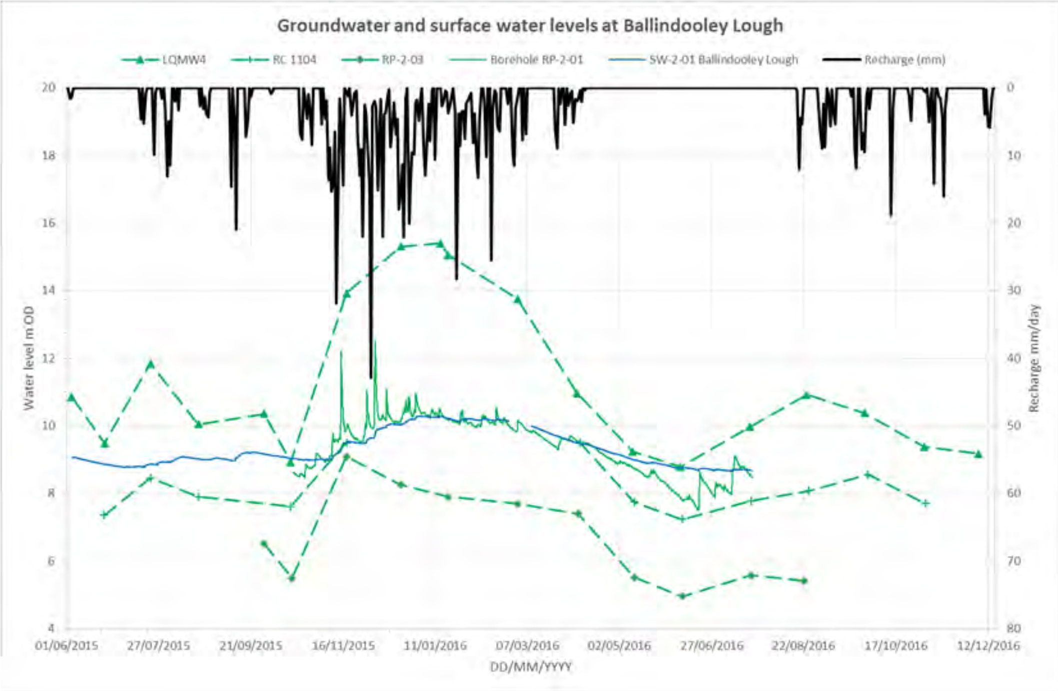


Plate 7: Schematic east west cross-section through Ballindooley Lough showing the interaction of groundwater with the lake during low groundwater levels



The hydrographs for the Clare-Corrib GWB below in **Plate 8** show that the groundwater level in wells surrounding Ballindooley Lough are continuous with the level of Ballindooley Lough during the winter. However, in the summer the groundwater level lowers below the permanent water level of the lough perching above it. Also notable are the groundwater levels in monitoring well RP-2-03 which are significantly lower than other groundwater levels in the area and the surface water level at Ballindooley Lough. The lower water table in RP-2-03 indicates the direction of flow southwards within the groundwater body.

Plate 8: Groundwater and surface water levels at Ballindooley Lough



Clare - Corrib GWB contributes directly to Lough Corrib cSAC and Lough Corrib SPA. As the River Corrib discharges into Galway Bay this GWB also contributes (indirectly) to Galway Bay Complex cSAC and Inner Galway Bay SPA.

4.2.6 Clarinbridge Groundwater Body

The Clarinbridge GWB as delineated by the GSI is a large groundwater body that extends from Galway City eastwards past Galway Airport to Athenry and then south from Athenry to Clarinbridge and as far south as Ardrahan. As the Clarinbridge GWB extends over a number of rivers and streams it can be subdivided into several smaller groundwater bodies that are distinct and isolated from each other. One of the sub-catchments of the Clarinbridge GWB is the area between the N83 Tuam Road and the existing N6 Coolagh Roundabout, which is restricted to the higher ground between Galway Airport and Ballybrit. Of note is that this area does not include any significant karst landforms.

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

The groundwater level monitoring data collected in the Clarinbridge GWB for the proposed road development has a shallow water table relative to the rest of the study area. The shallow groundwater table is generally within 4m of the surface and follows the topography, lowering southwards towards Galway Bay. The seasonal fluctuation in the aquifer is of the order of 1m to 2m. The characteristics of the Visean Undifferentiated Limestone at Briarhill indicate lower aquifer properties, with fracture flow present but no conduit flow indicated or karst landforms present.

The Clarinbridge GWB at Briarhill contributes groundwater to Galway Bay, although the lack of karst in the local area indicates that there are no significant pathways. As a contributor to Galway Bay the Clarinbridge GWB at Briarhill contributes to Galway Bay Complex cSAC and Inner Galway Bay SPA.

4.2.7 Summary

In summary, the proposed road development traverses the following groundwater bodies which support GWDTE in Lough Corrib cSAC, Lough Corrib SPA, Galway Bay Complex cSAC or Inner Galway Bay SPA:

- Spiddal
- Maam – Clonbur
- Ross Lake
- Lough Corrib Fen 1 (Menlough) and Lough Corrib Fen 1 (Lackagh)
- GWDTE Lough Corrib Fen 2
- Clare-Corrib
- Clarinbridge

A breakdown of the contributions from groundwater bodies traversed by the proposed road development that contribute to European sites are summarised below in **Table 4.**

Table 4: Summary of groundwater bodies traversed by the proposed road development that contribute to European sites

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

Groundwater Body	Lough Corrib cSAC	Lough Corrib SPA	Galway Bay Complex cSAC	Inner Galway Bay SPA
Clarinbridge GWB	-	-	Contributes	Contributes

5 Evaluation of Impacts

The potential impacts from the proposed road development to groundwater bodies that support groundwater dependant terrestrial ecosystems (GWDTE) within European sites are presented in this section of the report. Those groundwater bodies with the potential to be impacted are detailed above in **Section 4.**

5.1 Assessment Methodology

The potential impacts to groundwater bodies from the proposed road development are considered under construction and operation phase impacts. The potential impacts within the hydrogeological zone of influence (ZoI) from the construction phase are presented in **Section 5.1** and those from the operation phase are presented in **Section 5.2**. The hydrogeological ZoI during the construction phase for the proposed road development is shown on **Figures 6.01** and **6.02** and **Figures 7.01** to **7.02** for the operational phase.

The characteristics which determine the ZoI and in turn informs the potential impacts are:

- The proximity to the groundwater body that supports the GWDTE at the European site
- Hydraulic connectivity between the proposed road development and the groundwater bodies supporting GWDTE at European site
- The groundwater flow direction in the vicinity
- The seasonal fluctuation in groundwater level
- The water quality of the feature and the groundwater from which it receives its baseflow
- The level of excavation (whether in a road cutting or tunnel) of the proposed road development relative to the seasonal fluctuation in the groundwater table
- The activities during the construction and operational phases of the proposed road development that have the potential to pollute

Potential impacts on groundwater quantity are calculated based on the drawdown extent for those sections of the proposed road development that require dewatering of the bedrock aquifer. The drawdown extent is presented as a ZoI for both the construction and operation phases of the proposed road development. For potential water quantity impacts from dewatering of the bedrock aquifer the ZoI is presented as a radius on either side of the proposed road development that takes into account the aquifer properties and the hydraulic gradient.

Potential water quality impacts occur from pollutants, which differ between the construction and operation phases of the proposed road development. The potential of pollution of groundwater is assessed based on TII HD45/15 guidelines. The Geology Survey of Ireland provides guidance on aquifer classification and groundwater vulnerability both of which are part of the HD45/15 groundwater response matrix for the use of permeable drains in road schemes, presented below in **Table 5**. The groundwater protection response (GPR) is specific to the use of permeable drains in road schemes and does not deal with spillages.

Table 5: Groundwater response matrix for the use of permeable drains in road schemes (TII, HD45/15, 2015)

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

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

Groundwater vulnerability assesses the geological and hydrogeological characteristics of the subsoil overlying the aquifer and provides a rating response and these are presented below in **Table 6**. The GSI have a distinction between extreme vulnerability with bedrock at surface (X) and extreme vulnerability with subsoil being 0-3m thick (E) that is not presented in the groundwater vulnerability summary table. This distinction between extreme (X) and extreme (E) is shown in the TII HD45/15 GPR.

Table 6: Groundwater vulnerability summary (Geological Survey of Ireland)

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

Notes: (1) N/A = not applicable.
(2) Precise permeability values cannot be given at present.
(3) Release point of contaminants is assumed to be 1-2 m below ground surface.

Groundwater flows can be more complex in limestone than granite due to karst pathways and the ground investigation data includes aquifer testing of both rock types to calculate their range of hydraulic conductivity. The aquifer testing is presented in **Plate 9** below for granite and limestone. This data shows that whilst the granite has a relatively narrow range of values, the limestone spans a significantly wider range. For the limestone areas, this data (as well as the spatial distribution of karst features) is used to identify those areas where karst flow paths through the aquifer are likely but also areas where such pathways are not present. These assessments are based on a combination of trial pits, window samples, drilling, surface geophysical surveys, pumping test and groundwater monitoring and interpretation.

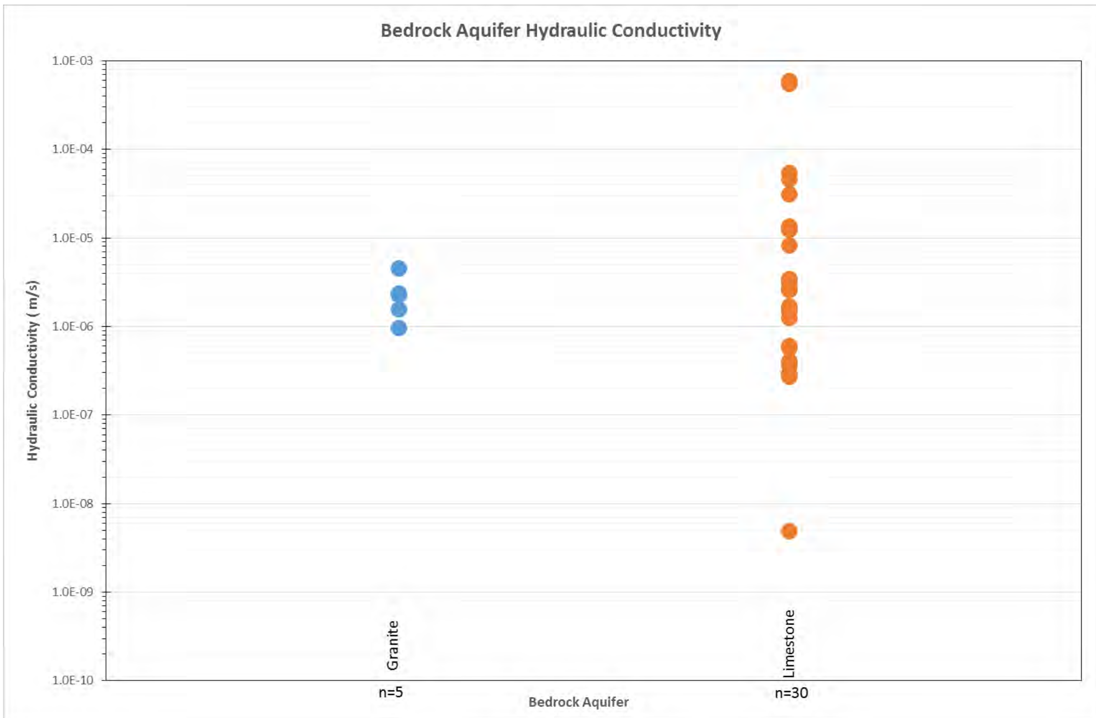
The karst survey (**Figure 1.01 and 1.02**) undertaken is used as an indicator that karst pathways are present within groundwater bodies. The observation of conduit flow at Western Coolagh Spring (K25) data and relative abundance of karst features in the area are indicative that karst pathways are likely within Lough Corrib Fen 1 (Menlough) GWB. Similarly, the karst survey identifies karst landforms across the Clare-Corrib GWB, which is also likely to have conduit pathways in the GWB. However, the karst survey has discounted all significant karst landforms in the footprint of the proposed road development in the Clarinbridge GWB between the N83 Tuam Road and the existing N6 Coolagh Roundabout. Features up gradient at K172, 175 and 179 were not found and are likely abandoned dug wells. The only karst features noted are springs K126 and K132, which lie 1km down gradient of the proposed road development.

Aquifer testing data also shows the distribution of hydraulic conductivity values measured at monitoring well locations along the proposed road development (**Plate 1**). **Plate 9** below shows the distribution of hydraulic conductivity and **Table 7** shows the distribution for both granite and limestone. This data shows that those groundwater bodies that do not have karst, the Galway Granite Batholith and the Clarinbridge GWB, have a relatively narrow range of hydraulic conductivity. In contrast the Visean Undifferentiated Limestone has significant karst in the Lough Corrib Fen 1 (Menlough) GWB, the GWDTE Lough Corrib Fen 2 GWB and the Clare-Corrib GWB. In these areas where karst is present the range of hydraulic conductivity is wider. Notably the maximum hydraulic conductivity is an order of magnitude higher (**Table 7**).

Table 7: Distribution of calculated hydraulic conductivity

Geological Unit	GWB	Min hydraulic conductivity m/s	Max hydraulic conductivity m/s
Galway Granite Batholith	Spiddal Maam - Clonbur	9.7×10^{-7}	4.6×10^{-6}
Visean Limestone Undifferentiated	Lough Corrib Fen 1 (Menlough) Clare-Corrib	5.0×10^{-9}	3.1×10^{-5}
Visean Limestone Undifferentiated	Clarinbridge	4.2×10^{-7}	1.7×10^{-6}

Plate 9: Distribution of calculated hydraulic conductivity.



The Galway Granite Batholith is 2,378km^2 (2,378,000,000m^2) in size (GSI Groundwater data viewer) and 1,000m thick (Pracht, 2015), giving an aquifer volume of 2,378,800,000,000m^3. A total of 905,345m^3 of granite will be excavated for the construction of the proposed road development. This volume is a very small percentage of the aquifer volume and for this reason there will be no significant impact to the hydrogeological regime of a European site from the removal of granite.

The Visean Undifferentiated Limestone is 7,062km^2 (7,062,000,000m^2) in size (GSI Groundwater data viewer) and 400m thick (Pracht, 2015), giving an aquifer volume of 2,824,800,000,000m^3. A total of 2,096,175m^3 of limestone will be excavated for the construction of the proposed road development, which is a very small percentage of the aquifer volume. There will be no significant impact to the hydrogeological regime of a European site from the removal of limestone.

5.2 Construction Phase

The hydrogeological zone of influence (ZoI) is the maximum area where there is a potential hydrogeological impact from the proposed road development. Impacts to groundwater quantity are caused by dewatering of the bedrock aquifer in excavations for construction of structures, tunnels and cuttings. Impacts to groundwater quality are caused by infiltration of contaminants to ground from the construction of the proposed road development. Groundwater at risk of potential pollution occurs as an area down gradient from pollutant sources.

5.2.1 Potential Impacts to Groundwater Flow

Potential impacts to groundwater flow are primarily caused by dewatering of the bedrock aquifer but impacts can also occur where groundwater pathways, specifically conduits in karst, are intercepted and modified by the proposed road development. The impact assessment below mainly deals with dewatering of the bedrock aquifer impacts but where there is a risk of a pathway interception this is identified and assessed.

The construction drawdown ZoI, calculated as a radius from excavations along the proposed road development, is presented below in **Table 8.** The ZoI is calculated based on the upper range of properties determined for each aquifer and the radius of this ZoI (radius of influence) is calculated from the proposed road cutting face or drain that groundwater emerges from.

The calculations below for the radius of influence for dewatering of the bedrock aquifer impacts are based on the design of the proposed road development, which includes construction dewatering of the bedrock aquifer at the following locations:

- Interception of groundwater for cuttings in the Galway Granite Batholith, with groundwater discharged to surface watercourses
- The cutting at EW27 may encounter groundwater seasonally during peak groundwater levels in the Visean Undifferentiated Limestone. The design includes drainage to intercept and carry groundwater away from the construction for discharge in the same groundwater body
- The Galway Racecourse Tunnel and its approaches will include dewatering of the Visean Undifferentiated Limestone. The construction drainage will intercept and carry groundwater away from the construction for discharge in the same groundwater body

Table 8: Summary of the drawdown ZoI at earthwork (EW) locations from dewatering of the bedrock aquifer during construction (pre-mitigation measures)

Feature type	Earth works Ref no.	Approx. Chainage	Length (m)	Max depth of finished road level (m BGL)	Max depth of construction excavation (m BGL)	Depth to peak winter groundwater level (m BGL)	Max groundwater drawdown (m)	Maximum Zone of influence radius (m) from footprint of the proposed road development
Galway Granite Batholith– R336 to N59 Moycullen Road								
Road Cutting	EW01	0+000 – 0+500	500	1.3	4.3	1.1	3	15
Road Cutting	EW02	1+150 – 1+350	200	0.9	3.9	1.9	2	9
Road Cutting	EW02	1+600 – 1+950	350	1.0	4.0	1.1	3	14
Road Cutting	EW02	2+230 – 2+640	410	3.1	6.1	3.6	2	12
Road cutting	EW04	3+100 – 4+080	980	5.9	8.9	1.5	8	35
Road cutting	EW07	5+250 – 5+580	330	5.3	8.3	3.4	5	23
Road Cutting Letteragh Junction	EW11	7+600 – 8+280	690	14.4	17.4	5.7	12	54
Visean Undifferentiated Limestone - River Corrib to existing N6 Coolagh, Briarhill								
River Corrib Structure	EW15	9+300 – 9+500	200	(Above ground)	(Above ground)	(Above ground)	0	0

Feature type	Earth works Ref no.	Approx. Chainage	Length (m)	Max depth of finished road level (m BGL)	Max depth of construction excavation (m BGL)	Depth to peak winter groundwater level (m BGL)	Max groundwater drawdown (m)	Maximum Zone of influence radius (m) from footprint of the proposed road development
Menlough Viaduct	EW17	9+500 – 10+100	600	(Above ground)	(Above ground)	(Above ground)	0	0
Western Approach to Lackagh Tunnel	EW19	10+810 – 11+140	350	13.5	16.5	12.2	0	0
Lackagh Tunnel	EW20	11+140 – 11+420	270	Drill & Blast Mined tunnel	Drill & Blast Mined tunnel	Drill & Blast Mined tunnel	0	0
Road Cutting	EW22	11+720 – 11+920	200	24.6	27.6	35.5	0	0
Road Cutting	EW25	12+500 – 12+920	370	7.6	10.6	15.6	0	0
Road cutting	EW27	13+050 – 13+650	600	12.0	15.0	12.1	3	70
Road cutting	EW28	14+150 – 14+450	300	12.3	15.3	18.6	0	0
Western Approach to Galway Racecourse Tunnel	EW30	14+450 – 14+950	500	11.4	14.4	18.5[*5]	2	14

Feature type	Earth works Ref no.	Approx. Chainage	Length (m)	Max depth of finished road level (m BGL)	Max depth of construction excavation (m BGL)	Depth to peak winter groundwater level (m BGL)	Max groundwater drawdown (m)	Maximum Zone of influence radius (m) from footprint of the proposed road development
Galway Racecourse Tunnel	EW31	14+950 – 15+190	240	9.2	12.2	8.9	4	35
Eastern Approach to Galway Racecourse Tunnel	EW32	15+190 – 15+500	310	8.7	11.7	7.8	4	35
Road Cutting	EW34-35	16+200 – 17+500	740	6.8	9.8	11.9[*6]	2	12

Notes:

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

The maximum depth of proposed road level refers to the finished road level. Structures will require excavation to a maximum depth of 3m below road level for installation of drainage and dewatering sumps/trenches.

5.2.1.1 Galway Granite Batholith

As shown in **Table 8** above, there are seven cuttings in the Galway Granite Batholith namely, EW01, EW02 (three cuttings), EW04, EW07 and EW11. Using the maximum groundwater levels for each location these seven cuttings have the potential to intersect the groundwater table locally. EW11 has the largest ZoI with drawdown extending up to 54m laterally from the footprint of the proposed road development.

Using the aquifer properties shown in **Table 7**, the construction drawdown ZoI within the Galway Granite Batholith will yield low volumes of groundwater. As the groundwater divides in the Galway Granite Batholith follow topography and the surface water divides, all groundwater intercepted by collection drains will remain within the stream catchments that they would naturally have been received by.

Construction dewatering in the Galway Granite Batholith will locally lower groundwater levels in cuttings where dewatering of the bedrock aquifer is required. As groundwater is managed within the local surface water catchments that they would naturally drain to there will be no net change in the groundwater contribution to surface water receptors. On this basis there will be no impact on the quantity of groundwater received by European sites.

The pre-mitigation construction impacts for the proposed road development for the Galway Granite Batholith are presented in **Figure 6.01.**

5.2.1.2 Visean Undifferentiated Limestone

As shown in **Table 8** above, there are fifteen earthworks in the Visean Undifferentiated Limestone with excavations required during construction. Inferring between the maximum groundwater levels presented in **Table 8** then nine of these earthworks have the potential to intersect the groundwater table locally. These include the piers of the River Corrib Bridge and Menlough viaduct, four road cuttings (EW27, EW29, EW34 and EW35), three tunnel approach cuttings (EW19, EW30 and EW27) and two tunnels (EW20 Lackagh Tunnel and EW31 Galway Racecourse Tunnel).

Of the earthworks in the Visean Undifferentiated Limestone, those between EW15 and EW27 have the potential to intersect karst, as well as side roads at Ard Na Locha, N59 Moycullen Road and Aughnacurra. Karst may also be intersected during the excavation of infiltration basins located on GWBs with the potential for karst, those infiltration basins that have the potential to intercept karst comprise of S19a, S19b, S21a, S21b and S22a. All of these listed features occur in the Lough Corrib Fen 1 (Menlough) GWB and the Clare-Corrib GWB. If karst is intercepted in any of these earthworks or infiltration basins excavations, then there is a risk that without mitigation there could be point input of runoff (such as a doline) from the construction site directly to the aquifer. Measures for mitigating against karst features is dealt with in **Section 6**. Earthworks and infiltration basins located within the Clarinbridge GWB are not considered to have the potential to encounter karst and as such do not have this risk.

The River Corrib Bridge (EW15) is included in the list of earthworks as excavations will be required on the east and west banks to install piers. These excavations will extend below the groundwater table and will require dewatering of the bedrock aquifer for dry working conditions. Due to their close proximity to the River Corrib the groundwater and surface water is in continuity. As the excavations occur on the margin of the Lough Corrib Fen 1 (Menlough) GWB and Ross Lake GWB, the potential for impact is only to the groundwater contribution to the River Corrib and not to Coolagh Lakes. Mitigation will be required to ensure that groundwater flow paths to the River Corrib will not be impacted, refer to **Section 6**.

The Menlough Viaduct (EW17) is included in the list of earthworks as although the structure lies above ground, excavation of subsoil and weathered limestone may be required to found the piers on competent rock. Based on the construction design the excavation footprint will be kept as small as possible, with the foundation depth kept close to ground level. No dewatering of the bedrock aquifer will be undertaken during construction of the bridge piers for the Menlough Viaduct. Concrete will need to be poured as part of the construction of the piers and there is a risk that concrete may enter the aquifer if karst is present in the foundation excavations, which could block pathways and modify the contribution of groundwater to European sites. As a result, there is a potential impact on the quantity of groundwater flow to European sites. Measures have been developed to mitigate these impacts and these are presented in **Section 6**.

The Western Approach to Lackagh Tunnel (EW19) and Lackagh Tunnel (EW20) are located at the groundwater divide between Lough Corrib Fen 1 (Menlough) and Clare-Corrib GWBs. Dewatering of the bedrock aquifer is not included as part of the design owing to the sensitivity of the groundwater divide, specifically for the surface area for the Lough Corrib Fen 1 (Menlough) GWB on which the Western Coolagh Spring and therefore the Coolagh Lakes (part of the Lough Corrib cSAC) are dependent on.

Dewatering of the bedrock aquifer will not be permitted during the construction of EW19 and EW20 so there is no reduction in groundwater flow transmitted by these pathways through the aquifer to the GWDTE. This will also maintain the boundary between Clare-Corrib GWB and Lough Corrib Fen 1 (Menlough) GWB and Lough Corrib Fen 1 (Lackagh) GWB. All construction works will remain above the groundwater table for the duration of the works to ensure the groundwater table is not intercepted and dewatering of the bedrock aquifer is not required. The construction schedule will be tailored so that the excavation of the lower section will occur only during the groundwater low when the water table is below the construction level.

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

The Western Approach to Lackagh Tunnel (EW19) and Lackagh Tunnel (EW20) are discussed in further detail in Appendix F of the NIS.

Cutting EW27 lies west of the N83 Tuam Road in a cutting through Visean Undifferentiated Limestone. The groundwater levels in this part of the Clare-Corrib

GWB show a seasonal variation of 9m (ref BH3/34). Groundwater has the potential to enter the cutting during peak winter water levels only. Groundwater will be controlled within the excavation by collection in drains or sumps. If groundwater is intercepted, it will be piped and discharged at an infiltration basin within the same GWB. This is shown in **Figure 6.02** and represents the maximum drawdown based on construction during peak groundwater conditions. Potential impact from the dewatering of the bedrock aquifer is localised around the cutting, as the intercepted groundwater is controlled and infiltrates back to the same groundwater body there is no impact on the groundwater support to a European sites.

Within the Clarinbridge GWB, the aquifer properties (specifically hydraulic conductivity) are low for a limestone classified as regionally important (Rkc) by the GSI. The characteristics shown in **Table 5** are indicative of a locally important aquifer rather than regionally important aquifer. There are four earthworks in the Clarinbridge GWB that will intercept groundwater. These comprise of two cuttings (EW34 and EW35), the Galway Racecourse Tunnel (EW31) and its eastern and western approaches (EW30 and EW32 respectively). Construction dewatering of the bedrock aquifer at the western portal and approach will be required during peak groundwater levels only, whilst the construction dewatering of the bedrock aquifer at the eastern portal will be required during summer and winter.

The impact from construction dewatering of the bedrock aquifer at EW30, EW31, EW32, EW34 and EW35 is calculated based on the aquifer properties measured at the Briarhill area of the Clarinbridge GWB, which have been measured as lower than the properties of the other GWBs in the Visean Undifferentiated Limestone traversed by the proposed road development. All groundwater abstraction required for construction will be piped eastwards along the alignment of the proposed road development and discharged to existing storm sewer or infiltration basins designed for the operation phase of the proposed road development. Based on the ZoI, **Figure 6.02** shows the maximum impact from construction dewatering of the bedrock aquifer at EW29, EW, EW27 and EW29. All intercepted groundwater will be piped away from the cuttings to infiltration basins within the same GWB. Construction dewatering in the Clarinbridge GWB will not impact on the quantity of groundwater contribution to European sites.

5.2.1.3 Summary of Potential Impacts to Groundwater Flow

In summary, potential impact to groundwater flow paths may occur due to construction dewatering of the bedrock aquifer or from karst encountered in excavations. Where karst is encountered during construction then there is a risk of increased point input to groundwater via the karst feature which could increase or reactivate flow paths in the aquifer that had been sediment filled. There is also a risk of conduit pathways becoming blocked if excavations encounter karst and concrete is poured as part of the construction. Encountering karst is dealt with as a mitigation measure which is discussed in **Section 6**. No groundwater impacts are predicted where karst is not present.

Drawdown impacts may occur at specific locations along the proposed road development where dewatering of the bedrock aquifer will occur. These dewatering locations are summarised below:

- The groundwater table of the Galway Granite Batholith will be intersected in earthworks EW01, 02 (three cuttings), 04, 07 and 09. Groundwater intercepted will be collected and piped to the surface water receptor it would naturally have drained to. By maintaining groundwater collection and discharge within the same surface water catchments there will be no net change in the groundwater contribution in the Galway Granite Batholith to receiving waters. On this basis there will be no impact on the groundwater flow rates to European sites.
- The Menlough Viaduct will have no dewatering of the bedrock aquifer associated with its construction. As a result there will be no reduction in groundwater flow rates due to dewatering to a European site.
- As part of the design of the proposed road development there will be no dewatering of the bedrock aquifer undertaken at Lackagh Tunnel or its approaches, furthermore the construction sequence will take into account the seasonal groundwater fluctuation. During the winter groundwater high it may be necessary to limit the depth of works so that dewatering of the bedrock aquifer is not required. As there is no dewatering of the bedrock aquifer at Lackagh Tunnel and given that the construction will be restricted to above the water table during peak groundwater levels there will be no dewatering impact to groundwater flow rates that contribute to European sites.
- Construction dewatering of the bedrock aquifer may seasonally be required in EW27 during peak groundwater levels. Any dewatering will be discharged to the same GWB. As there is no net change in groundwater flow within the GWB there will be no dewatering impact to groundwater flow rates that contribute to European sites.
- Construction of the Galway Racecourse Tunnel and its approaches will require dewatering of the bedrock aquifer. All groundwater intercepted will be managed and discharged within the same GWB so that there is no net change in the groundwater contribution to receiving waters. The construction of the Galway Racecourse Tunnel and its approaches will have no dewatering impact to groundwater flow rates that contribute to European sites.

Construction dewatering of the bedrock aquifer for the proposed road development has been assessed and based on the ZoI the construction dewatering of the bedrock aquifer required as part of the proposed road development will have no impact on the groundwater flow within groundwater bodies that support European sites. Where concrete is to be used in construction excavations, such as for the Menlough Viaduct, Lackagh Tunnel and its western approach there is a risk that if karst is encountered that the pouring of concrete could lead to conduit pathways becoming blocked. There is also a risk that if karst is encountered in excavations that these could lead to point inputs of surface water runoff, which could increase the flow through existing conduits or reactivate conduits that had been naturally sealed by sediment. Measures to deal with karst intercepted in excavations is covered in **Section 6 Mitigation**.

5.2.2 Potential Pollution Impacts

This section presents the potential groundwater quality impacts from the construction phase of the proposed road development to European sites. The assessment follows HD45/15 'Road Drainage and the water Environment', which provides guidance on assessing potential impacts. The assessment takes into account the potential pollutants, groundwater vulnerability and the aquifer classification.

As presented in HD45/15 regarding construction impacts, '*The prime concern is generally the mobilisation of suspended solids but spillage of fuels, lubricants, hydraulic fluids and cement may lead to incidents especially where there are inadequate mitigation measures*.' Based on the HD45/15 guidelines the potential pollutants that could impact on groundwater quality during the construction phase are listed below:

- Runoff across surfaces stripped of vegetation
- Spillages of fuels, lubricants, hydraulic fluids and cement (accidental or by vandalism)
- Pouring of concrete for structures
- Discharge from infiltration basins

The potential impacts from these potential pollutants are assessed below for both the Galway Granite Batholith and the Visean Undifferentiated Limestone.

5.2.2.1 Galway Granite Batholith

The Geological Survey of Ireland data classifies recharge for the Galway Granite Batholith at 100mm/yr. which equates to a very low recharge coefficient of less than 10%. Based on the GSI recharge quantification, the GSI classification of poor aquifer and well testing undertaken for this assessment (Refer to **Table 5)**, then the hydraulic conductivity of the Galway Granite Batholith and the rate of infiltration through the overlying subsoils are very low.

GSI Groundwater vulnerability for the Galway Granite Batholith varies between extreme (X) and moderate (M). The ground investigation data collected for proposed road development confirms the vulnerability range presented by the GSI. Whether extreme or moderate the limit of recharge equates to approximately 100mm/yr. which is limited by the aquifer properties of the granite rather than the vulnerability.

The GSI aquifer classification of the granite as a poorly productive (Pl) indicates that there may be localised flow paths where faulting is present but based on the characteristics of the rock these flow paths will be limited in their extent. The GSI describe groundwater bodies in granite as typically having a maximum flow path of 100m, which is also supported from the ground investigation undertaken for the proposed road development. On this basis the length of a pathway in any local productive zones of the Galway Granite Batholith is 100m.

Of the pollutants listed above suspended solids in site runoff is the prime concern, with pollution from spillages also being a risk. As the Galway Granite Batholith does not include karst and due to any pathways being limited to 100m in length the pouring of concrete at structures is not considered a potential pollutant.

Furthermore, the proposed road development does not include infiltration basins on the Galway Granite Batholith.

On the basis of the above hydrogeological characterisation there is a risk of suspended solids in site runoff and spillages potentially impacting on groundwater quality during construction. Based on the recharge cap of 100mm more than 90% of the runoff will remain as overland flow and not recharge to ground. Of the runoff that does recharge to ground, the restricted nature of the pathways and low flow rate with promote settlement rather than transport. On this basis high turbidity runoff across outcrop of the Galway Granite Batholith will be limited to the construction footprint with a maximum of 100m down gradient of the site if any local groundwater pathways are encountered. For spillages, accidental or by vandalism, the low infiltration rate will promote runoff rather than infiltration. Pollutants that do infiltrate to ground will have limited mobility and will be limited to the construction footprint with a 100m buffer. Mitigation measures are detailed in Appendix B Hydrology of the NIS for the clean-up and remediation of any spills. The zone of influence for construction phase pollution risk is presented for the Galway Granite Batholith in **Figure 6.01.**

As groundwater quality impacts are restricted to within 100m of the construction footprint there will be no groundwater quality impacts to European sites on the Galway Granite Batholith. Surface water impacts from runoff are covered in Appendix B Hydrology of the NIS.

5.2.2.2 Visean Undifferentiated Limestone

The GSI classify the Visean Undifferentiated Limestone as being a regionally important karst aquifer in the Galway region. However, the hydrogeology of the aquifer based on the desk study and ground investigation undertaken for the proposed road development (**Section 4.2**) has identified that the Visean Undifferentiated Limestone in the section between the N83 Tuam Road and existing N6 does not include karst (refer to **Section 4.2.6**) and also has lower aquifer properties. This section of the proposed road development comprises of the Clarinbridge GWB.

On the basis of the hydrogeological characterisation the Visean Undifferentiated Limestone has been divided into two aquifer types, a regionally important karst aquifer (Rkc) and a locally important aquifer productive in local zones (Ll). Flow in the Visean Undifferentiated Limestone is typically by fracture flow, with conduit flow in the part of the aquifer where karst is present.

The groundwater bodies (GWB) that have karst present are Ross Lake GWB, Lough Corrib Fen 1 (Menlough) GWB, GWDTE Lough Corrib Fen 2 GWB and Clare-Corrib GWB. Where karst occurs there is a risk that the natural dilution and attenuation in the aquifer may be bypassed by flow in a conduit. This is a concern if karst is encountered in excavations for the proposed road development and is a concern for all of the potential pollution sources listed above.

Each of the potential pollutants are assessed below individually for the groundwater bodies that have the regionally important (Rkc) and locally important (Ll) Visean Undifferentiated Limestone.

Site runoff

The Visean Undifferentiated Limestone has a high recharge coefficient when karst is present and in these areas site runoff generally recharges to ground rather than becoming overland flow. As such, those groundwater bodies that include karst and which the proposed road development traverses, namely Ross Lake GWB, Lough Corrib Fen 1 (Menlough) GWB, GWDTE Lough Corrib Fen 2 GWB and the Clare-Corrib GWB have high recharge rates and no surface water features. Surface water features such as Coolagh Lakes and Ballindooley Lough, which are located near these GWB have been demonstrated to lie on areas of buried valleys where there is a significant thickness of low permeability subsoil.

In the Clarinbridge GWB there are no recorded karst features but there is significant surface water ponding and overland flow during storm events, which is due to the lower recharge rates that are present in this area (refer to **Section 4.2.6**). The contrast between the Clarinbridge GWB and the other limestone GWB demonstrate the difference in recharge rates between karst and non karst limestone. Both limestones have fracture flow but the capacity of the pathways in karst limestone allow it to be free draining, which generally leads to a thicker unsaturated zone and deeper groundwater table

The primary permeability of the limestone (both karst and non-karst) is characteristically low with the only significant infiltration occurring along the secondary permeability along fractures or zones of weathering. In the natural environment, recharge to limestone where there is no karst relies in part on storage in the overlying subsoil which provides superficial storage to the fracture flow network in the underlying limestone. In the situation where the subsoil is removed there is an increase in overland flow with recharge significantly reduced. As such, where the limestone bedrock is exposed in all GWB there will be an increase in runoff. Exceptions to this are zones of weathered limestone, karst (in those GWB with karst) or the fill of buried valleys where they are encountered. Weathered limestone will lead to an increase in diffuse recharge, karst will lead to dominant point recharge and areas of thick low permeability subsoil will lead to overland flow.

For the Ross Lake GWB, Lough Corrib Fen 1 (Menlough) GWB, GWDTE Lough Corrib Fen 2 GWB and Clare-Corrib GWB the runoff from the construction site will be managed on site, collected and treated prior to disposal by infiltration basins. Details on the infiltration basins are presented in the Infiltration basins section below.

- If zones of thick subsoil are encountered within the footprint, then runoff will continue as overland flow. In these areas the groundwater will be protected from site runoff
- Diffuse recharge will occur within the construction footprint where thin subsoils or exposed bedrock occurs without karst. In these zones some runoff will infiltrate to ground by fracture flow or weathered limestone but the majority of the runoff will continue as overland flow. In these zones infiltration to ground will diffuse and provide slow pathways to the groundwater table that will naturally promote settlement of fines. In the groundwater there will be significant dilution and some attenuation of any fines. However, a low risk

remains and mitigation measures are required to manage runoff on site, which is presented in **Section 6**

- If karst is encountered, then there is a risk of point recharge and there is a risk of high suspended solids impacting on groundwater. Mitigation is required, which is detailed in **Section 6**

In the Clarinbridge GWB the pathways comprise of fracture flow or weather limestone rather than conduit flow. In these zones the majority of the runoff will continue as overland flow. Infiltration to ground will diffuse and provide slow pathways to the groundwater table that will naturally promote settlement of fines. In the groundwater there will be significant dilution and some attenuation of any fines. However, a low risk remains and mitigation measures are required to manage runoff on site, which is presented in **Section 6 Mitigation**.

Earthworks along the proposed road development include areas where the subsoil is removed leaving a reduced thickness of subsoil or exposing the underlying limestone. The removal of subsoil will reduce the natural protection for groundwater and increases the groundwater vulnerability (**Table 6)**.

The vulnerability rating for the existing environment along the proposed road development ranges from extreme to low. With extreme (X) occurring in areas where limestone bedrock is exposed and low in areas of buried valleys where the thicknesses of low permeability clayey subsoil is greater than 10m thick. For assessing the ZoI it is assumed that bedrock will be encountered with the extents of the proposed road development where is traverses the Visean Undifferentiated Limestone. In this regard the ZoI for pollution to groundwater extends over the full extent of the construction area.

For the Ross Lake GWB, Lough Corrib Fen 1 (Menlough) GWB, GWDTE Lough Corrib Fen 2 GWB and the Clare-Corrib GWB, where there is a potential for karst and point input of site runoff, the area at risk of pollution is extended over the full extent of the GWB downgradient of the proposed road development. For the Clarinbridge GWB where karst is not present, the area at risk of pollution encompass the full extent of the construction footprint with a further 100m buffer applied.

The area at risk for pollution is presented in **Figure 6.01** and **Figure 6.02**. The ZoI for those GWB, that have the potential for karst, has the potential to impact on groundwater quality contributing to European sites and for these GWBs mitigation of site runoff is required, which is detailed in **Section 6**. For the Clarinbridge GWB there is no significant karst and as such the hydraulic connectivity of the aquifer is limited and there will be no quality impact to the groundwater contribution of European sites.

Spillages of fuels, lubricants, hydraulic fluids and cement (accidental or by vandalism)

Spillages within the construction footprint pose a threat to groundwater quality. The mechanism for migration of the spillage from source is the same as the characteristics described in the site runoff section above. On this basis the potential area of pollution from spillages is the same as for site runoff and mitigation is required to manage spillages on site, which is presented in **Section 6.**

Pouring of concrete for structures

There is a risk specific to karst areas that if concrete is poured, for example with the foundations of bridge piers or lining of a tunnel, that concrete could be lost to ground and karst pathways blocked. Of the GWBs with karst there are three structures that have a risk to groundwater quality, namely the River Corrib Bridge, Menlough Viaduct and Lackagh Tunnel. This risk requires mitigation in order to prevent potential water quality impacts to groundwater that contributes to European sites. Mitigation is presented in **Section 6**.

Infiltration Basins

In the area of the Visean Undifferentiated Limestone there are few surface water features present. In the absence of surface water or storm water sewers the proposed road development incorporates infiltration basins during construction and operation phases for the discharge of treated runoff. Infiltration basins will be part of the initial works for the proposed road development to ensure that they are available for use at the earliest stage of construction.

The treatment of site runoff during construction includes a settlement pond prior to discharge via infiltration basin. The settlement ponds will be used for containment if an accidental fuel spillage occurs so that the polluted water can be contained and tankered off site for appropriate disposal.

As a design measure all infiltration basins have a minimum thickness of 2m of appropriate material overlying the excavated bedrock. Appropriate material is defined as per TII HD45/15 and will have a hydraulic conductivity of $1x10^{-5}$m/s. As per TII HD45/15 groundwater protection response, 2m of appropriate material has an extreme (E) vulnerability.

Reference is made to the TII HD45/15 groundwater protection matrix (**Table 5**). Based on the design of the infiltration basin the groundwater response is R3(2) as no karst landforms are located within 30m of the infiltration basin locations. In the case of karst being encountered in the excavation then without mitigation the groundwater response will be R4. Procedures are detailed in the section on mitigation measures in the case of karst features encountered in excavations (**Section 6**).

As there is potential for karst to be encountered in the Lough Corrib Fen 1 (Menlough) GWB, Lough Corrib Fen 1 (Lackagh) GWB and Clare-Corrib GWB, then the pre-mitigation potential area where impact on groundwater quality could occur is defined as being the full extent of the groundwater body downgradient of the proposed road development. Note there are no infiltration basins in either Ross Lake GWB or GWDTE Lough Corrib Fen 2 GWB (refer to **Figure 6.01** and **Figure 6.02**).

The Clarinbridge GWB does not have significant karst and as such the risk of then the area for water quality from infiltration basins with pre-treatment is assessed as being the unsaturated zone of the aquifer below the infiltration basin.

5.2.2.3 Summary of Potential Pollution Impacts

In summary, the zone of influence for pollution from the construction phase of the proposed road development has been assessed for the Galway Granite Batholith and Visean Undifferentiated Limestone:

- For the Galway Granite Batholith, the risk of contaminants polluting groundwater is restricted to untreated site runoff within the construction footprint of the proposed road development, with an additional buffer of 100m applied to accommodate local fracture flow where is occurs. There will be no water quality impacts to groundwater that contribute to European sites from the Galway Granite Batholith. Assessment of runoff impacts to surface water are presented in Appendix B Hydrology of the NIS.
- For the Visean Undifferentiated Limestone without karst, which comprises of the extent of the Clarinbridge GWB, the risk of pollution comes from untreated site runoff and spillages within the construction footprint. An additional buffer of 100m applied to accommodate any localised fractures that could include fracture flow paths. There will be no water quality impacts to groundwater that contribute to European sites from the Clarinbridge GWB. Runoff and spillage mitigation is presented in **Section 6.**
- For the Visean Undifferentiated Limestone with karst, which encompasses the Ross Lake GWB, Lough Corrib Fen 1 (Menlough) GWB, Lough Corrib Fen 1 (Lackagh) GWB, GWDTE Lough Corrib Fen 2 GWB and Clare-Corrib GWB the risk of contamination comes from untreated site runoff and spillages in the construction footprint of the proposed road development. The ZoI identified presents a risk to groundwater quality that contributes to European sites and mitigation is required, which is presented in **Section 6**.
- For the Visean Undifferentiated Limestone with karst there is a risk that where concrete is to be poured, such as River Corrib Bridge, Lackagh Tunnel and Menlough Viaduct that concrete grout may enter the aquifer and have a water quality impact on groundwater that contributes to European sites. Mitigation is required and is presented in **Section 6**.
- For the Visean Undifferentiated Limestone with karst there is a risk that if karst is encountered in the infiltration basins then the natural dilution and attenuation relied on for treatment of runoff will be bypassed with potential water quality impacts to groundwater that contributes to European sites. Mitigation of this potential impact is presented in **Section 6.**

In conclusion, where the proposed road development traverses groundwater bodies with karst there is the potential for groundwater to be impacted from high turbidity runoff and accidental fuel spillages, if they are not mitigated against. Furthermore, in the GWBs with karst the construction of infiltration basins, foundations for bridge piers and all excavations in general require mitigation measures, which are presented in **Section 6**.

5.2.3 Placement of non-native construction materials

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. Therefore, there is a potential hydrogeological risk if limestone was placed on granite which has a pathway to a European site. Granite can be considered inert over the lifespan of the proposed road development and as such there is no risk from placement of granite on limestone.

5.3 Operation Phase

There are a number of operation phase activities or features of the proposed road development that can interact with those European sites, listed in **Table 4**. As with construction activities, the main impacts to groundwater that contributes to a European site from operation activities arise from the potential to impact on flow paths and water quality. Operation activities which can alter the groundwater regime are:

- Changes to flow paths from operational dewatering of the bedrock aquifer and intersection of flow paths by excavations
- Discharge of treated road runoff to ground
- Placement of non-native construction materials

The operational ZoI for dewatering of the bedrock aquifer impacts and pollution impacts are presented in **Figure 7.01** and **Figure 7.02**.

5.3.1 Potential Impacts to Groundwater Flow

Impacts to groundwater flow from the operation of the proposed road development are primarily from operational dewatering impacts, however, impacts may also occur if flow pathways are intercepted by the proposed road development. The aspect of flow pathways is specific to the karst limestone where conduits may occur and is largely a construction issue, which is when these features may be encountered. As measures to ensure that these pathways are not impacted during the construction phase there are no potential impacts due to karst during the operation of the proposed road development (refer to **Section 5.1.1**).

The ZoI is presented below for all excavations. As described in **Section 5.1.1** the ZoI for excavations is calculated as a radius (radius of influence) that extends from the excavation. For cuttings and tunnels the radius extends out from the foot of the cutting face or drain that receives groundwater. The radii are calculated based on aquifer properties derived from site (described in **Section 5**) using the most conservative values measured. The ZoI in excavations during operation is presented in **Table 9** below.

Table 9: Summary of radius of influence at earthwork (EW) locations from operation dewatering of the bedrock aquifer (pre-mitigation)

Feature type	Ref no.	Chainage	Max depth of finished road level (m)	Length	Max drawdown depth (m)	Maximum Zone of influence Radius (m)
Galway Granite Batholith– R336 to N59 Moycullen Road						
Road Cutting	EW01	0+000 – 0+500	1.3	500	3.1	29
Road Cutting	EW02	1+150 – 1+350	0.9	200	2	20
Road Cutting	EW02	1+600 – 1+950	1.0	350	3	24
Road Cutting	EW02	2+230 – 2+640	3.1	410	2	27
Road cutting	EW04	3+100 – 4+080	5.9	980	8	50
Road cutting	EW07	5+250 – 5+580	5.3	330		38
Road Cutting	EW11	7+600 – 8+280	14.4	690	12	69
Visean Limestone Undifferentiated - N59 Moycullen Road to existing N6 Coolagh, Briarhill						
Structure (side road)	Ard Na Locha	0+000 – 0+168	0.1	168	0	0
Structure (side road)	N59	0+000 – 0+393	0.0	393	0	0
Structure (side road)	Aughna curra	0+000 – 0+117	0.0	117	0	0
River Corrib Structure	EW15	9+300 – 9+500	(Above ground)	200	0	0
Menlough Viaduct	EW17	9+500 – 10+100	(Above ground)	600	0	0
Western Approach to Lackagh Tunnel	EW19	10+810 – 11+140	9.8	350	0	0
Lackagh Tunnel	EW20	11+140 – 11+420	19.6	270	0	0
Road Cutting	EW22	11+720 – 11+920	12.3	200	0	0
Road cutting	EW25	12+550 – 13+050	5.2	370	0	0
Road cutting	EW27	13+050 – 13+650	8.5	600	3	110

Feature type	Ref no.	Chainage	Max depth of finished road level (m)	Length	Max drawdown depth (m)	Maximum Zone of influence Radius (m)
Road Cutting	EW29	14+150 – 14+450	12.9	300	0	0
Western Approach to Galway Racecourse Tunnel approach	EW30	14+450 – 14+950	11.2	500	0	0
Galway Racecourse Tunnel	EW31	14+950 – 15+190	9.2	240	0	0
Eastern Approach to Galway Racecourse Tunnel approach	EW32	15+190 – 15+500	8.7	310	0	0
Road Cutting	EW34-35	16+160 – 16+900	6.8	740	1	23

Notes:

Structure depths are presented to 10cm. Predicted drawdown and radius of extent presented to 1m.

The maximum depth of proposed road level refers to the finished road level. Structures will require excavation to a maximum depth of 3m below road level for installation of drainage and dewatering sumps/trenches.

5.3.1.1 Galway Granite Batholith

Based on the results presented above in **Table 9** there are seven cuttings in the Galway Granite Batholith which have the potential to intersect the groundwater table locally. These road cuttings are EW01, EW02 (three cuttings), EW04, EW07 and EW11. EW11 has the largest ZoI with drawdown extending up to 54m laterally from the footprint of the proposed road development.

Using the reported aquifer properties, the operation ZoI within the Galway Granite Aquifer will yield relatively small volumes of groundwater, which will be managed on site and discharged to those nearby watercourses that the groundwater would contribute too. On this basis groundwater will be managed on site so that the fall of groundwater trenches keep groundwater within the respective groundwater bodies. Due to the low quantities of groundwater that would be intersected, and by maintaining management within known groundwater bodies, there will be no change in the contributing groundwater to a European sites from groundwater bodies in the Galway Granite Batholith traversed by proposed road development.

5.3.1.2 Visean Undifferentiated Limestone

During the operation phase of the proposed road development, there are thirteen sections in the Visean Undifferentiated Limestone that remain in an open cutting (see **Table 9**). This is two less than during construction as the River Corrib Bridge and Menlough Viaduct do not have excavations during operation. Seven of these cuttings have the potential to intersect the water table locally during operation. These include three road cuttings (EW27, EW34 and EW35), three tunnel approaches (EW19, EW30 and EW32) and two tunnels (EW20 Lackagh Tunnel and EW31 Galway Racecourse Tunnel). Both the Lackagh Tunnel and its western approach and the Galway Racecourse with its eastern approach will be sealed as part of the road design.

The hydrogeology appraisal of Lackagh Tunnel (and its approaches) is described in further detail in Appendix F of the NIS. The sealing of Lackagh Tunnel and the cutting on its western approach will prevent operation impacts to groundwater flow paths. Any karst intersected during construction will be managed so as not to impact on groundwater flows during operation (refer to **Section 5.1.1**).

The properties of the Visean Undifferentiated Limestone, in the Ross lake GWB, Lough Corrib Fen 1 (Menlough) GWB, Lough Corrib Fen 1 (Lackagh) GWB and Clare-Corrib GWBs, are presented as larger ZoI than are calculated for the Galway Granite Batholith or the Visean Undifferentiated Limestone in the Clarinbridge GWB. Based on the water level data collected for the proposed road development and the sealed design of the tunnels and their approaches the only excavation that have the potential to require operational dewatering of the bedrock aquifer is EW27, which lies in the Clare-Corrib GWB and EW34 and EW35, which lies within the Clarinbridge GWB.

EW27 lies immediately west of the N83 Tuam Road and is a cutting where the finished road level lies 10m above the summer groundwater level and 0.5m above the peak recorded groundwater level. As part of the design permanent drains will be installed during construction to control the groundwater level 2m below the finished road level. All groundwater intercepted by drains during the peak groundwater rise will be carried eastwards by 150mm unlined perforated pipes either side of the proposed road development with discharge along the pipe length and overflow to an infiltration basin. Groundwater levels will be managed below the cutting and all intercepted groundwater will be discharged back into the groundwater body further east where groundwater levels are <5m below the groundwater levels at all times.

Within the Clarinbridge GWB the aquifer properties are relatively low and on this basis the volumes of groundwater to be generated during excavations are relatively small. Any groundwater lowering required will be kept within the same GWB so that groundwater volumes are maintained. On this basis there will be no impact from lowering of groundwater within the Clarinbridge GWB to the groundwater supporting a European sites.

5.3.1.3 Summary of Potential Impacts to Groundwater Flow

In summary, excavations from cuttings, structures and tunnels have the potential to intersect groundwater in seven excavations in the Galway Granite Batholith and seven excavations to the Visean Undifferentiated Limestone. The sealed design of the tunnels and their approaches, where required, will ensure that groundwater bodies that support a European site will not be impacted. EW27 includes groundwater interception drains that will activate during peak groundwater levels and carry groundwater within the same GWB to where levels are lower. Therefore, there will be no impacts from operational dewatering of the bedrock aquifer that could impact on the groundwater bodies that support a European site during the operation phase.

5.3.2 Potential Pollution Impacts

5.3.2.1 Galway Granite Batholith

GSI Groundwater vulnerability for the Galway Granite Batholith varies between extreme (X) and high (H). The ground investigation data collected for the proposed road development confirms the vulnerability range presented by the GSI. Whether extreme or moderate the limit of recharge equates to approximately 100mm/yr. which is limited by the aquifer properties of the granite rather than the vulnerability.

The GSI aquifer classification of the granite as poorly productive (Pl) indicates that there may be localised flow paths where faulting is present but based on the characteristics of the rock these flow paths will be limited in their extent. The GSI describe groundwater bodies in granite as typically having a maximum flow path of 100m, which is also supported from the ground investigation undertaken for the proposed road development. On this basis the length of a pathway in any local productive zones of the Galway Granite Batholith is 100m.

The drainage design in the area of the Galway Granite Batholith is rated using TII HD45/15 guidelines. The HD45/15 responses vary between R1 and R3(1) with the

R3(1) responses occurring in areas of cutting, which are located on topographic highs. The drainage design is based on the use of permeable drains.

Due to the low hydraulic conductivity of the granite bedrock the potential impact to groundwater quality is local to the proposed road development. The drainage system collects runoff and directs it towards surface water for discharge. A hydrocarbon interceptor and settlement pond treat the runoff before it is discharged to surface water.

There will be no change in the quality of groundwater contributing to a European sites from groundwater bodies in the Galway Granite Batholith.

5.3.2.2 Visean Undifferentiated Limestone

In the area of the Visean Undifferentiated Limestone there are few surface water features present. Where there is no option for discharge via surface water or storm water sewers the drainage for the proposed road development will discharge to ground. This section presents a hydrogeological assessment for the drainage design which follows TII HD45/15 guidelines. The drainage networks that will discharge to ground are presented in **Table 10**, which provides the footprint areas that will generate the runoff discharging to ground.

The runoff volumes are calculated on an annual basis using an annual average rainfall of 1,250mm/yr. All road drainage in the Visean Undifferentiated Limestone is sealed up to the point of discharge of the runoff in an infiltration basin, which follows treatment by hydrocarbon interceptor and wetland. There is also a containment area in each drainage network that can manually be activated to contain spillage on the carriageway.

Table 10: Drainage networks with infiltration basins, showing the footprint area for each network and the road runoff

Drainage Network	Footprint area m^2	Road runoff av m^3/yr.
S19A	19,490	24,363
S19B	22,221	27,776
S21A	33,070	41,338
S21B	82,830	103,538
S22A	56,810	71,013
S22B	30,637	38,297
S22C2	5,459	6,824
S22E	7,913	9,892
S27	54,734	68,418

Drainage Network	Footprint area m^2	Road runoff av m^3/yr.
S40	1,600	2,000

TII provides data on the event mean concentrations (EMC) of significant contaminants in HD45/15 and has developed a groundwater protection response (GPR) that provides an assessment on the suitability of road runoff discharging to groundwater. The potential contaminant and their EMC are reported in HD45/15 and reproduced below in **Table 11**. The EMC data presented in TII HD45/15 is indicative of runoff water pre- treatment.

Table 11: Significant pollutants and their EMC

Determinand	Routine runoff Mean EMC µg/l
Total Copper	91.22
Dissolved Copper	31.31
Total Zinc	352.63
Dissolved Zinc	111.09
Total Cadmium	0.63
Total Fluoranthene	1.02
Total Pyrene	1.03
Total PAHs	7.52

All drainage of untreated carriageway runoff across the Visean Undifferentiated Limestone is sealed and meets TII HD45/15 guidelines. Where discharge from drainage networks cannot be accommodated to surface water or sewer, then infiltration basins are used (**Table 12**).

The infiltration basin design uses a 2m over excavation from the invert to place a 2m thick subsoil that will meet the TII definition of being an appropriate material (TII HD45/15). All of the infiltration basins are more than 15m distant from surface karst mapped during the survey stage of the project (refer to **Figure 1.01** and **Figure 1.02**). Additionally, all infiltration basins are designed to include the following features as standard design

- A containment area
- A hydrocarbon interceptor
- A wetland

Groundwater levels have been monitored along the alignment between April 2015 and January 2017 in order to determine the seasonal variation in the groundwater level. On the basis of these measurements the minimum thicknesses of the saturated zone have been calculated for the infiltration basins.

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

Networks S19a, S19b, S20 and S40, however, do not meet the R2(3) criteria during the winter period when groundwater levels are elevated and there is less than 2m unsaturated zone. However, as the standard design for infiltration basins for the proposed road development includes containment, a hydrocarbon interceptor and a wetland, then each infiltration basin includes significant pre-treatment of runoff prior to infiltration. As the pre-treatment aspect exceeds the requirements of HD45/15 for all infiltration basins then the treated run-off at infiltration basins S19a, S19b, S20 and S40 is of a higher quality than that listed in **Table 11**.

Networks S19a, S19b and S20 are located on the Lough Corrib Fen 1 (Menlough) GWB, which supports groundwater dependant terrestrial ecosystems (GWDTE) at Coolagh lakes. Due to the sensitivity of the Lough Corrib Fen 1 (Menlough) GWB those drainage networks that drain the carriageway above the GWB, which include S19a and S19b, also have a liner installed to ensure that the treated run-off percolates through the full thickness of the subsoil.

On the basis of the pre-treatment all infiltration basins will discharge a higher quality of treated runoff than listed in **Table 11** and are not considered to pose a risk to the quality of groundwater bodies that European sites rely on.

Table 12: Table summarising the groundwater protection scheme used to assess discharge by infiltration basins

Network Ref	S19 A	S19B	S20	S21 A	S21B	S22 A	S22B	S22 C2	S22E	S40
Minimum unsaturated zone (m)	1.4	0.3	0	2.6	9.1	2.0	3.9	15.2	9.9	1.0

For locally important limestone aquifers (Ll or Lm) discharging to ground is not permitted unless there is a minimum thickness of 2m of appropriate subsoil and attention is paid to karst features and receptors. If the above criteria are met then the GPR will have a R2(2) response which is acceptable for discharge to ground as long as karst features are not identified, in that case the R2(3) criteria apply (refer to **Table 5**).

The design for discharge for the proposed road development, where there is no surface water to dispose runoff to, is by bespoke infiltration basins with pre-treatment. This design will be used for infiltration basins on both regionally important and locally important aquifers.

The treatment pre-disposal comprises of a hydrocarbon interceptor, wetland and 2m appropriate subsoil in the infiltration basin. Furthermore, a network specific containment area is included upgradient of the hydrocarbon interceptor that will be closed in the event of a spill and is designed contain the spillage. On discharge of the treated water to ground there will be further dilution and attenuation in the aquifer.

The presence of karst has been accommodated in the placement of the infiltration basins and no known active surface karst is present within 30m of any infiltration basin. However, there is a potential for karst to be encountered during the construction of infiltration basins and this is dealt with in the evaluation of construction impacts in **Section 5.1.2**.

The potential impact of karst is recognised as a significant aspect of the infiltration basins and is included in the mitigation measures of **Section 6,** which includes inspections to ensure that the infiltration basins remain in good working order for the operational life of the proposed road development.

The ZoI for the risk of groundwater pollution has been delineated for each infiltration basin pre-mitigation and is presented in **Figure 7.02**. As there is potential for karst to be encountered during construction of infiltration basins in the Lough Corrib Fen 1 (Menlough) GWB and Clare-Corrib GWB, then the ZoI may impact on groundwater quality if karst is encountered. As karst is dealt with by mitigation, in the pre-mitigation scenario a water quality impact could occur downgradient of an infiltration basin in a karst aquifer if a karst pathway is encountered in the excavation, with the potential ZoI being the full extent of the groundwater pathway and body downgradient of the proposed road development. This is on the basis that the treated runoff could travel via karst conduits through the aquifer to a receptor without dilution and attenuation. Those GWB with karst that are traversed by the proposed road development have the potential to impact on European sites. This includes infiltration basins S19a, S19b, S21a, S21b, S22a and S22b. Based on the hydrogeological assessment, mitigation is required to provide assurance that discharge from the infiltration basins will not point input to karst.

As the Clarinbridge GWB does not have karst then the ZoI for water quality from infiltration basins with pre-treatment is assessed as being the unsaturated zone of the aquifer below the infiltration basin. This is on the basis that dilution and attenuation will occur in the saturated zone. Infiltration basins S22c2, S22e, S27 and S40 are located on the Clarinbridge GWB.

In summary, the operation phase of the proposed road development has the potential to impact on European sites if karst is encountered in the infiltration basins.

5.3.2.3 Summary of Potential Pollution Impacts

There will be no change in the quality of groundwater contributing to a European site from groundwater bodies in the Galway Granite Batholith. However, there is a potential to impact on the groundwater contributing to a European site if karst is encountered in the Visean Undifferentiated Limestone.

5.4 Summary

The design of the proposed road development is cognisant of the hydrogeological existing environment. Below is a summary of the hydrogeological measures to manage the potential risk to groundwater that contributes to European sites:

- Dewatering of the bedrock aquifer (construction and operation) will be required within cuttings in the Galway Granite Batholith. Any intercepted groundwater will be diverted to its natural receiving water
- Dewatering (construction or operation) of the bedrock aquifer will not be undertaken in the Lough Corrib Fen 1 (Menlough) GWB or in the adjacent Clare-Corrib GWB within 500m of the GWB divide. This area of the proposed road development includes Menlough Viaduct and Lackagh Tunnel (including its approaches)
- Dewatering (construction and operation) of the bedrock aquifer will be required in cutting EW27 during the seasonal groundwater peak. Any intercepted groundwater will remain within the GWB but diverted to where it will infiltrate back to ground in an infiltration basin
- Dewatering (construction only) of the bedrock aquifer will be required at the Galway Racecourse Tunnel (and its approaches). Any intercepted groundwater will remain within the GWB but diverted back to ground in an infiltration basin
- Infiltration from construction runoff on the Galway Granite Batholith will be small (<10%) and have no impact on groundwater quality. Runoff from the Galway Granite Batholith is discharged of to surface water, which is documented in Appendix B Hydrology of the NIS
- Infiltration from construction runoff on the Visean Undifferentiated Limestone will occur both on the construction footprint and from infiltration basins. There is the potential for impact to groundwater quality if karst is encountered. Hydrogeological mitigation measures are required to control runoff and ensure that infiltration both on the construction footprint and within infiltration basins is prevented from point inputs to karst
- Accidental spills have the potential to impact on groundwater and are dealt with in mitigation
- The drainage design in the Galway Granite Batholith is not sealed. Discharge of treated runoff will be to surface water. There will be small (<10%) losses of runoff (treated and untreated) to ground and these have no impact on groundwater quality beyond the footprint of the proposed road development
- The Drainage design of the proposed road development in the Undifferentiated Visean Limestone has sealed drainage and uses infiltration basins (operational phases) to discharge of treated runoff

The design assessment has identified a risk specific to areas karst in the Visean Undifferentiated Limestone. There is potential for karst in Lough Corrib Fen 1 (Menlough) GWB, GWDTE Lough Corrib Fen 2 GWB and the Clare-Corrib GWB. If karst was encountered in these groundwater bodies then there is a risk that runoff and accidental spills could impact on groundwater quality and in turn impact on a

European site. These potential impacts require mitigation and are discussed further in **Section 6**.

The ZoI pre-mitigation is shown in **Figure**s **6.1 and 6.2** for construction and **Figures 7.1** and **7.2** for operation.

Table 8: Summary of European sites at risk from groundwater impact from the design of the proposed road development (pre-mitigation)

Groundwater body	Lough Corrib cSAC	Lough Corrib SPA	Galway Bay Complex cSAC	Inner Galway Bay SPA
Spiddal GWB	Not at risk	Not at risk	Not at risk	Not at risk
Maam Clonbur GWB	Not at risk	Not at risk	Not at risk	Not at risk
Ross Lake GWB	At risk from runoff and spillage	At risk from runoff and spillage	Not at risk	Not at risk
Lough Corrib Fen 1 (Menlough) GWB and Lough Corrib Fen 1 (Lackagh) GWB	At risk from runoff and spillage	Not at risk	At risk from runoff and spillage	At risk from runoff and spillage
GWDTE Lough Corrib Fen 2 GWB	At risk from runoff and spillage	At risk from runoff and spillage	At risk from runoff and spillage	At risk from runoff and spillage
Clare-Corrib GWB	Not at risk	Not at risk	At risk from runoff and spillage	At risk from runoff and spillage
Clarinbridge GWB	Not at risk	Not at risk	Not at risk	Not at risk

6 Mitigation

6.1 Introduction

This section describes mitigation measures proposed to mitigate potential impacts outlined in **Section 5** of this report.

Specific construction mitigation measures are required to mitigate the potential construction impacts outlined in **Section 5** of this report and these mitigation measures are outlined below.

6.2 Mitigation - Construction Phase

The measures listed below will be adopted during the construction phase of the proposed road development.

6.2.1 Potential Impacts to Groundwater Flow

The design of the proposed road development includes dewatering of the bedrock aquifer in cuttings in the Galway Granite Batholith and cuttings in the Visean Undifferentiated Limestone. The drawdown from these cuttings has been assessed in **Section 5** and there are no impacts on European sites. No mitigation is therefore required with regard to the design of construction dewatering of the bedrock aquifer.

With regard to karst features being intercepted in excavations for earthworks (including viaducts, bridges and tunnels) and infiltration basins, mitigation measure has been developed to preserve the hydraulic connectivity of the feature but then seal it from the excavation. The mitigation measure is detailed in the Construction Environmental Management Plan (CEMP) (Appendix C of the NIS) and will ensure that there is no impact on groundwater flow paths that GWDTE within a European site are dependent on.

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

6.2.2 Pollution prevention

Mitigation is divided into those standard measures that apply to both the Galway Granite Batholith and the Visean Undifferentiated Limestone and those measures that are specifically designed for karst in the Visean Undifferentiated Limestone.

6.2.2.1 Standard Mitigation Measures

- Mitigation of potential construction impacts will be achieved through the stringent implementation of good construction practice procedures and environmental controls so as minimise the opportunity for contaminated releases of construction runoff as set out in the CEMP (Appendix C of the NIS). Such practices will include adequate bunding for oil containers, wheel washers and dust suppression on site roads, and regular plant maintenance
- The following measures included in the CEMP will be implemented to control the potential for pollution from accidental spillages on site:
    - Stockpiling of contaminated material is not permitted
    - Good housekeeping (daily site clean-ups, use of disposal bins, etc.) on the site during construction, and the proper use, storage and disposal of these substances and their containers will prevent groundwater contamination
    - For all activities involving the use of potential pollutants or hazardous materials, under the CEMP, the contractor will be required to ensure that material such as concrete, fuels, lubricants and hydraulic fluids will be carefully handled and stored to avoid spillages. Potential pollutants shall also be adequately secured against vandalism and will be provided with proper containment according to codes of practice. Any spillages will be immediately contained and contaminated soil removed from the site and properly disposed of
    - The contractor will be required to implement a contingency plan for pollution emergencies which will be developed by the appointed contractor prior to work commencing and regularly updated, which will identify the actions to be taken in the event of a pollution incident. As recommended in the CIRIA document, the contingency plan for pollution emergencies will include the following:
        - Containment measures
        - Emergency discharge routes
        - List of appropriate equipment and clean-up materials
        - Maintenance schedule for equipment
        - Details of trained staff, location and provision for 24-hour cover
        - Details of staff responsibilities
        - Notification procedures to inform the Environmental Protection Agency (EPA) or environmental department of the Galway County Council
        - Audit and review schedule
        - Telephone numbers of statutory water consultees
        - List of specialist pollution clean-up companies and their telephone numbers
- No direct untreated point discharge of construction runoff to groundwater will be permitted
- Where a pollution incident is detected, construction works will be stopped until the source of the construction pollution has been identified and remedied

- Pollution control facilities and procedures set out in the Sediment, Erosion and Pollution Control Construction Management Plan included in the CEMP will be implemented if required
- The pollution control and treatment facilities will be installed and the monitoring network including instrumentation and procedures established prior to construction activities taking place on the ground in the vicinity of watercourses and sensitive surface and groundwater receptors. It is envisaged that the pollution control facilities will be monitored daily to ensure their continued integrity and desired function

6.2.2.2 Karst Specific Mitigation Measures

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

- Where karst features are encountered during construction works these will be assessed by a qualified hydrogeologist. These features will require their extent across the proposed road development to be delineated. In the case of excavations (road cuttings, tunnels, bridge pier excavations) then the karst feature shall be excavated and backfilled with course fill and sealed. This will prevent runoff draining into the feature and therefore protect against accidental spillage. On this basis, construction runoff will not discharge to a karst pathway and will receive natural attenuation and dilution in the aquifer
- With regard to karst features being intercepted in excavations for earthworks (including viaducts, bridges and tunnels) and infiltration basins. The Karst Protocol preserves the hydraulic connectivity of the feature using granular material to fill but then seals the karst from the excavation using a liner (geotextile and or concrete depending on the site specifics) that will prevent linkage between excavation and the karst.
- Given the proximity of the proposed road development to the Coolagh Lakes, which are groundwater dependant via karst springs, construction impacts represent a potential source of impact on the water quality of the lake from uncontrolled construction site runoff and potential contamination of the groundwater from construction spillages. There will be no surface water discharges to the Coolagh lakes and all runoff will be treated before being discharged to ground at infiltration basins. Infiltration basins are designed to include settlement to remove sediment and have 2m of subsoil below invert level. All infiltration basins include containment to protect against spillages. Infiltration basins require regular inspection to confirm that no observable subsidence in the infiltration has occurred due to karst. There are no guidelines on the inspection frequency for infiltration basins, however, based on the mitigation measures implemented the risk of subsidence occurring is considered to be low and inspection is recommended on 5-year frequency.
- Pouring of the concrete in excavations (River Corrib Bridge, Menlough Viaduct and Lackagh Tunnel) will only be undertaken when the excavation has been inspected by a qualified hydrogeologist. Inspection of the full depth and extent

of each excavation will be undertaken to identify if any significant flow paths, such as the karst enhancement of the bedrock permeability, are present. If no significant flow paths are present, then the hydrogeologist will document accordingly and confirm that there is no risk to groundwater from concrete leakage. If significant pathways are present then impacts which may arise from flow along these pathways shall be designed by the hydrogeologist based on the karst mitigation plan, these may comprise of installing a high permeability zone to replace the groundwater pathways which would be removed by the foundations and/or sealing the linkage from excavation to protect the karst. The design of the mitigation measures shall be approved by a qualified hydrogeologist to confirm that there will be no negative impacts to groundwater.

These above measures will ensure that the risk of pollution of groundwater bodies is controlled and that there will be no impact to European sites.

6.2.3 Placement of non-native construction materials

A construction earthworks programme will be finalised by the contractor as part of the CEMP for the proposed road development which categorises the source of material for each fill section. During the finalisation of this programme, the following fill limitations will be incorporated, to prevent impact due to the placement of non-native construction materials:

- The use of fill material is limited where sites have a pathway to a European site
- Only pavement and capping layers protected from surface water runoff and groundwater movements are permitted to be derived from non-native material at sensitive locations
- All other acceptable fill material will be derived from native material or other pH compatible material

6.3 Mitigation - Operation Phase

As per the design, inspection and maintenance will occur during the operation phase to ensure that the appropriate thickness of subsoil remains across the basin surface area. If karst features and potential pathways are found to be present during inspection and maintenance in the infiltration basin, then the Karst Protocol will be implemented to ensure that there are no preferential pathways within the infiltration basin.

7 Conclusion

The potential hydrogeological impacts to European sites from the proposed road development have been identified and assessed, which include specific hydrogeological impacts for the Lackagh Tunnel including its western and eastern approaches (Appendix F of the NIS). The hydrogeological zone of influence is presented in **Figure** set **6** and **7**.

Potential impacts to groundwater quality and quantity have been assessed. These include:

- Construction impacts from excavation dewatering of the bedrock aquifer
- Construction impacts from runoff infiltration
- Construction impacts from accidental spillage
- Operational impacts from dewatering of the bedrock aquifer
- Operational impacts from sealing of structures
- Operational impacts from discharge of treated road runoff to ground by infiltration basins
- Operational impacts from placement of non-native material

Based on this assessment, with the implementation of design requirements proposed and a range of mitigation measures during both construction and operation, it can be concluded that the proposed road development will not modify the hydrogeological regime in the location of any European sites.

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A3

FOR INFORMATION

Legend

- City Boundary
- Proposed Development Boundary
- Proposed Road Development

Bedrock Aquifer Classification (GSI)

- Bedrock which is Generally Unproductive except for Local Zones , Poor Aquifers (Pl)
- Regionally important karstified bedrock aquifers dominated by conduit flow (Rkc)

Karst Features (K)

- Enclosed Depression
- Estavelle
- Spring Swallow Hole
- Spring
- Swallow Hole
- Turlough
- Well
- Cave
- Superficial solution features

Clients

Key Plan

Sheet 1
Sheet 2

Consultant

ARUP

Corporate House
City East Business Park
Ballybrit, Galway, Ireland

Tel +353 (0)91 460675
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Job Title

N6 Galway City Ring Road

Scale: **1:25,000**

Date: **July 2018**

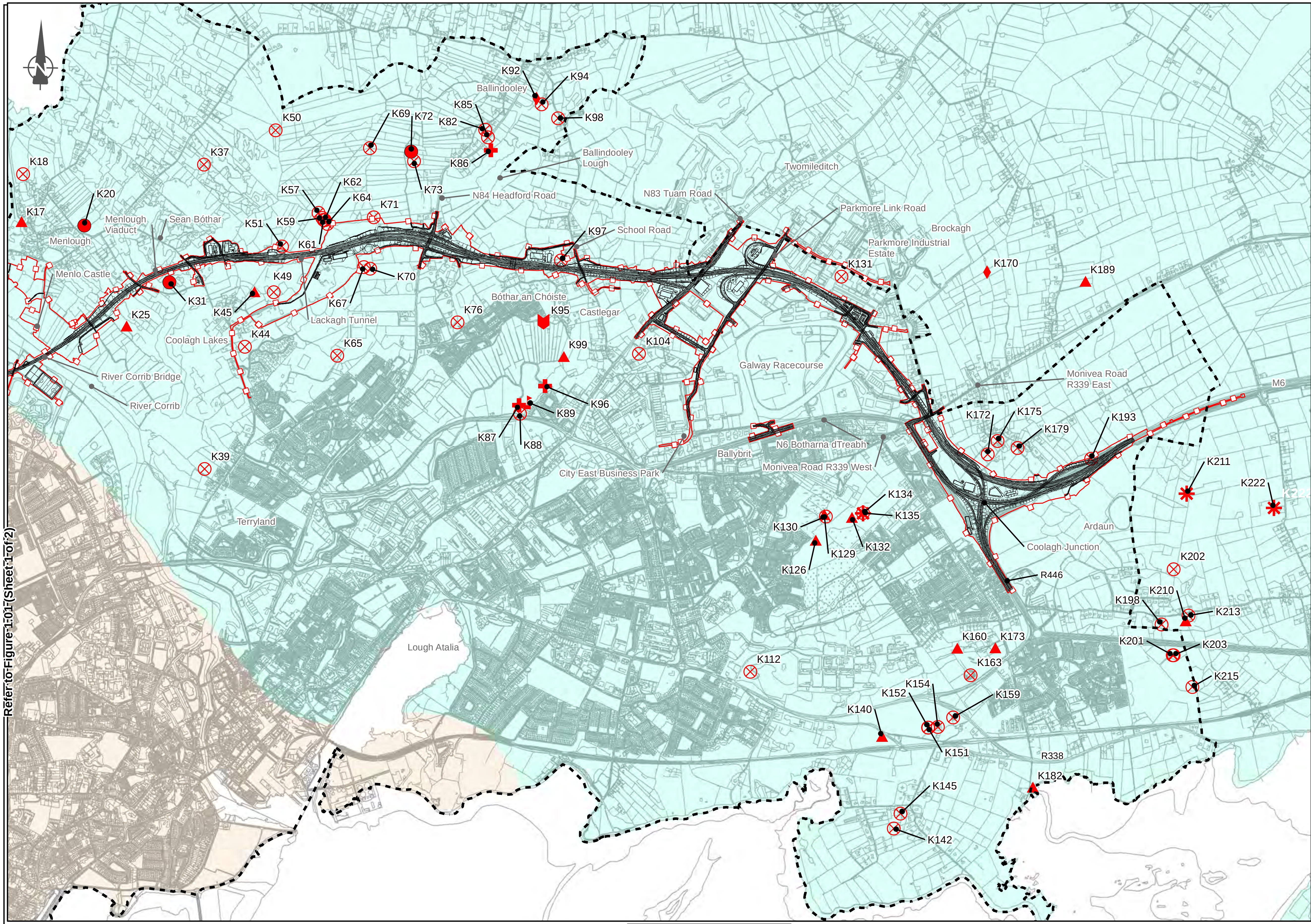
Issue	Date	By	Chkd	Appd
I3	26/07/2018	AG	LB	EMC
I2	30/09/2017	AG	LB	EMC
I1	23/06/2017	JF	LB	EMC

Drawing Title
Bedrock Aquifer Classification with Karst Features
Sheet 1 of 2

Drawing Status
For Information

Job No	Drawing No	Issue
233985-00	Figure 1.01	I3

A3



FOR INFORMATION

Legend

- City Boundary
- Proposed Development Boundary
- Proposed Road Development

Aquifer Classification (for legend)

- Bedrock which is Generally Unproductive except for Local Zones , Poor Aquifers (PI)
- Regionally important karstified bedrock aquifers dominated by conduit flow (Rkc)

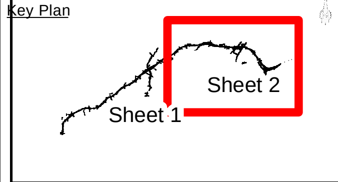
Karst Features (K)

- Enclosed Depression
- Estavelle
- Spring Swallow Hole
- Spring
- Swallow Hole
- Turlough
- Well
- Cave
- Superficial solution features

Clients

Comhairle Chontae na Gaillimhe
Galway County Council

Key Plan



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Job Title

N6 Galway City Ring Road

Scale: **1:25,000**

Date: **July 2018**

Issue	Date	By	Chkd	Appd
I3	26/07/2018	AG	LB	EMC
I2	30/09/2017	AG	LB	EMC
I1	23/06/2017	JF	LB	EMC

Drawing Title

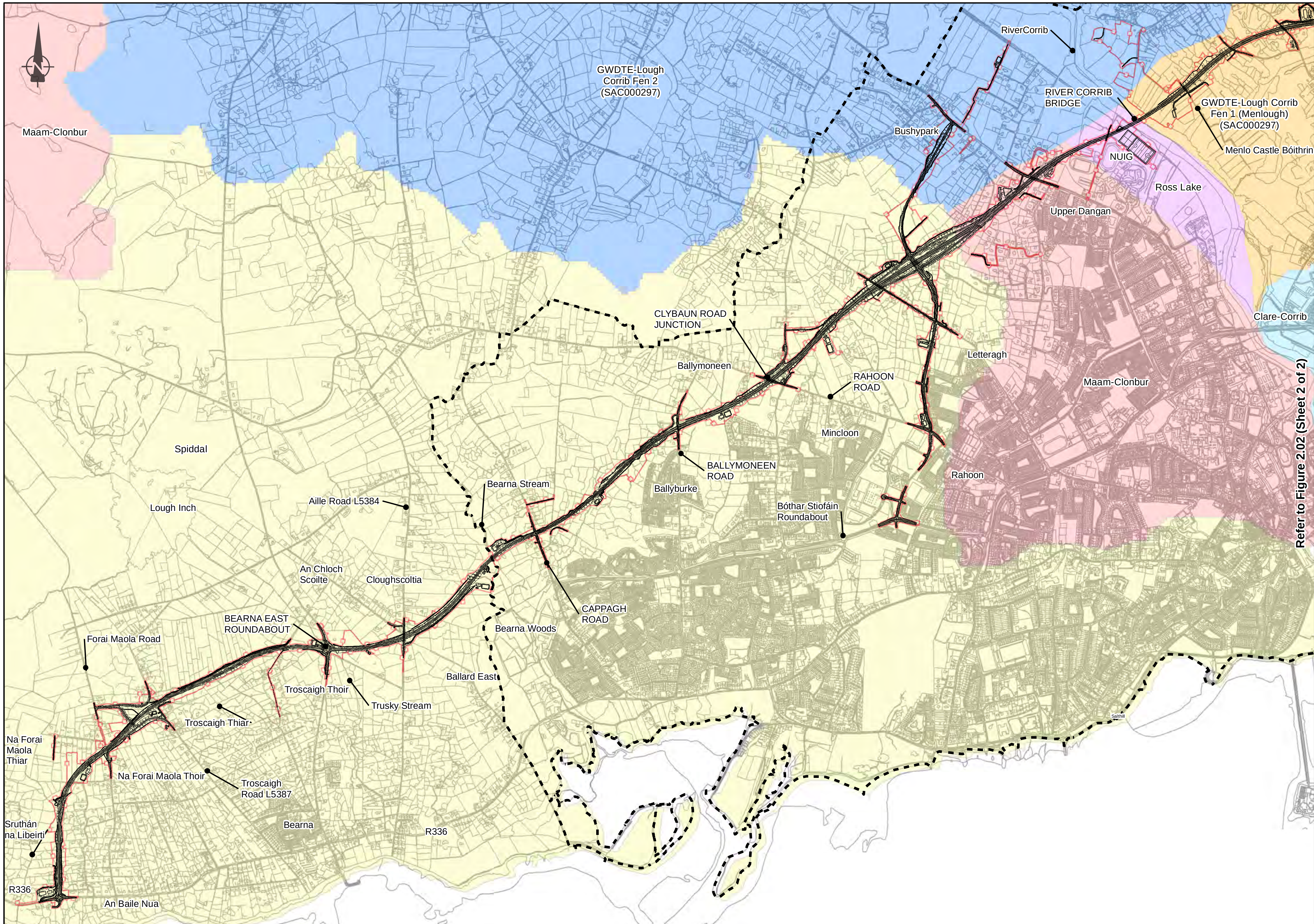
Bedrock Aquifer Classification with Karst Features
Sheet 2 of 2

Drawing Status

For Information

Job No	Drawing No	Issue
233985-00	Figure 1.02	I3

A3



FOR INFORMATION

Legend

- City Boundary
- Proposed Development Boundary
- Proposed Road Development

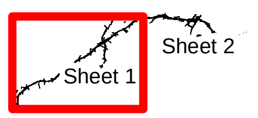
Groundwater Bodies (GSI)

- Clare-Corrib
- GWDTE-Lough Corrib Fen 2 (SAC000297)
- GWDTE-Lough Corrib Fen 1 (Menlough) (SAC000297)
- Maam-Clonbur
- Ross Lake
- Spiddal

Clients

Comhairle Chontae na Gaillimhe Galway County Council

Key Plan



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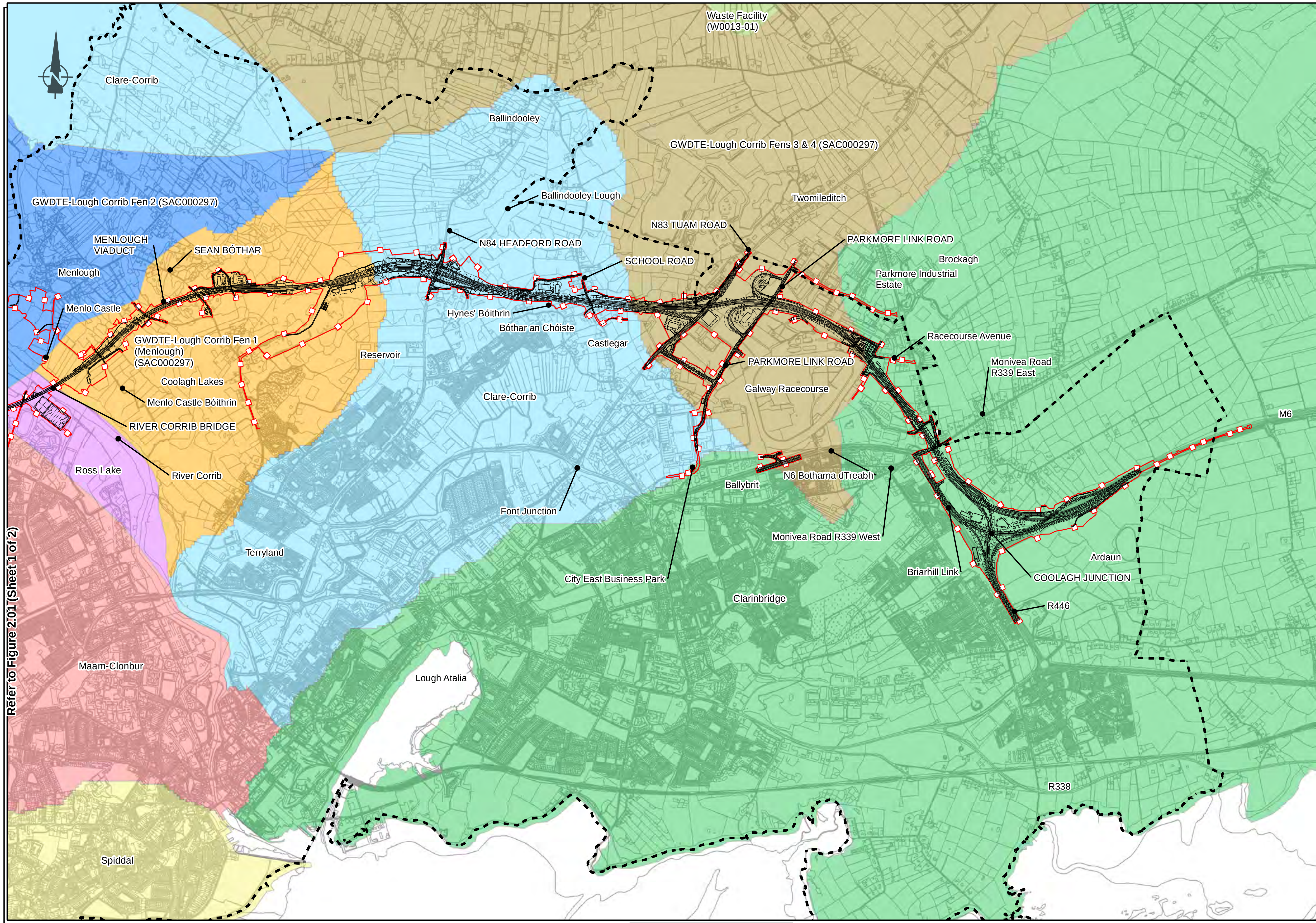
I3	26/07/2018	AG	LB	EMC
I2	30/10/2017	AG	LB	EMC
I1	23/06/2017	JF	LB	EMC

Drawing Title
Groundwater Bodies Overview Sheet 1 of 2

Drawing Status
For Information

Job No	Drawing No	Issue
233985-00	Figure 2.01	I3

A3



FOR INFORMATION

Legend

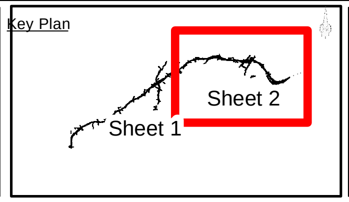
- City Boundary
- Proposed Development Boundary
- Proposed Road Development

Groundwater Bodies (GSI)

- Clare-Corrib
- Clarinbridge
- GWDTE-Lough Corrib Fen 2 (SAC000297)
- GWDTE-Lough Corrib Fen 1 (Menlough) (SAC000297)
- GWDTE-Lough Corrib Fens 3 & 4 (SAC000297)
- Maam-Clonbur
- Ross Lake
- Spiddal
- Waste Facility (W0013-01)

Clients

Key Plan



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N6 Galway City Ring Road

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Date: **July 2018**

Issue	Date	By	Chkd	Appd
I3	26/07/2018	AG	LB	EMC
I2	30/09/2017	AG	LB	EMC
I1	23/06/2017	PC	LB	EMC

Drawing Title

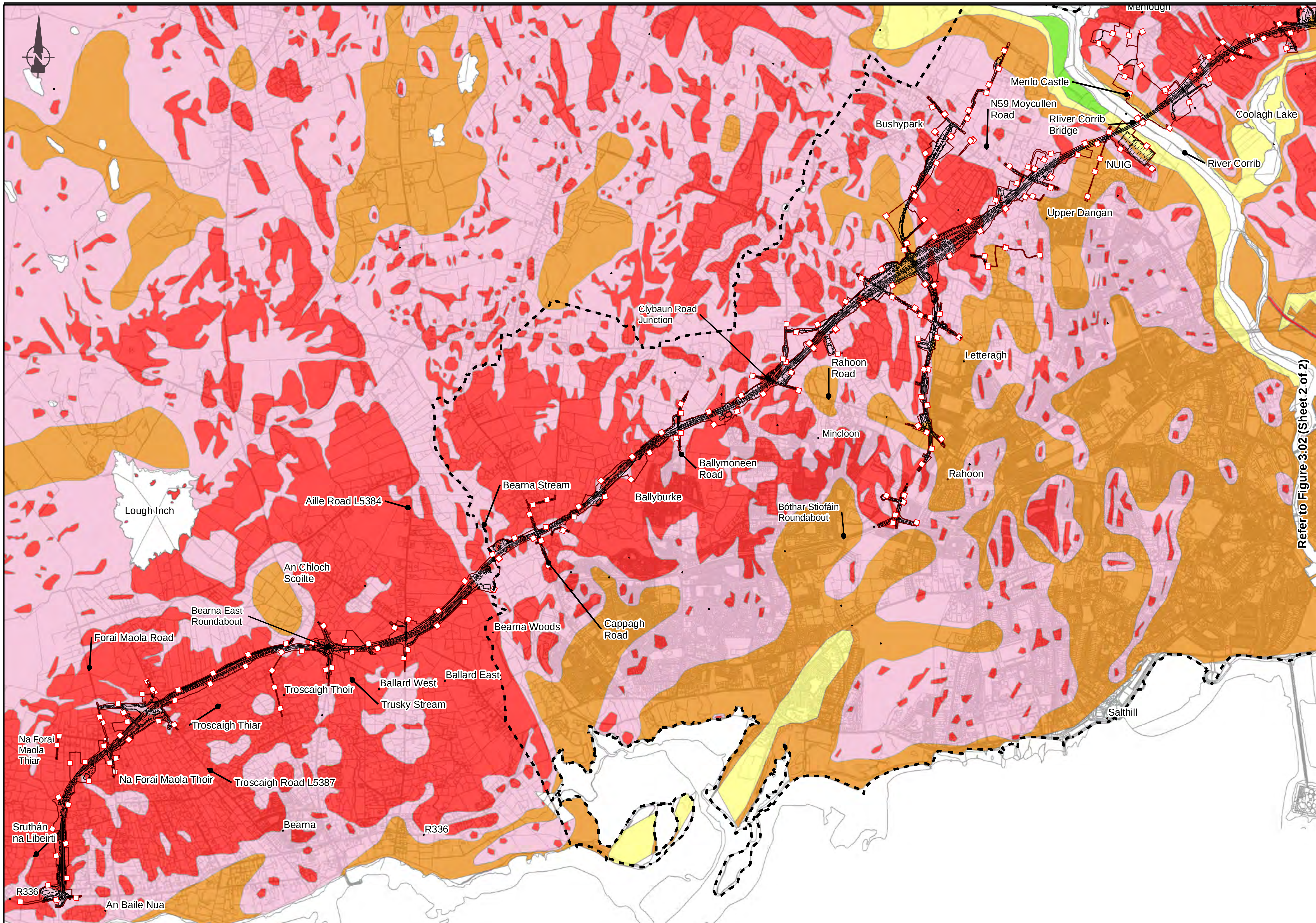
Groundwater Bodies Overview Sheet 2 of 2

Drawing Status

For Information

Job No	Drawing No	Issue
233985-00	**Figure 2.02**	**I2**

A3



FOR INFORMATION

Legend

- City Boundary
- Proposed Development Boundary
- Proposed Road Development

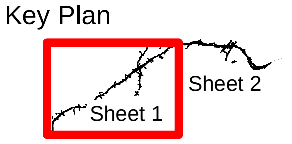
Groundwater Vulnerability (GSI)

- Rock at or near Surface or Karst
- Extreme
- High
- Moderate
- Low

Clients

Comhairle Chontae na Gaillimhe
Galway County Council

Key Plan



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Date: **July 2018**

Issue	Date	By	Chkd	Appd
I3	26/07/2018	AG	LB	EMC
I2	30/09/2017	AG	LB	EMC
I1	23/06/2017	PC	LB	EMC

Drawing Title

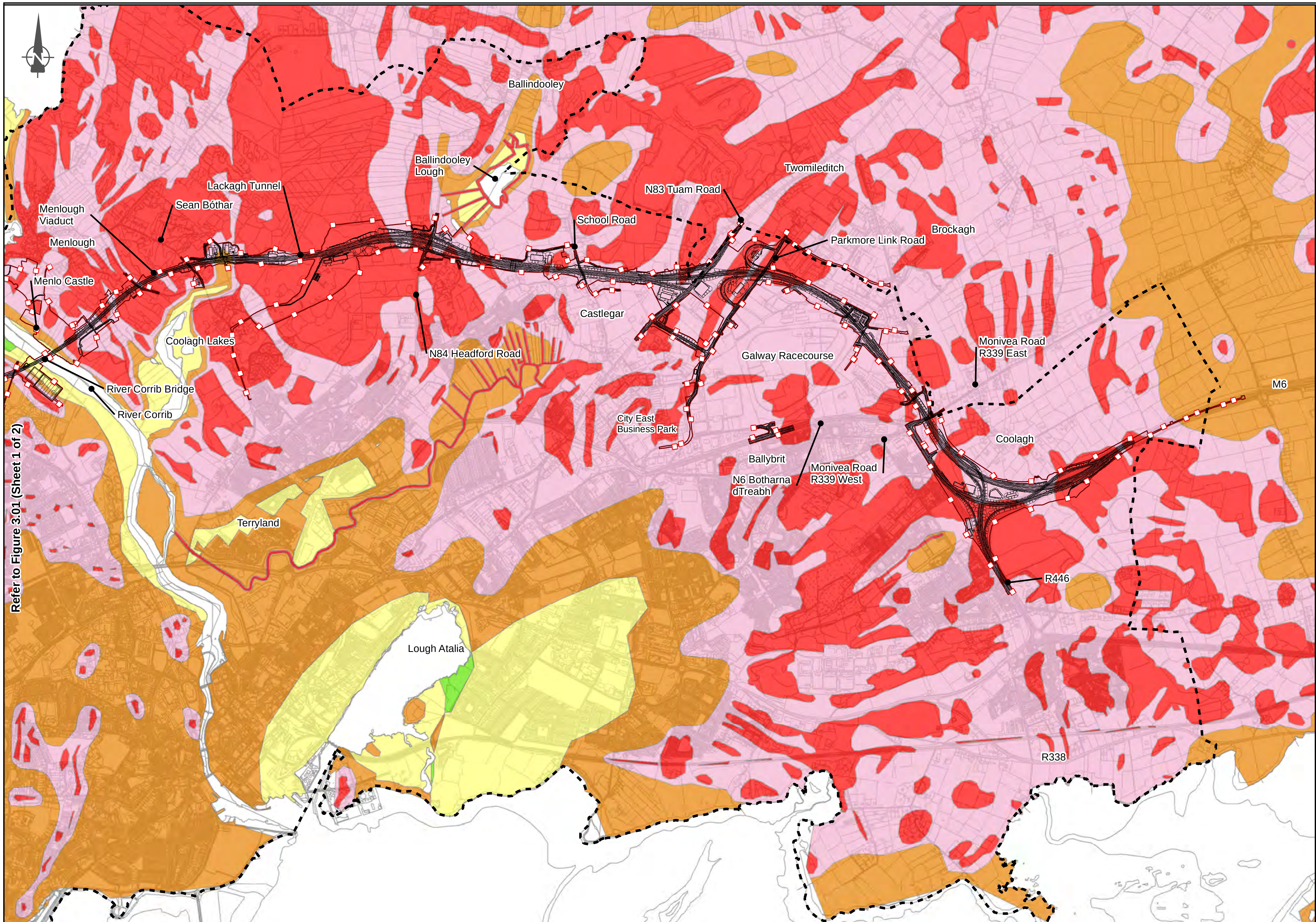
Groundwater Vulnerability - Existing Environment Overview Sheet 1 of 2

Drawing Status

For Information

Job No	Drawing No	Issue
233985-00	Figure 3.01	I3

A3



FOR INFORMATION

Legend

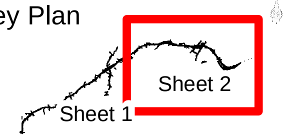
- City Boundary
- Proposed Development Boundary
- Proposed Road Development

Groundwater Vunerability (GSI)

- Rock at or near Surface or Karst
- Extreme
- High
- Moderate
- Low

Clients

Key Plan



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I3	26/07/2018	AG	LB	EMC
I2	30/09/2017	AG	LB	EMC
I1	23/06/2017	PC	LB	EMC

Drawing Title

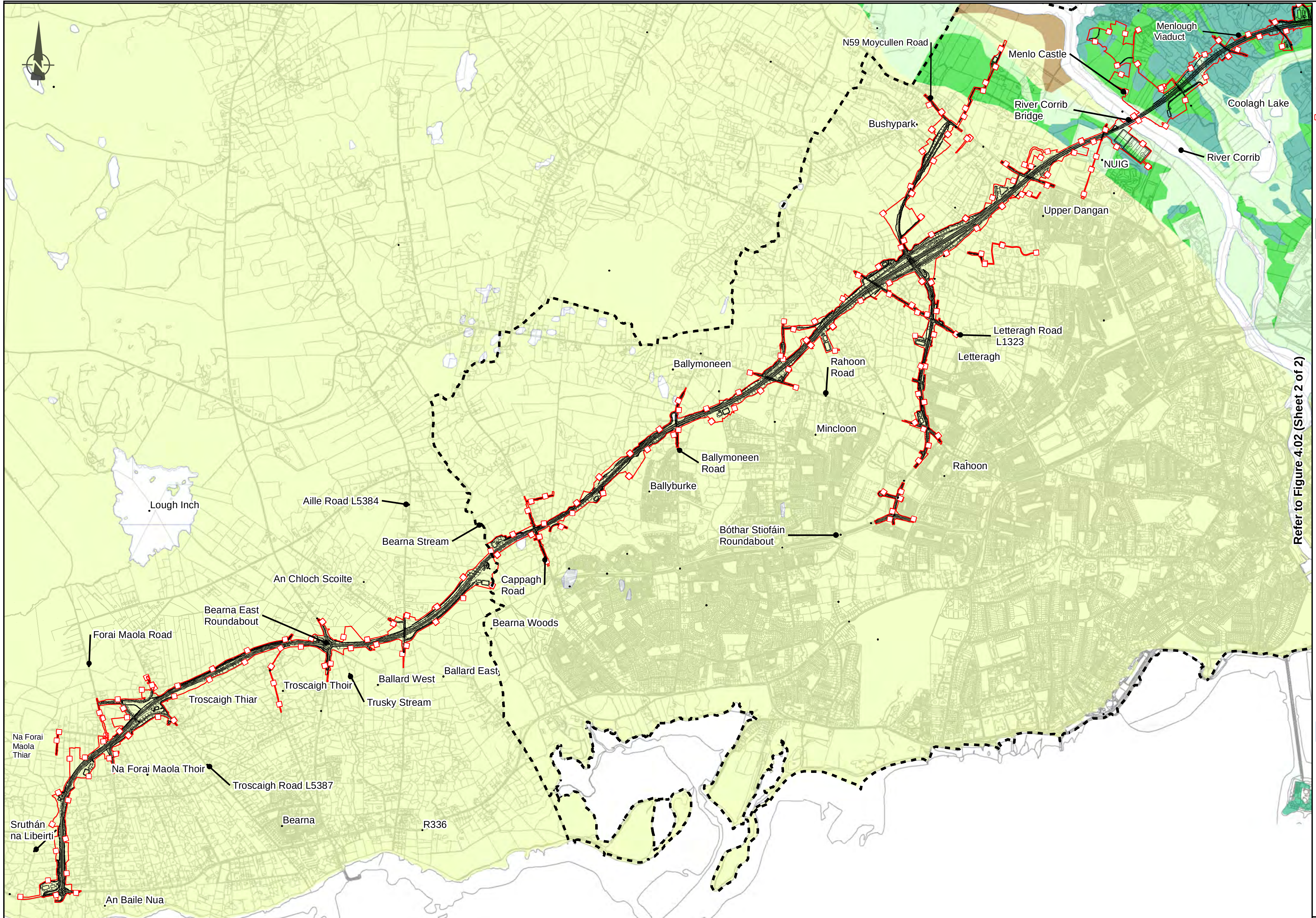
Groundwater Vulnerability - Existing Environment Overview Sheet 2 of 2

Drawing Status

For Information

Job No	Drawing No	Issue
233985-00	Figure 3.02	I3

A3



FOR INFORMATION

Legend

- City Boundary
- Proposed Development Boundary
- Proposed Road Development

National Recharge Range(mm)

- 0
- 1-50
- 51-100
- 101-150
- 151-200
- 201-250
- 251-300
- 301-350
- 351-400
- 401-450
- 451-500
- 501-550
- 551-600
- 601-700
- 701-800
- 801-900
- 901-1000
- 1001-1400
- 1401-2000
- water

Clients

Comhairle Chontae na Gaillimhe
Galway County Council

Key Plan

Sheet 1
Sheet 2

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Scale: **1:25,000**

Date: **July 2018**

Issue	Date	By	Chkd	Appd
I3	26/07/2018	AG	LB	EMC
I2	29/09/2017	AG	LB	EMC
I1	23/06/2017	PC	LB	EMC

Drawing Title

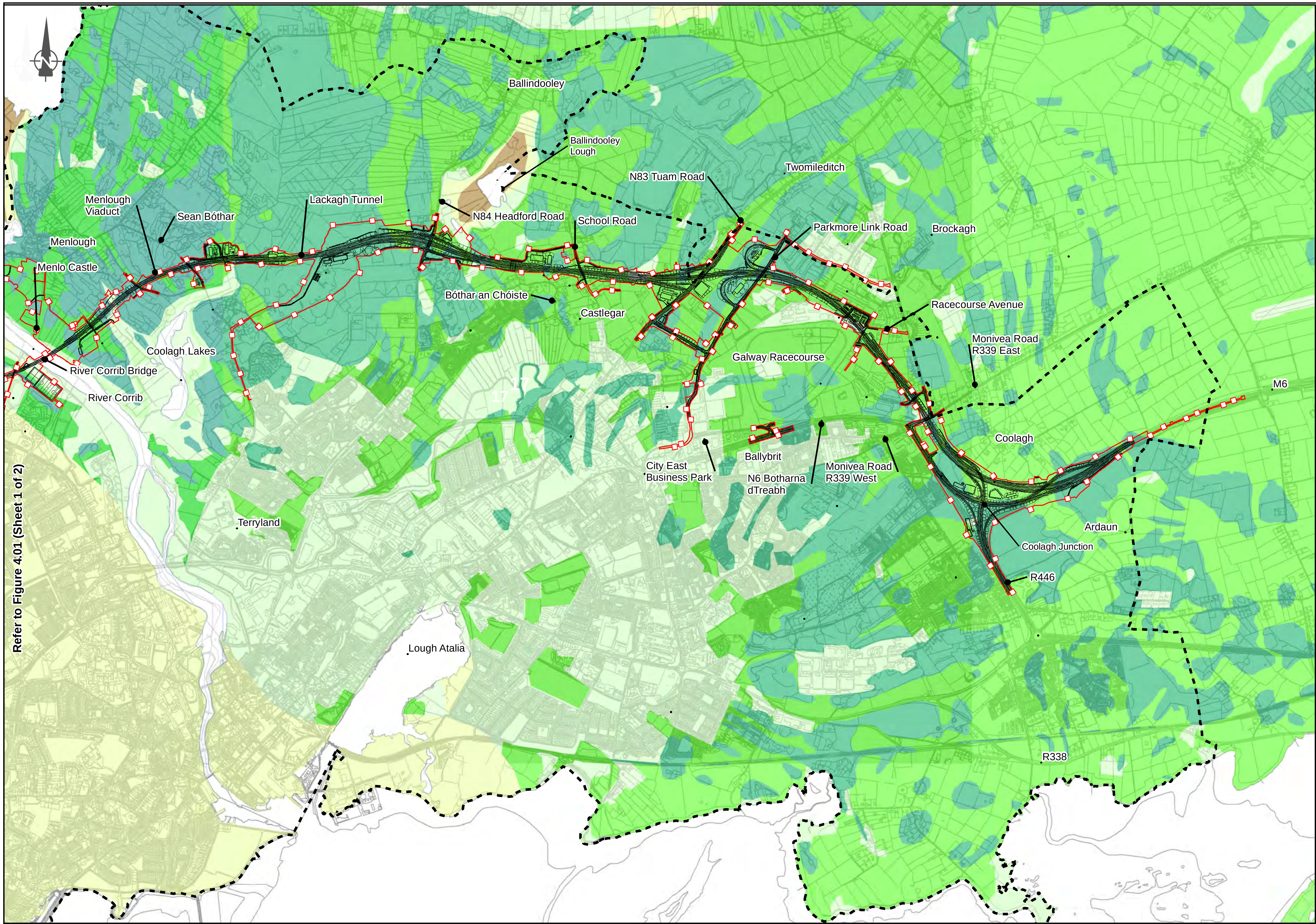
Recharge Coefficient - Existing Environment Overview Sheet 1 of 2

Drawing Status

For Information

Job No	Drawing No	Issue
233985-00	Figure 4.01	I3

A3



FOR INFORMATION

Legend

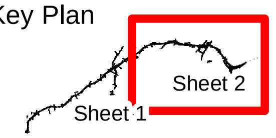
- City Boundary
- Proposed Development Boundary
- Proposed Road Development

National Recharge Range(mm)

- 0
- 1-50
- 51-100
- 101-150
- 151-200
- 201-250
- 251-300
- 301-350
- 351-400
- 401-450
- 451-500
- 501-550
- 551-600
- 601-700
- 701-800
- 801-900
- 901-1000
- 1001-1400
- 1401-2000
- water

Clients

Key Plan



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Job Title
N6 Galway City Ring Road

Scale: **1:25,000**

Date: **July 2018**

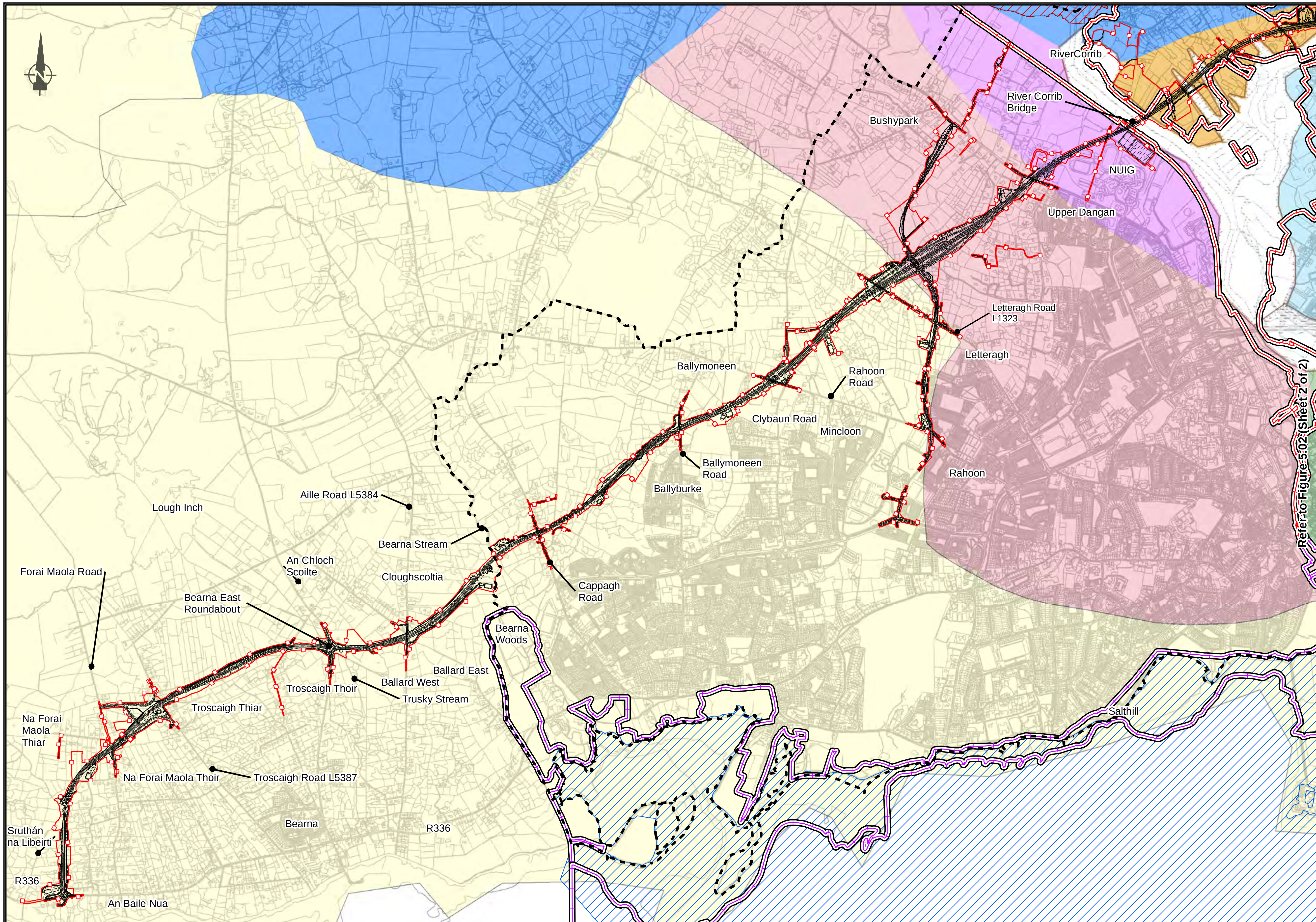
Issue	Date	By	Chkd	Appd
I3	26/07/2018	AG	LB	EMC
I2	30/09/2017	AG	LB	EMC
I1	23/06/2017	PC	LB	EMC

Drawing Title
Recharge Coefficient - Existing Environment Overview Sheet 2 of 2

Drawing Status
For Information

Job No	Drawing No	Issue
233985-00	Figure 4.02	I3

A3



FOR INFORMATION

Legend

- City Boundary
- Proposed Development Boundary
- Proposed Road Development

European Sites

- Lough Corrib cSAC
- Galway Bay Complex cSAC
- Inner Galway Bay SPA
- Lough Corrib SPA
- Estimated extent of buried landscape

Groundwater Bodies (2017)

- Clare - Corrib (Terryland) GWB
- Clare-Corrib (Ballindooley East) GWB
- Clare-Corrib (Ballindooley West) GWB
- Clarinbridge GWB
- Maam-Clonbur GWB
- Lough Corrib Fen 1 (Lackagh) GWB
- Lough Corrib Fen 1 (Menlough) GWB
- Lough Corrib Fen 2 GWB
- Spiddal GWB
- Ross Lake GWB

Clients

Key Plan

Sheet 1
Sheet 2

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Job Title

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Scale: **1:25,000**

Date: **July 2018**

Issue	Date	By	Chkd	Appd
I3	26/07/2018	AG	LB	EMC
I2	29/09/2017	AG	LB	EMC
I1	23/06/2017	PC	LB	EMC

Drawing Title

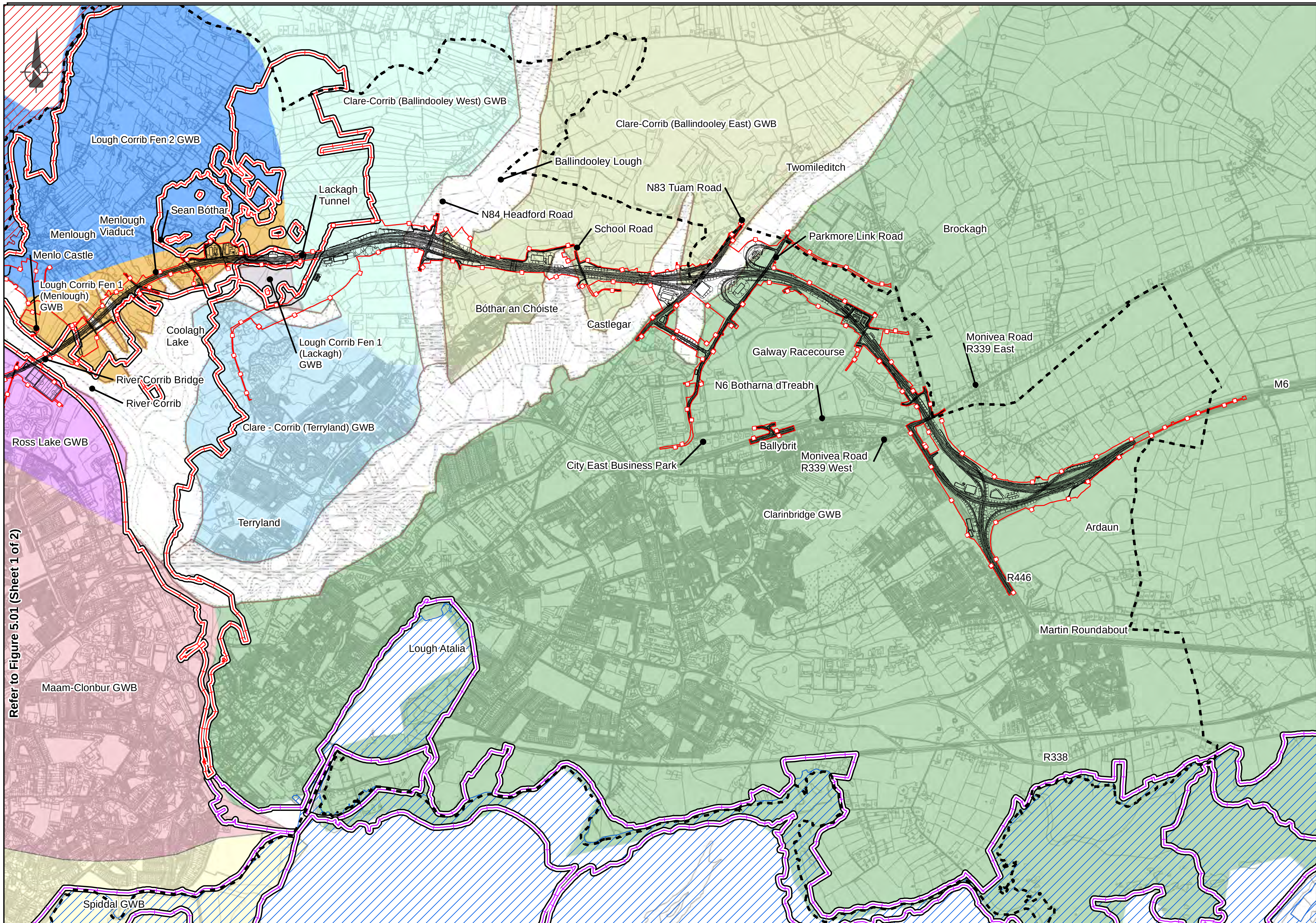
Revised groundwater bodies (2017) and European sites Sheet 1 of 2

Drawing Status

For Information

Job No	Drawing No	Issue
233985-00	Figure 5.01	I3

A3



FOR INFORMATION

Legend

- City Boundary
- Proposed Development Boundary
- Proposed Road Development

European Sites

- Lough Corrib cSAC
- Galway Bay Complex cSAC
- Inner Galway Bay SPA
- Lough Corrib SPA
- Estimated extent of buried landscape

Groundwater Bodies (2017)

- Clare - Corrib (Terryland) GWB
- Clare-Corrib (Ballindooley East) GWB
- Clare-Corrib (Ballindooley West) GWB
- Clarinbridge GWB
- Maam-Clonbur GWB
- Lough Corrib Fen 1 (Lackagh) GWB
- Lough Corrib Fen 1 (Menlough) GWB
- Lough Corrib Fen 2 GWB
- Spiddal GWB
- Ross Lake GWB

Clients

Key Plan

Sheet 1
Sheet 2

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Job Title

N6 Galway City Ring Road

Scale: **1:25,000**

Date: **July 2018**

Issue	Date	By	Chkd	Appd
I3	26/07/2018	AG	LB	EMC
I2	30/09/2017	AG	LB	EMC
I1	23/06/2017	PC	LB	EMC

Drawing Title

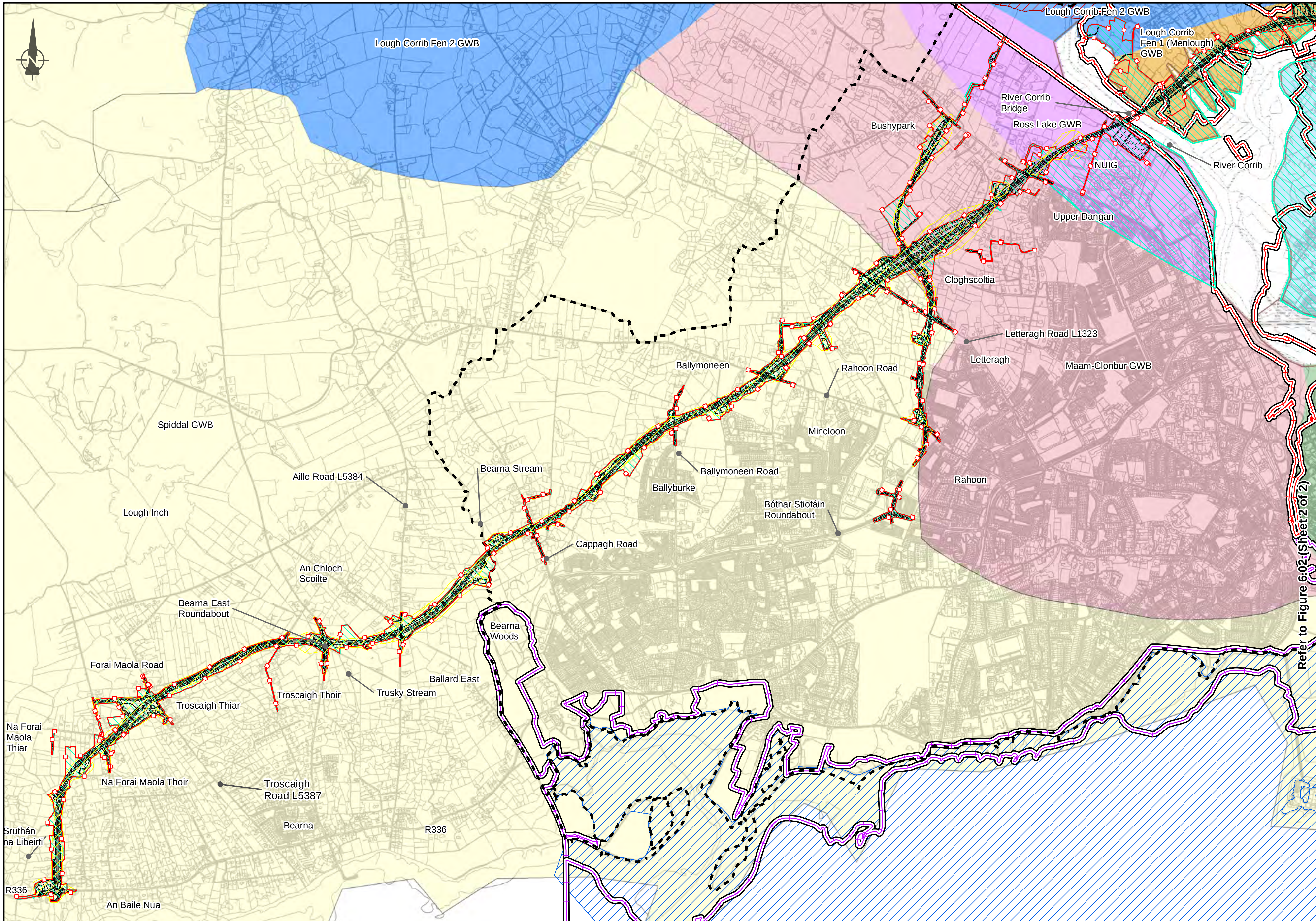
Revised groundwater bodies (2017) and European sites Sheet 2 of 2

Drawing Status

For Information

Job No	Drawing No	Issue
233985-00	Figure 5.02	I3

A3



FOR INFORMATION

Legend

- City Boundary
- Proposed Development Boundary
- Proposed Road Development

European Sites

- Lough Corrib cSAC
- Galway Bay Complex cSAC
- Inner Galway Bay SPA
- Lough Corrib SPA
- Estimated extent of buried landscape

Zone of Influence

- Drawdown Zone of Influence
- Area Liable to Contamination

Groundwater Bodies (2017)

- Clare - Corrib (Terryland) GWB
- Clare-Corrib (Ballindooley East) GWB
- Clare-Corrib (Ballindooley West) GWB
- Clarinbridge GWB
- Maam-Clonbur GWB
- Lough Corrib Fen 1 (Lackagh) GWB
- Lough Corrib Fen 1 (Menlough) GWB
- Lough Corrib Fen 2 GWB
- Spiddal GWB
- Ross Lake GWB

Clients

Comhairle Chontae na Gaillimhe Galway County Council

Key Plan

Sheet 1

Sheet 2

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Scale: **1:25,000**

Date: **July 2018**

Issue	Date	By	Chkd	Appd
I3	26/07/2018	PC	LB	EMC
I2	30/09/2017	PC	LB	EMC
I1	23/06/2017	AO	LB	EMC

Drawing Title

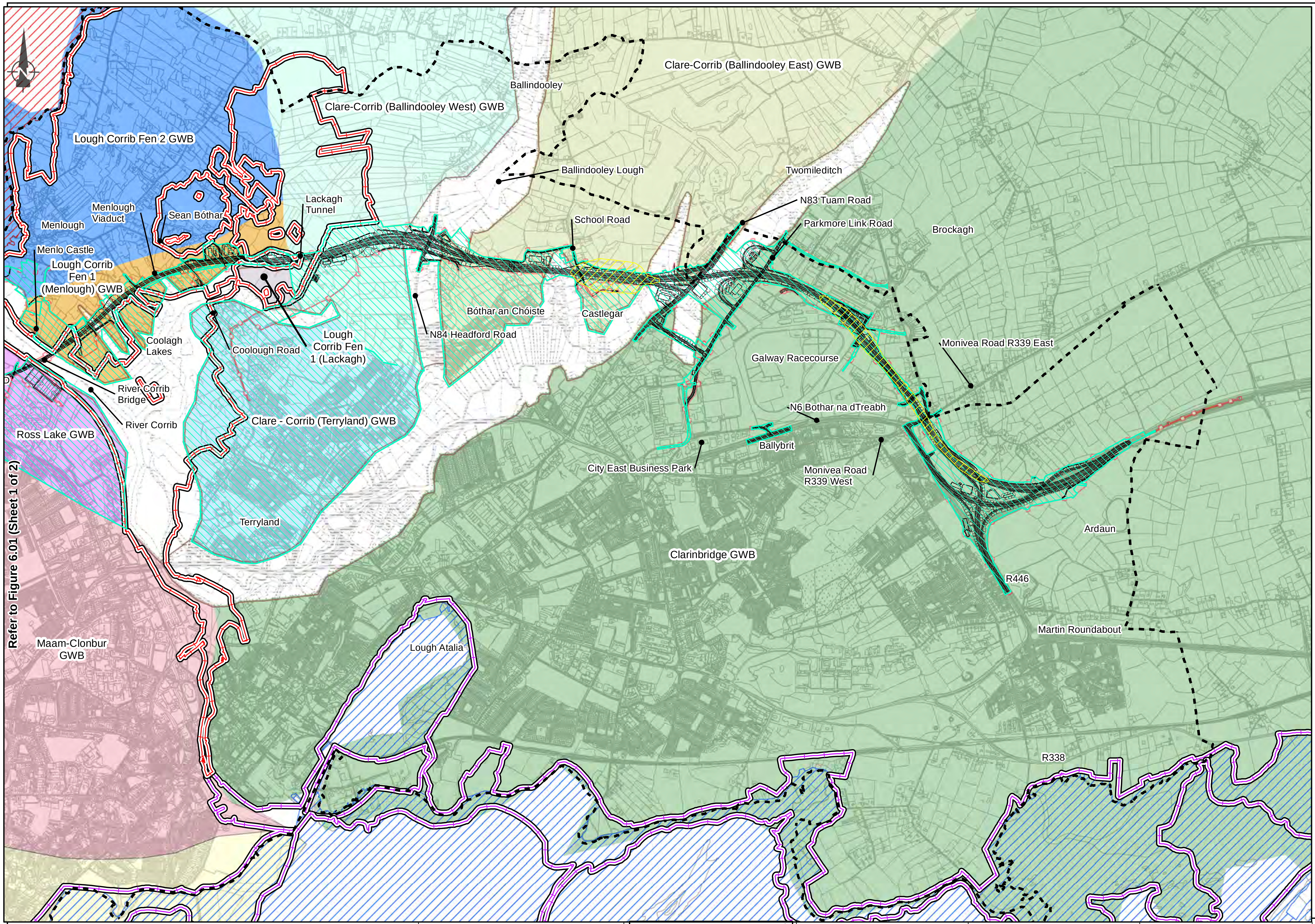
Pre-mitigation potential drawdown and WQ impacts during the construction phase (Sheet 1 of 2)

Drawing Status

For Information

Job No	Drawing No	Issue
233985-00	Figure 6.01	I3

A3



FOR INFORMATION

Legend

- City Boundary
- Proposed Development Boundary
- Proposed Road Development

European Sites

- Lough Corrib cSAC
- Galway Bay Complex cSAC
- Inner Galway Bay SPA
- Lough Corrib SPA
- Estimated extent of buried landscape

Zone of Influence

- Drawdown Zone of Influence
- Area Liable to Contamination

Groundwater Bodies (2017)

- Clare - Corrib (Terryland) GWB
- Clare-Corrib (Ballindooley East) GWB
- Clare-Corrib (Ballindooley West) GWB
- Clarinbridge GWB
- Maam-Clonbur GWB
- Lough Corrib Fen 1 (Lackagh) GWB
- Lough Corrib Fen 1 (Menlough) GWB
- Lough Corrib Fen 2 GWB
- Spiddal GWB
- Ross Lake GWB

Clients

Comhairle Chontae na Gaillimhe / Galway County Council

Key Plan

Sheet 1 / Sheet 2

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Job Title

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Date: **July 2018**

Issue	Date	By	Chkd	Appd
I3	26/07/2018	PC	LB	EMC
I2	30/09/2017	PC	LB	EMC
I1	23/06/2017	AO	LB	EMC

Drawing Title

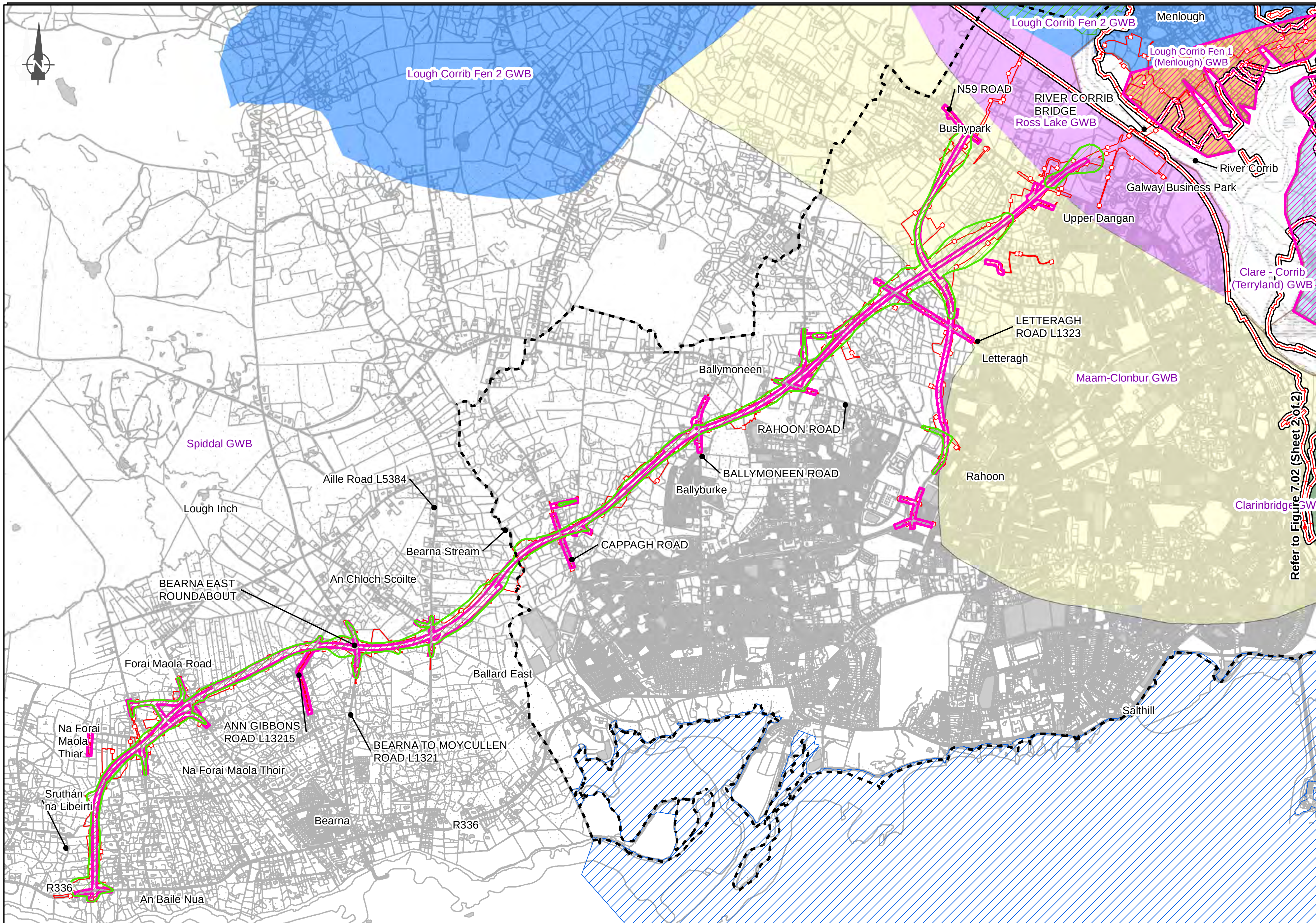
Pre-mitigation potential drawdown and WQ impacts during the construction phase (Sheet 2 of 2)

Drawing Status

For Information

Job No	Drawing No	Issue
233985-00	Figure 6.02	I3

A3



FOR INFORMATION

Legend

Ci... B...

Clients

Comhairle Chontae na Gaillimhe Galway County Council

N6 Galway City Transport Project

An Roinn Iompair Turasóireachta agus Spóirt

Key Plan

Sheet 1

Sheet 2

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www.arup.ie

Job Title

N6 Galway City Ring Road

Scale: 1:25,500

Date: July 2018

Issue	Date	By	Chkd	Appd
I1	26/07/2018	PC	LB	EMC

Drawing Title

Pre-mitigation potential drawdown and WQ impacts during the operation phase (Sheet 1 of 2)

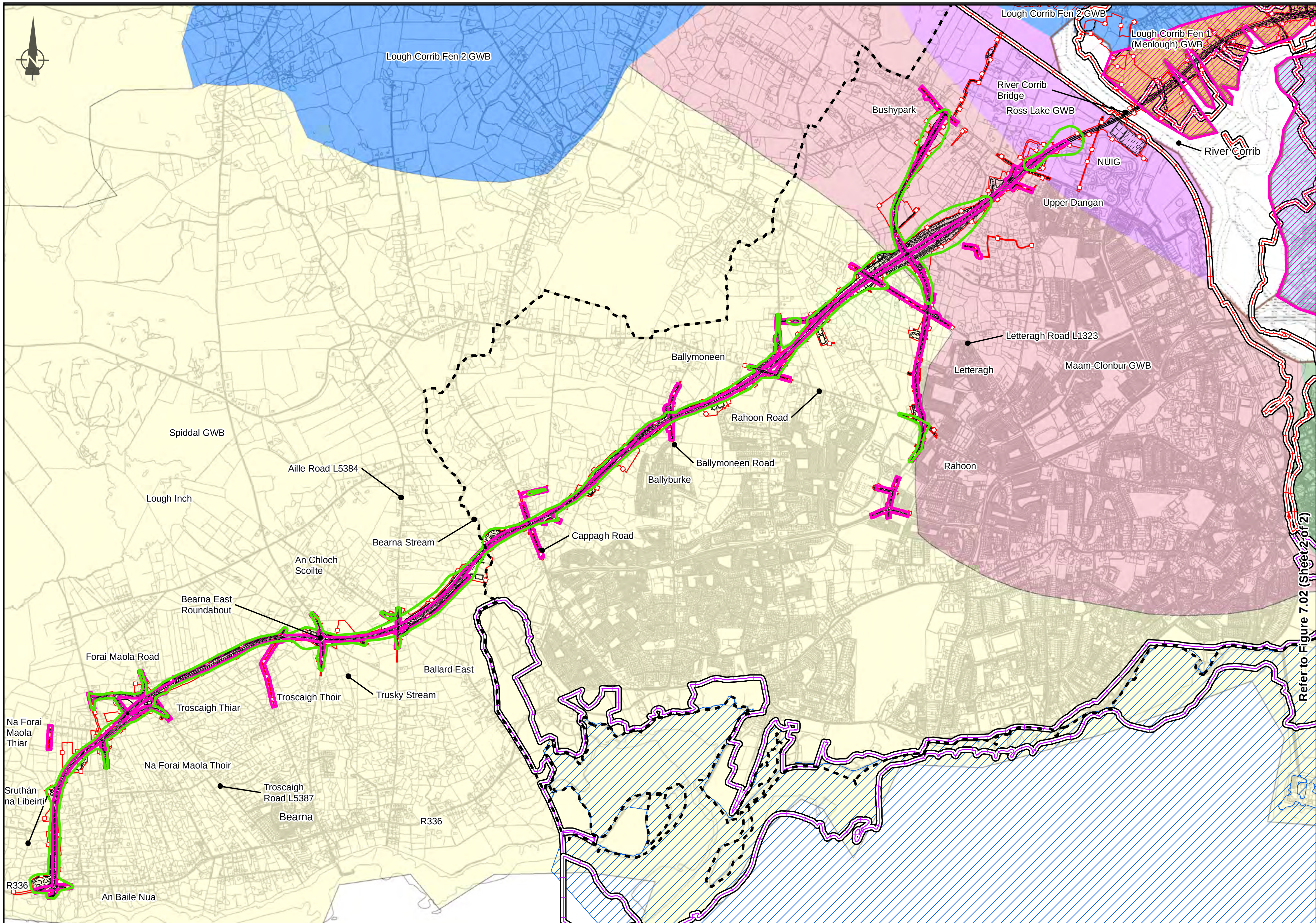
Drawing Status

For Information

Job No	Drawing No	Issue
233985-00	Figure 7.01	I1

A3

FOR INFORMATION



Legend

- City Boundary
- Proposed Development Boundary
- Proposed Road Development

European Sites

- Lough Corrib cSAC

Zone of Influence

- Drawdown Zone of Influence
- Area Liable to Contamination
- Galway Bay Complex cSAC
- Inner Galway Bay SPA
- Lough Corrib SPA
- Estimated extent of buried landscape

Groundwater Bodies (2017)

- Clare - Corrib (Terryland) GWB
- Clare-Corrib (Ballindooley East) GWB
- Clare-Corrib (Ballindooley West) GWB
- Clarinbridge GWB
- Maam-Clonbur GWB
- Lough Corrib Fen 1 (Lackagh) GWB
- Lough Corrib Fen 1 (Menlough) GWB
- Lough Corrib Fen 2 GWB
- Spiddal GWB
- Ross Lake GWB

Clients

Comhairle Chontae na Gaillimhe
Galway County Council

Key Plan

Sheet 1
Sheet 2

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Job Title
N6 Galway City Ring Road

Scale: **1:25,000**

Date: **July 2018**

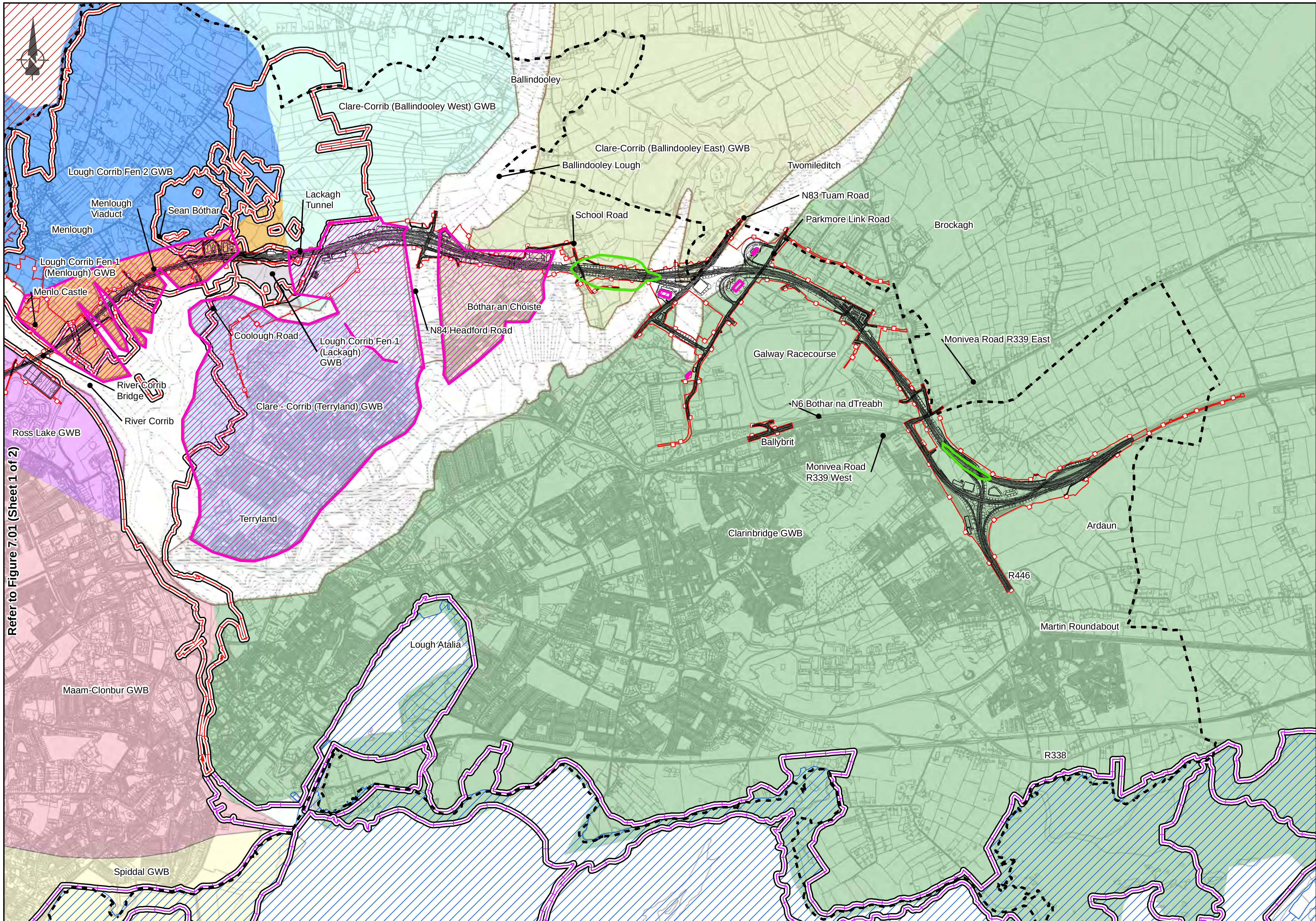
Issue	Date	By	Chkd	Appd
I3	26/07/2018	AG	LB	EMC
I2	30/09/2017	AG	LB	EMC
I1	23/06/2017	PC	LB	EMC

Drawing Title
Pre-mitigation potential drawdown and WQ impacts during the operation phase (Sheet 1 of 2)

Drawing Status
For Information

Job No	Drawing No	Issue
233985-00	Figure 7.01	I3

A3



FOR INFORMATION

Legend

- City Boundary
- Proposed Development Boundary
- Proposed Road Development

European Sites

- Lough Corrib cSAC
- Galway Bay Complex cSAC
- Inner Galway Bay SPA
- Lough Corrib SPA
- Estimated extent of buried landscape

Zone of Influence

- Drawdown Zone of Influence
- Area Liable to Contamination

Groundwater Bodies (2017)

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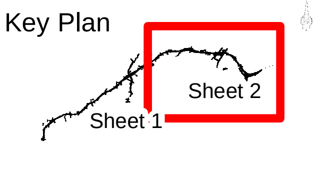
- Clare-Corrib (Ballindooley West) GWB
- Clarinbridge GWB
- Maam-Clonbur GWB
- Lough Corrib Fen 1 (Lackagh) GWB
- Lough Corrib Fen 1 (Menlough) GWB
- Lough Corrib Fen 2 GWB
- Spiddal GWB
- Ross Lake GWB

Clients

Key Plan



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I3	26/07/2018	AG	LB	EMC
I2	30/09/2017	AG	LB	EMC
I1	23/06/2017	PC	LB	EMC

Drawing Title

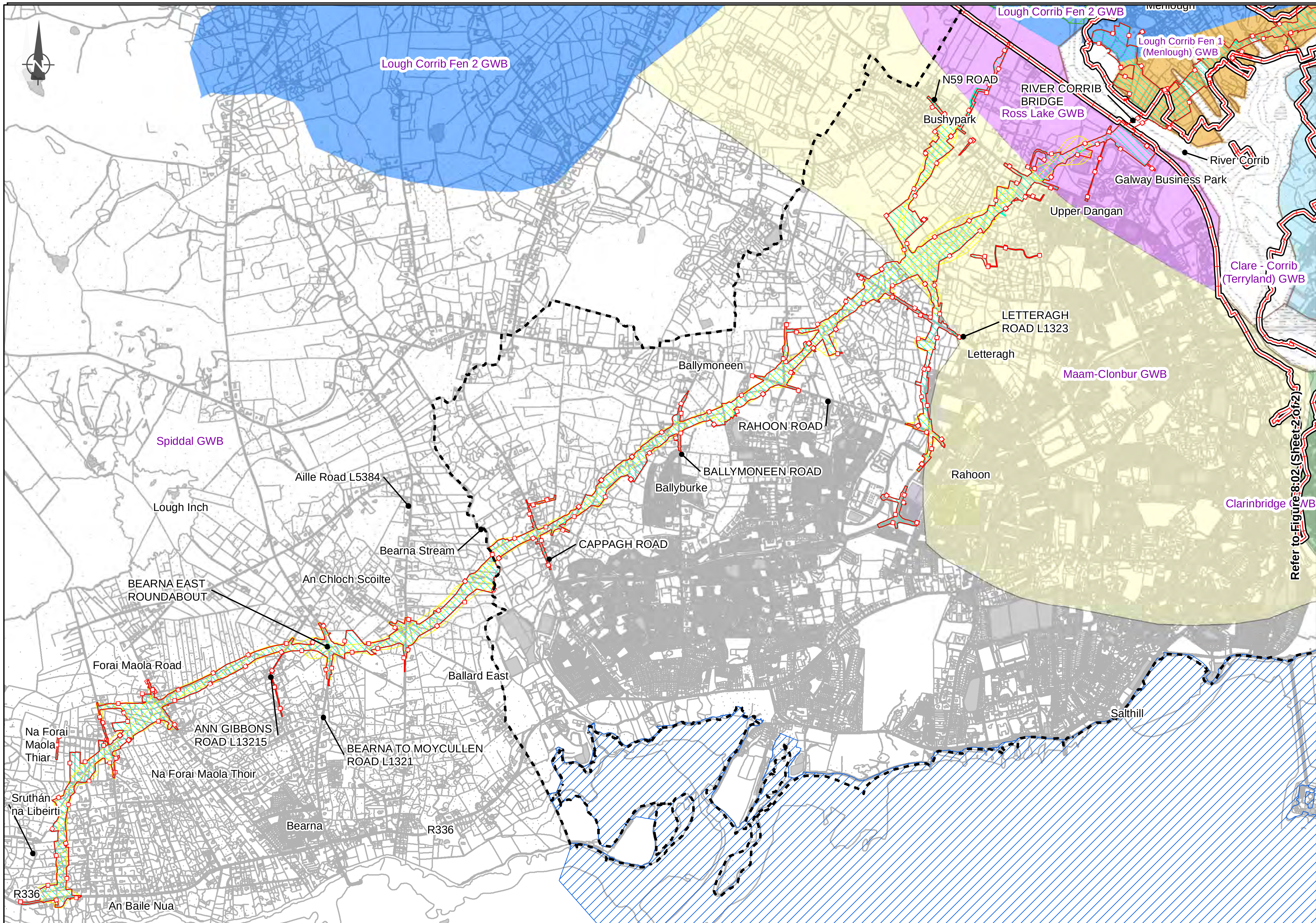
Pre-mitigation potential drawdown and WQ impacts during the operation phase (Sheet 2 of 2)

Drawing Status

For Information

Job No	Drawing No	Issue
233985-00	Figure 7.02	I3

A3



FOR INFORMATION

Legend

Ci... B...

Clients

Comhairle Chontae na Gaillimhe
Galway County Council

Key Plan

Sheet 1
Sheet 2

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www.arup.ie

Job Title

N6 Galway City Ring Road

Scale: **1:25,000**

Date: **July 2018**

Issue	Date	By	Chkd	Appd
I1	26/07/2018	AO	LB	EMC

Drawing Title

Post-mitigation potential drawdown and WQ impacts during the construction phase (Sheet 1 of 2)

Drawing Status

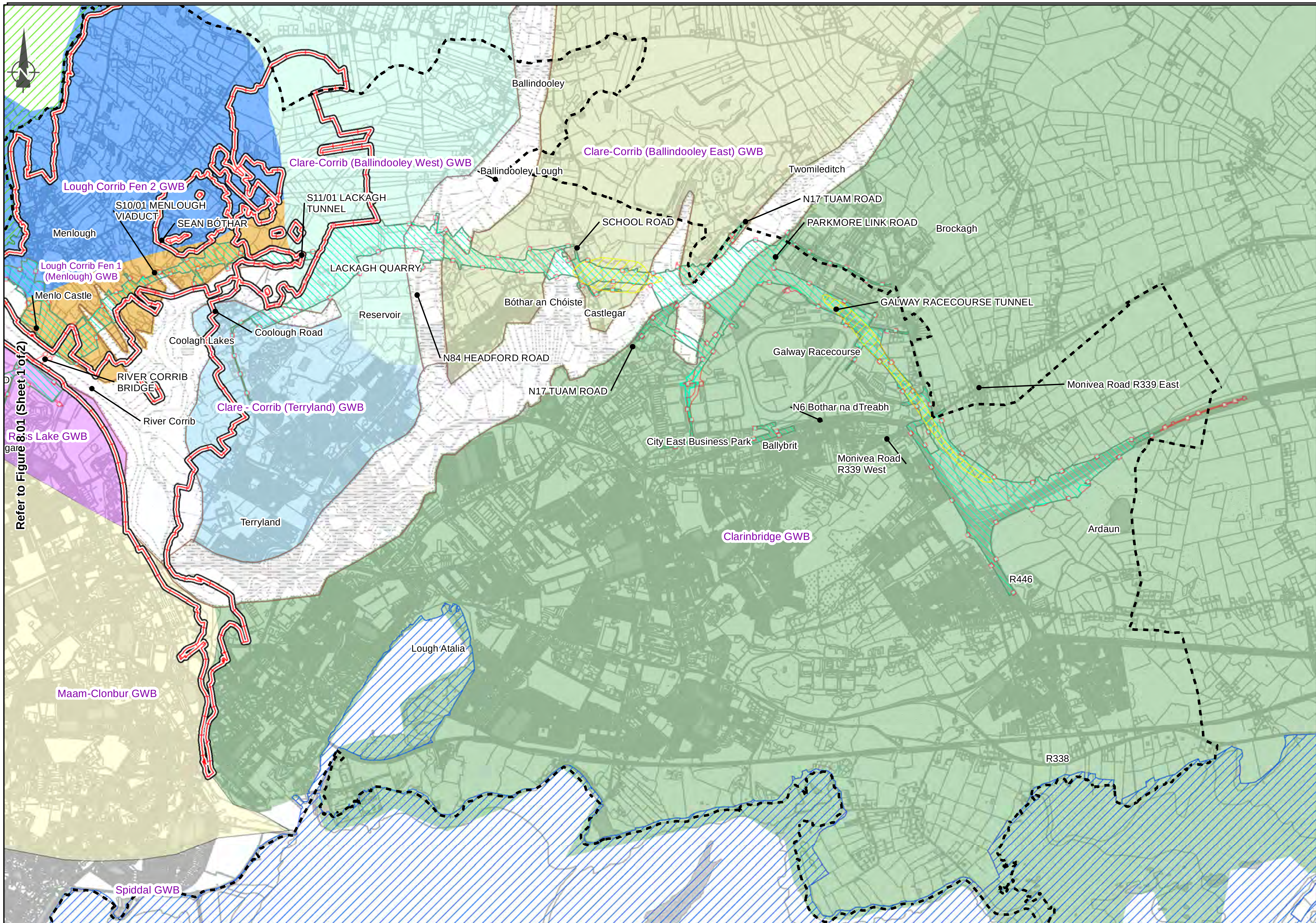
For Information

Job No	Drawing No	Issue
233985-00	Figure 8.01	I1

A3

FOR INFORMATION

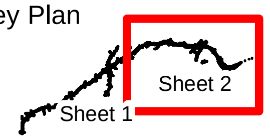
Legend



Ci... B...

Clients

Key Plan



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Job Title

N6 Galway City Ring Road

Scale: **1:25,000**

Date: **July 2018**

I1	26/07/2018	AO	LB	EMC
Issue	Date	By	Chkd	Appd

Drawing Title

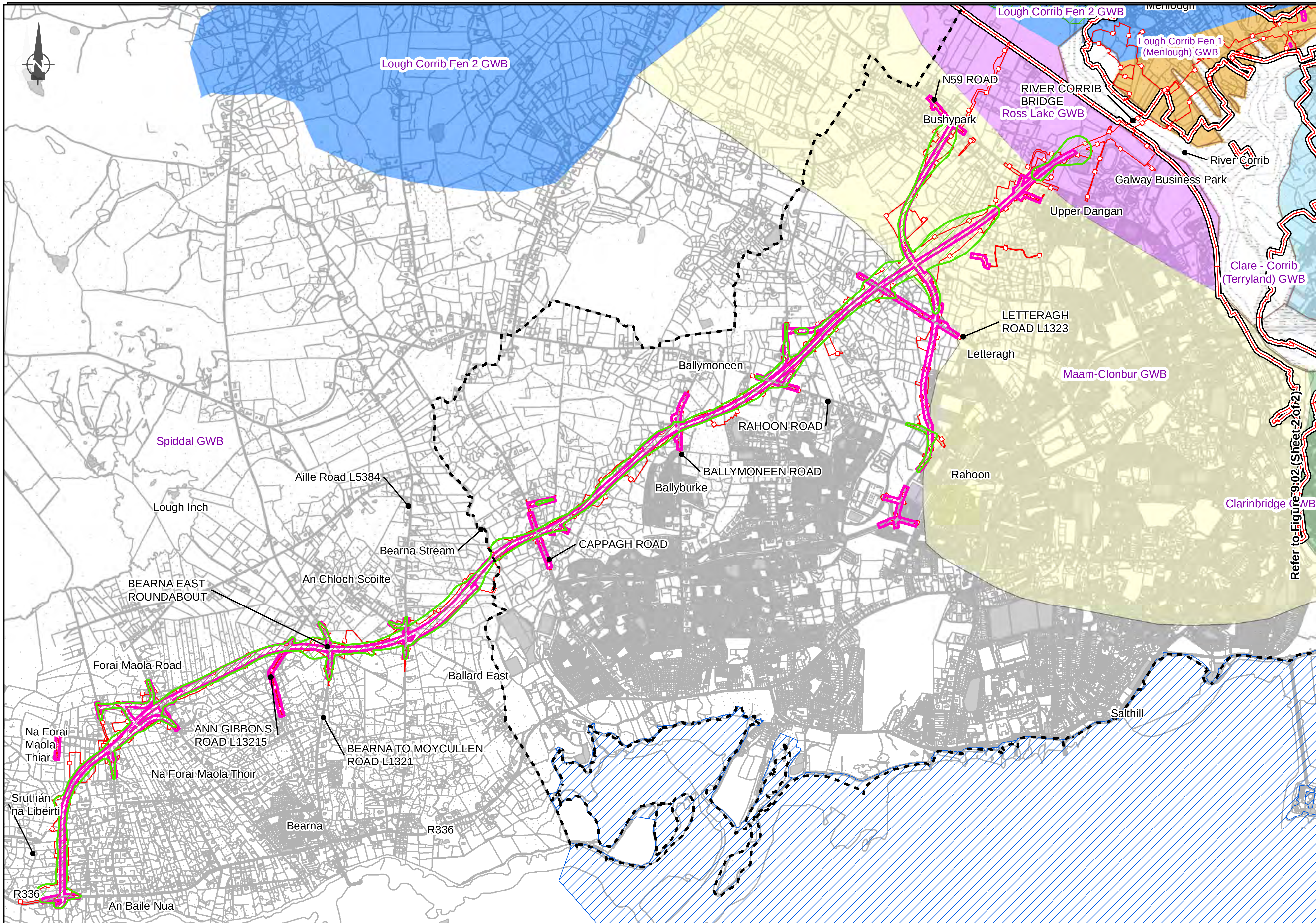
Post-mitigation potential drawdown and WQ impacts during the construction phase (Sheet 2 of 2)

Drawing Status

For Information

Job No	Drawing No	Issue
233985-00	Figure 8.02	I1

A3



FOR INFORMATION

Legend

Ci... B...

Clients

Comhairle Chontae na Gaillimhe Galway County Council

N6 Galway City Transport Project

An Roinn Iompair Turasóireachta agus Spóirt

TII

Key Plan

Sheet 1

Sheet 2

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Issue	Date	By	Chkd	Appd
I1	26/07/2018	DM	LB	EMC

Drawing Title

Post-mitigation potential drawdown and WQ impacts during the operation phase (Sheet 1 of 2)

Drawing Status

For Information

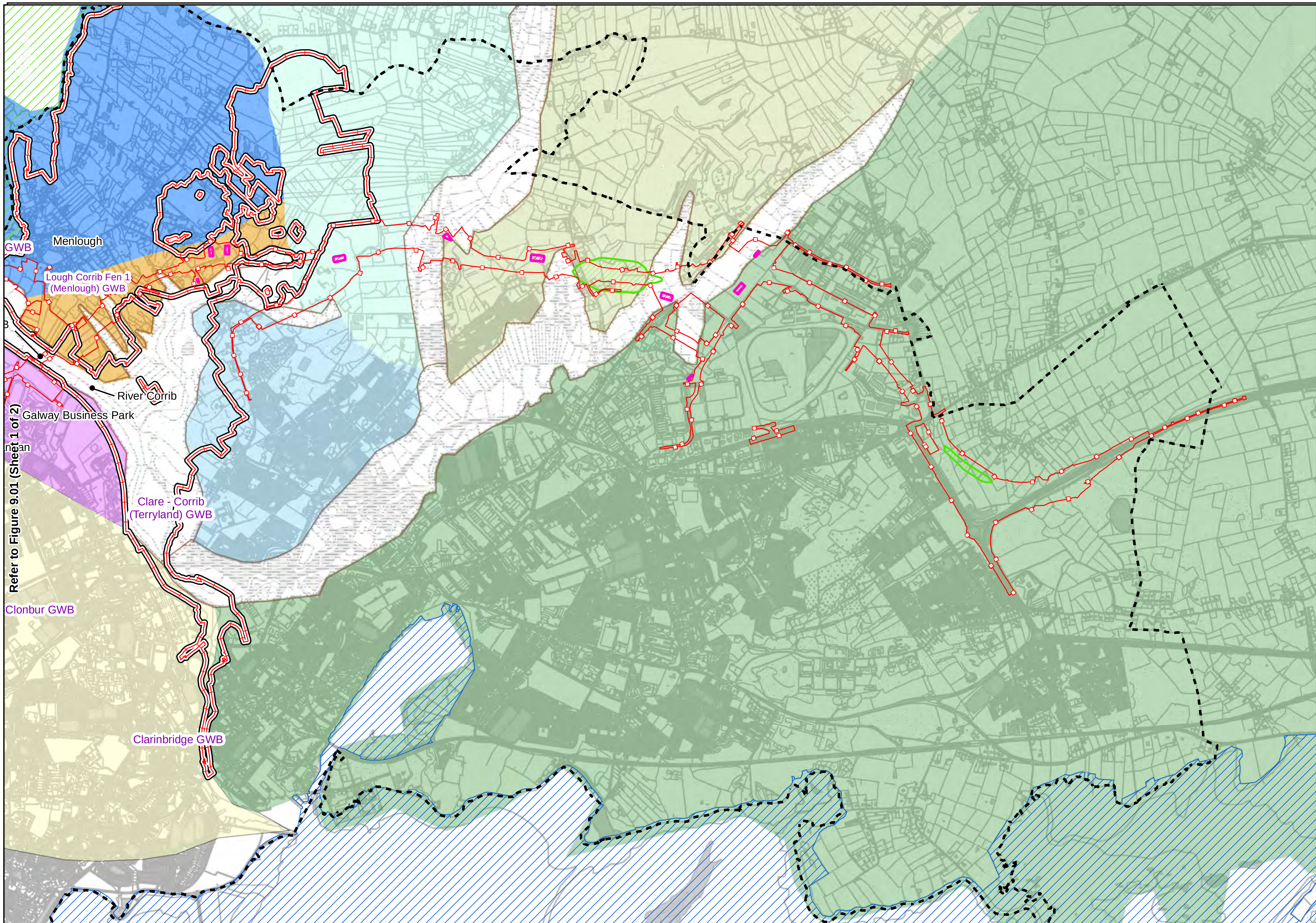
Job No	Drawing No	Issue
233985-00	Figure 9.01	I1

A3

FOR INFORMATION

Legend

Ci... B...



Clients

Key Plan

Sheet 1

Sheet 2

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Issue	Date	By	Chkd	Appd
I1	26/07/2018	DM	LB	EMC

Drawing Title

Post-mitigation potential drawdown and WQ impacts during the operation phase (Sheet 2 of 2)

Drawing Status

For Information

Job No	Drawing No	Issue
233985-00	Figure 9.02	I1