IN THE MATTER OF AN APPLICATION TO

AN BORD PLEANÁLA

FOR APPROVAL OF (I) THE N6 GALWAY CITY RING ROAD PURSUANT TO SECTION 51 OF THE ROADS ACT 1993 (AS AMENDED); (II) THE N6 GALWAY CITY RING ROAD MOTORWAY SCHEME 2018; and (III) THE N6 GALWAY CITY RING ROAD PROTECTED ROAD SCHEME 2018

ABP Ref. ABP-302848-18 and ABP-302885-18

ORAL HEARING

STATEMENT OF Evidence

Responses to Hydrogeology

Objection/Submissions

by

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and assisted by

Catherine Buckley, M.Sc, BA, PGeo, EurGeol

20 February 2020

1 Qualifications and Experience

1.1 Lead Witness

1.1.1 My name is Dr Leslie Brown and I am a senior hydrogeologist with Arup. I have 22 years' experience of which 16 have been based in Ireland. My academic qualifications include a Ph.D. in karst hydrogeology (study area in the northwest of Ireland), a M.Sc. in Engineering Geology and a B.Sc. in Geology. As part of my academic research I have completed post-doctoral studies into recharge and vulnerability of groundwater in Ireland.

1.1.2 I have been working as a hydrogeologist both in Ireland and Great Britain since 1999. Between 2011-2014 I was based in the Middle East. As a consultant, I am a technical groundwater specialist for linear developments (such as road and rail) as well as undertaking assessments on groundwater resources and management. The projects in Ireland on which I have worked include multiple groundwater assessments in limestone areas in the west of Ireland, including the M17/18 Gort to Tuam Motorway Scheme, the N17 Sligo, groundwater flooding at turloughs in County Fermanagh and karst hydrogeology assessments in the borders area of Counties Cavan and Fermanagh. I am a co-author of the 2009 TII Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes.

1.2 Support Witness

1.2.1 I am supported by my colleague Catherine Buckley who peer reviewed my work. Catherine is the Water team leader for Arup in Ireland and has 14 years' experience in the assessment of hydrogeological impacts on major infrastructure projects. She has a MSc in hydrogeology and is a Professional Geologist with the Institute of Geologists of Ireland (the professional body for geologists in Ireland) and the European Federation of Geologists. She is a recent past President of the IGI and former board member of the International Association of Hydrogeologists (Irish Group). Catherine was a co-author of the 2013 IGI guidance document 'Guidelines for the Preparation of Soils, Geology and Hydrogeology chapters is Environmental Impact Assessment Reports' and the TII design document 'Road Drainage and the Water Environment'. She is currently Chair of the Working Group updating the IGI EIAR guidelines to reflect recent legislation changes.

2 Role in Proposed Road Development

2.1 My role in the N6 Galway City Ring Road Project involved undertaking the hydrogeological appraisal in respect of the proposed road development as the senior hydrogeologist, including the constraints and route options studies and the hydrogeological assessment to inform the EIAR and NIS. My responsibilities include:

- Managing the hydrogeology team to ensure that potential impacts to groundwater receptors are appropriately assessed in the EIAR
- Working with cross topic specialists (specifically, Soils and Geology, Biodiversity and Hydrology) to ensure that potential hydrogeological interactions are appropriately considered in the EIAR
- Working with the Biodiversity team to ensure that groundwater dependent terrestrial ecosystems (GWDTE) of Natura 2000 sites are fully considered in the NIS

2.2 Catherine acted as a reviewer on this project since 2014 including a peer review of the hydrogeology chapter of the EIAR.

3 Key issues in relation to Hydrogeology

3.1 Chapter 10 (Hydrogeology) of the EIAR and Appendix A (Hydrogeological Assessment) of the NIS are to be taken as read in their entirety and are not replicated here. To assist the Board in its consideration of the applications for approval, and for the convenience of all participants at this hearing and to set the context for responding to the objections and submissions, the key items pertaining to the hydrogeological assessment of the proposed road development detailed in Chapter 10 of the EIAR and Appendix A of the NIS are summarised briefly below.

3.2 The key issues related to hydrogeology arise where there is potential for changes to groundwater levels, groundwater flows or groundwater quality during the construction or operation of a proposed road development. Where these potential changes occur at groundwater features then the features may be impacted.

3.3 Water levels or flow paths can change in a number of construction or operation scenarios including situations where groundwater is artificially lowered by groundwater pumping (dewatering) during construction or where cuttings permanently lower the groundwater table during operation. These are discussed in more detail in Section 4.2 of this Statement of Evidence and in Section 10.5.3 (construction) and Section 10.5.4 (operation) of Chapter 10 of the EIAR as well and Section 5.2 (construction) and 5.3 (operation) of Appendix A of the NIS. Groundwater quality changes that could potentially arise are discussed in detail in Section 4.3 of this Statement of Evidence and in Section 10.5.3 (construction) and Section 10.5.4 (operation) of Chapter 10 of the EIAR as well and Section 5.2 (construction) and 5.3 (operation) of Appendix A of the NIS. Based on the

characteristics of the design (presented in Section 10.4 of Chapter 10 of the EIAR) and the ground/groundwater, zones where groundwater levels or quality may change have been conservatively defined in the EIAR and the NIS. These are presented in Section 10.5 of Chapter 10 of the EIAR and Section 5.2.1 of Appendix A of the NIS.

3.4 The proposed road development crosses two main aquifer types: (i) granite in the west and (ii) limestone in the east, with the boundary between these two main aquifer types coinciding approximately with the N59 Moycullen Road. In the west the study area extends 250m from the proposed development boundary – this is because of the limited movement of groundwater in granite. In the east, the study area extends as far as the GSI groundwater catchment boundaries, as water is able to move faster and easier through limestone.

3.5 Within the Study Area 45 groundwater receptors were identified in Section 10.3.4 of the Chapter 10 of the EIAR. These included two aquifers, four commercial abstraction wells, one groundwater group water scheme, 21 agricultural/domestic abstraction wells, one geothermal well, 16 groundwater dependent terrestrial ecosystems (GWDTE – these are ecological sites that depend on groundwater), four of which are European sites, and one location where surface water is dependent on groundwater. These are presented on Figures 10.5.001 and 10.5.002 of the EIAR. The study area for the NIS includes European sites as detailed in Section 4 of Appendix A of the NIS.

3.6 Extensive data was collected in the study area, particularly in the vicinity of the receptors to allow the baseline environment to be understood. The baseline hydrogeological environment is presented in Section 10.3 of Chapter 10 of the EIAR and Section 4 of Appendix A of the NIS. The water level data collected includes peak groundwater levels recorded during the winter of 2015/16 where storms caused significant groundwater flooding in the west of Ireland as well as low groundwater levels from the summers of 2015, 2016 and 2017. Indeed, it should be noted that the monitoring between 2015 and 2017 captured one of the wettest winters and driest summers. This is of particular importance as it allows the maximum and minimum water levels to be considered in the design levels of the proposed road development and the arising impacts to be fully assessed in extreme scenarios.

3.7 The extensive data collected identified a number of deep, steep sided valleys (up to 106m below surface) that are buried below the landscape of Galway City. These buried valleys have only been found in the limestone aquifer to the east of the River Corrib. These features represent an ancient landscape that has been filled in with clay over time. The steep sided and deep nature of the palaeolandscapes explain why sudden changes in depth to rock were detected during the ground investigations. Analysis of the groundwater levels in these palaeolandscapes has allowed new groundwater catchments to be defined as the clay filled valleys do not allow groundwater to flow across them i.e. they act as barriers to groundwater flow. The outlines of the new catchments are presented in Figure 10.5.002 of the EIAR and Figure3. 10.1.1 and 10.1.2 of Appendix A of the NIS.

3.8 As outlined above, 16 of GWDTE have been identified in the EIAR. Of these four are European sites, namely Lough Corrib cSAC, Galway Bay Complex cSAC, Lough Corrib SPA and Inner Galway Bay SPAs, and three are National Heritage Areas (NHAs), namely Moycullen Bogs NHA (these bogs are three separate bog sites), Lough Corrib pNHA and Galway Bay Complex pNHA. The updated groundwater catchments illustrate these connections, or lack of, between groundwater bodies and these features.

3.9 There are four GWDTE sites in the study are for the NIS, namely Lough Corrib cSAC, Galway Bay Complex cSAC, Lough Corrib SPA and Inner Galway Bay SPAs as detailed in Section 4 of Appendix A of the NIS.

3.10 One site, Coolagh Lakes, was highlighted as being of critical importance as it is part of the Lough Corrib cSAC and it is fed by a single spring, Western Coolagh Spring, which is supplied by groundwater from the Lough Corrib Fen 1 (Menlough) groundwater body (GWB). The impact assessment identified that if groundwater dewatering was required during the construction of the Menlough Viaduct and Lackagh Tunnel then there could be potential reduction in flow at Western Coolagh Spring. Detailed mitigation measures were designed to remedy this potential risk and these are outlined in Section 10.4 and Section 10.5.3.1.2 of Chapter 10 of the EIAR. and Section 6 of the NIS Appendix A.

3.11 Of the wells identified, there will be a significant impact to one agricultural/domestic abstraction wells and four commercial abstraction wells. Mitigation measures such as replacement of the wells or alternative supply have been proposed where necessary. From submissions/objections received, four further agricultural/domestic wells have been identified as being impacted.3.12. The modification to the Parkmore Link Road includes revision to drainage network S22C2, including the location of the infiltration basin associated within. Based on the hydrogeological assessment for the proposed road development the thickness of the unsaturated zone at infiltration basin S22C2 is anticipated to have a minimum thickness of 6m. Table 10.22 of Chapter 10 of the EIAR has been updated accordingly and is presented below in Table 1. The minimum unsaturated zone thickness for the revised basin location meets TII Road Drainage and the Water Environment Guidelines (reference HD45/15 Appendix C, March 2015).

Table 1: Summary the unsaturated thicknesses below invert level for all infiltration basins

Network Ref	S19A	S19B	S20	S21A	S21B	S22A	S22B	S22C2	S22E	S40
Minimum unsaturated zone (m)	1.4	0.3	0	2.6	9.1	2.0	3.9	6.0	9.9	1.0

3.12 The proposed modification to the Parkmore Link Road will have no effect on the hydrogeology assessment results contained in the EIAR, NIS and RFI Response.

3.13 The current NUIG planning permission application (Ref 19/373) to construct additional playing pitches and the two proposed strategic housing development applications Ob_229 and Ob_469 and S_003 do not change the conclusions of the cumulative impact assessment on Hydrogeology contained in the EIAR and NIS.

4 Responses to Submissions/Objections

4.1 Overview

4.1.1 22 of the 296 submissions/objections made to An Bórd Pleanála (ABP) in respect of the N6 Galway City Ring Road (GCRR) Environmental Impact Assessment Report (EIAR), Natura Impact Statement (NIS), Motorway Scheme (MS) and Protected Road Scheme (PRS) include observations relevant to hydrogeology. Six of the 17 submissions made to ABP in respect of the Request for Further Information (RFI) Response submitted August 2019 also include observations relevant to hydrogeology. The issues raised are:

- Potential impacts to private domestic wells
- Potential impacts to private commercial wells
- Possible impacts to water supply quality
- Potential impacts to private wastewater treatment systems
- Potential impact to a geothermal borehole
- Potential for groundwater flooding at Lackagh Quarry
- Potential for structural instability in areas of groundwater drawdown
- Potential for impacts to Lough Corrib cSAC through the hydrogeological interactions
- Potential for impact to Moycullen Bogs NHA through hydrogeological interactions

4.1.2 Each of these issues are discussed in detail below with specific responses provided for each of the individual submissions/objections that raised groundwater related issues.

4.2 Supporting technical information for responses

4.2.1 Two concerns that were raised across a number of submissions/objections, and interlink with many of the items listed above, relate to impacts associated with (1) lowering groundwater levels or (2) deterioration of water quality on a number of different features. For this reason, a brief overview of these assessments is given here to provide context for the responses to the specific submissions and to avoid repeating the same information in each response. The responses to specific submissions are detailed in the subsequent sections. Potential impacts due to the lowering of groundwater levels has been discussed and assessed extensively in Sections 10.5.3 and 10.5.4 of Chapter 10 of the EIAR and Sections 5.2 and 5.3 of Appendix A of the NIS.

Groundwater levels

4.2.2 Groundwater levels measured along the proposed road development have been recorded during the monitoring period 2015 to 2017. This data is presented in Section 10.3.2 of Chapter 10 of the EIAR and Section 4 of Appendix A of the NIS.

4.2.3 During construction groundwater levels can be lowered by dewatering operations (this is where groundwater is pumped out of the ground to allow foundations etc to be constructed). During the operation of the proposed road development, groundwater can be lowered by drainage, for example if the invert level of the drain is below the groundwater level, groundwater will flow into the drain – this is more likely to occur where there is a 'cut' required in the ground level. In these scenarios, groundwater levels can be reduced in the surrounding area and this is referred to as 'drawdown'. Every location where groundwater drawdown may occur was assessed extensively in Chapter 10 of the EIAR, with detailed assessments are presented in Table 10.17, and NIS Section 10.4.

4.2.4 In order to establish if dewatering, or drainage in cuts will influence the groundwater levels in the surrounding area, the radius of influence was calculated. The radius of influence is the area within which groundwater levels are affected by drawdown. Outside the radius of influence, there will be no effect on groundwater levels. The radius of influence was calculated using the Sichardt empirical formula as follows:

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

Where,

Ro = radius of influence

C = empirical calibration factor

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

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

4.2.5 Based on this calculation, the greater the drawdown and the hydraulic conductivity, the greater the radius of influence will be. This radius of influence is referred to as the 'Zone of Influence' or 'ZoI' in Chapter 10 of the EIAR and that phrase will be

used for the rest of this submission to allow comparison between the EIAR and this response.

4.2.6 Section 10.4 of Chapter 10 of the EIAR, together with Appendix A.10.6 of the EIAR provides the details of how drawdown and the zone of influence is calculated. The drawdown and zone of influence is summarised in Table 10.17 of Chapter 10 of the EIAR and Section 5.2.1 of Appendix A of the NIS. This analysis was undertaken on a highly conservative basis to ensure that the calculated zone of influence would be as large as possible. Some of the conservative assumptions used included:

1. Using the maximum recorded winter groundwater level so that maximum drawdown was used in the calculation, which accordingly increases the ZoI.
2. The hydraulic conductivity used is the highest recorded for the section of aquifer along the proposed road development. Details of the range of hydraulic conductivity for both granite and limestone are presented in Plate 10.1 of Chapter 10 of the EIAR and Plate 9 of Appendix A of the NIS.
3. The drawdown calculation was applied at 100m points in each cutting to ensure that the ZoI accommodates changes cutting length such as depth of cut and hydraulic gradient.
4. It is assumed that the dewatering of the groundwater level is 1m deeper than the drainage invert depth to allow for sumps or excavations that may be required during construction. During operation the dewatering of the groundwater level is assumed to be the drainage invert level. On this basis construction dewatering of the groundwater is deeper than that required for operation and drawdown may be presented were the proposed road development is at grade or on embankment. This is particularly the case in the granite area, where the groundwater level is assumed to be at surface.

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

4.2.8 As outlined previously, these calculations were presented in detail in Section 10.4 of Chapter 10 of the EIAR with the summary of each cutting presented in Table 10.17 of the EIAR and are discussed again here to minimise repetition in the responses to the submissions/objections which are outlined below.

Groundwater quality

4.2.9 In addition to this, a detailed assessment was undertaken in Sections 10.5.3 and 10.5.4 of Chapter 10 of the EIAR and Section 5.2.2 of Appendix A of the NIS of the potential for impacts to water quality from the proposed road development. Suspended solids in site runoff during construction is the prime concern, with pollution from accidental spillages or vandalism also being a risk. In Section 10.5.3.2 of Chapter 10 of the EIAR and Section 5 of Appendix A of the NIS, the risks to the water quality of a well were assessed based on a number of factors including:

- The likelihood of contaminated runoff entering groundwater: as outlined in Section 10.5.3 of Chapter 10 of the EIAR and Section 5.2.2 of Appendix A of the NIS, there are a number of factors that determine if any potentially contaminated water at the surface will enter groundwater. Areas with thick soil or subsoil, with low permeability (i.e. water flows through it slowly) are more likely to cause water to stay on the surface and runoff to drains or watercourses than to enter groundwater, or areas with a low 'recharge cap' (the amount of water the rock comprising the aquifer can accept) are unlikely to be vulnerable to surface spills. Areas with thinner subsoil or a higher recharge cap are more vulnerable to contamination. These locations are shown in detail on Figures 10.3.1 and 10.3.2 of the EIAR but it can broadly be said that the east of the city is more vulnerable than the west to any spillages at the surface.

- The position of a feature of interest relative to any potential source of contamination: if a features such as a well is 'up-gradient' of the potential source then the groundwater will flow away from the feature and towards the source of contamination, but if the feature is 'down-gradient' of the potential source, then any potential contamination that enters groundwater would flow towards the it. Features up-gradient of any locations where spillages may occur (e.g. storage compounds etc) are not at risk.

- The permeability of the rock that groundwater flows through: The higher the permeability of a rock, the faster water can travel through it. This can also be referred to as the hydraulic conductivity of the rock. As outlined in Section 10.3.2 of Chapter 10 of the EIAR and Appendix A10.5 of the EIAR extensive testing was undertaken to fully understand this and how it varied across the length of the proposed road development.

4.2.10 A detailed assessment was undertaken in Section 10.5.3 of Chapter 10 of the EIAR to calculate where contamination would potentially travel to if a spill or contamination event occurred. These are shown as Water quality zones and are based on the criteria above, which are presented on the maps in Figure 10.7.001 and 10.7.002 of the EIAR for construction and Figure 10.8.001 and 10.8.002 of the EIAR for operation. Based on the water level and aquifer properties (flow types and hydraulic conductivity) of the granite the potential dispersal of contaminant in the event of an accidental spill is small and would be contained within the proposed development boundary. For the limestone, as the aquifer properties have the potential for karst flow then there is potential for wider dispersal downgradient from the proposed road development. To ensure conservative assessment, in the limestone areas with karst flow paths, in these areas the aquifer extent downgradient of proposed road development discharge points is considered to have potential for deterioration in water quality. To protect against this risk additional measures for managing karst are detailed in a karst protocol that is part of the Construction Environmental Management Plan (CEMP), in Appendix A.7.5 of the EIAR.

4.2.11 As outlined above, detailed analysis has been undertaken to ensure that the potential impacts to changing groundwater levels and quality are fully understood and assessed. The following sections outlines how these assessments relate to each of the submissions/objections received.

4.3 Potential impacts to Private Domestic Wells

Issues

4.3.1 Five submissions/objections raise concerns over potential impacts to private domestic wells: Ob_152, Ob_239, Ob_311, Ob_496 and S_78. A summary of the concerns raised regarding domestic wells in each submission is presented below:

- S_078: The submission from the Health Service Executive raises a query regarding mitigation measures proposed to mitigate against potential impacts to groundwater quality at a well.
- Ob_152: The submission notes the presence of a 'natural spring well' on their grounds and questions whether it will be impacted during construction. It notes that this spring is not identified as a constraint in the EIAR.
- Ob_239: The submission (point no. 4) notes concern regarding impact to well located close to the proposed road development.
- Ob_311: The submission requests that their water source (private well on site) will not be interfered with.
- Ob_496: The submission states that a road cutting included as part of the proposed road development will impact their well and queries whether the well will be monitored.

Response

4.3.2 Extensive assessments were undertaken and presented in Section 10.4, 10.5.3 and 10.5.4 of Chapter 10 of the EIAR to assess any potential impacts on identified private wells. This response outlines the methodology behind the assessments undertaken and summarises the mitigation measures included in Chapter 10 of the EIAR for private wells.

4.3.3 The wells included in the assessment in Chapter 10 of the EIAR were identified through a detailed well survey, all public databases (Geological Survey of Ireland, National Federation of Group Water schemes etc) and discussions with landowners. The wells identified in the submissions/objections above were not identified and are now assessed individually in this response.

4.3.4 Potential impacts that may occur at private wells include lowering the groundwater level, which may reduce the supply at the well, or a deterioration in water quality at the well. For clarity, the response to each of the submissions listed above will consider both concerns.

4.3.5 The potential impacts on water quality are presented in Section 10.4 of Chapter 10 of the EIAR, those potential construction impacts to private wells are presented in Section 10.5.3.1 to 10.5.3.4 of Chapter 10 of the EIAR. These highlighted areas conservatively show the worst-case scenario of where contamination may spread to and are based on assessment of the aquifer properties and potential flow paths. Further details on the assessment of potential water quality impacts and the mitigation measures thereof are presented in Section 4.2 above. In the case that any wells occur within the areas where water quality could deteriorate then those wells will be replaced by an alternate supply.

4.3.6 An extensive assessment was undertaken in Section 10.4 of Chapter 10 of the EIAR and Appendix A.10.6 of the EIAR to determine the locations where groundwater levels would be lowered during construction and operation. As outlined in Section 4.2 above, the zone of influence (area within which groundwater levels are lowered) was calculated for all areas where groundwater lowering may happen during construction. This included large cuts during construction where dewatering may be required or sections of drainage below the current groundwater level. Each of these locations had a conservative zone of influence calculated for it as presented in Figure 10.7.001 and 10.7.002 of the EIAR.

4.3.7 As outlined in Section 10.6.2.2 of Chapter 10 of the EIAR, all wells within 150m of the proposed development boundary (or 50m from the calculated ZoI if greater) would be included in a programme of monitoring designed to ensure any changes that occur during construction are identified quickly and a replacement water supply established. This monitoring programme includes monitoring the water quality and level for a year prior to any construction occurring – this allows the natural fluctuations in the water levels and quality parameters to be understood throughout the year. This monitoring will continue throughout the construction period and for 1 year into the operation of the proposed road development to ensure that no impacts have been observed in the well. These mitigation measures have been outlined in detail in Section 10.6.2.2.2 of Chapter 10 of the EIAR.

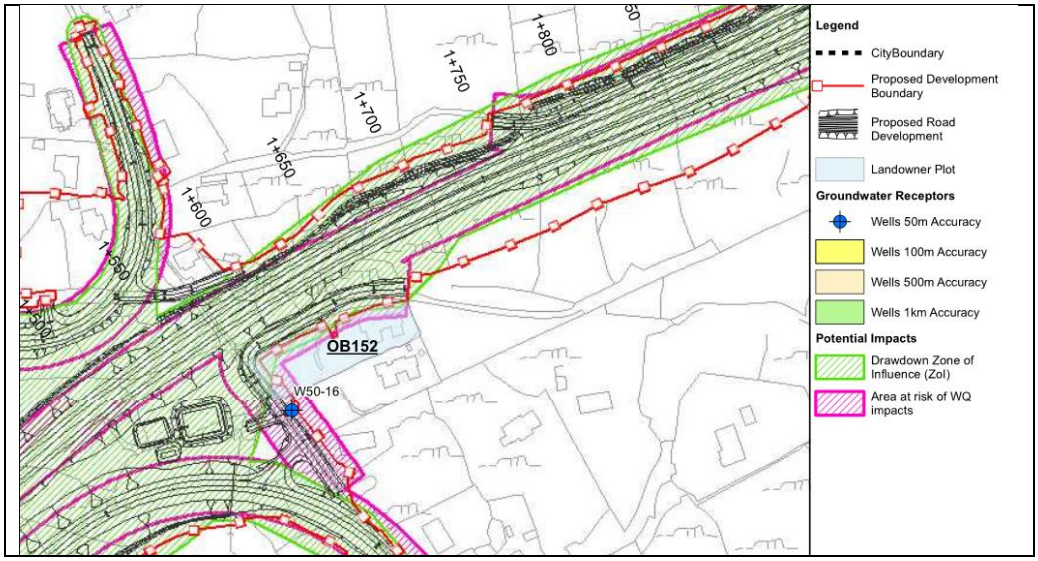
4.3.8 If any impacts are detected then an alternative supply will be arranged. It should be noted that groundwater levels increase and fall slowly, allowing time for a replacement well or alternative water supply to be developed. Similarly, if a spillage of any contaminated material does occur, which is very unlikely in circumstances where the mitigation measures identified in the application documentation are effectively implemented, the travel time that it will arrive at a specific well will be dependent on the flow rate of the groundwater at that location. Groundwater flow and aquifer properties for individual sections of the proposed road development are discussed in detail in Section 10.3.2 of Chapter 10 of the EIAR and is assessed below for each of the wells in the submission list above.

4.3.9 Reference to Well W1000-02 is made in submission S_078 from the Health Service Executive. This well is listed in error in Chapter 10 of the EIAR. Data on W1000-02 was acquired from the Geological Survey of Ireland. However, upon inspection during site surveys it became apparent that no such well exists. During these site surveys Well W50-10 was located in the vicinity of where the GSI data had

suggested W1000-02 existed. W50-10 was assessed in Chapter 10 of the EIAR and, as noted in Chapter 10, the loss of W50-10 will be replaced as part of the mitigation measures. W50-10 will be decommissioned as part of the proposed road development following the commissioning of the replacement well into production.

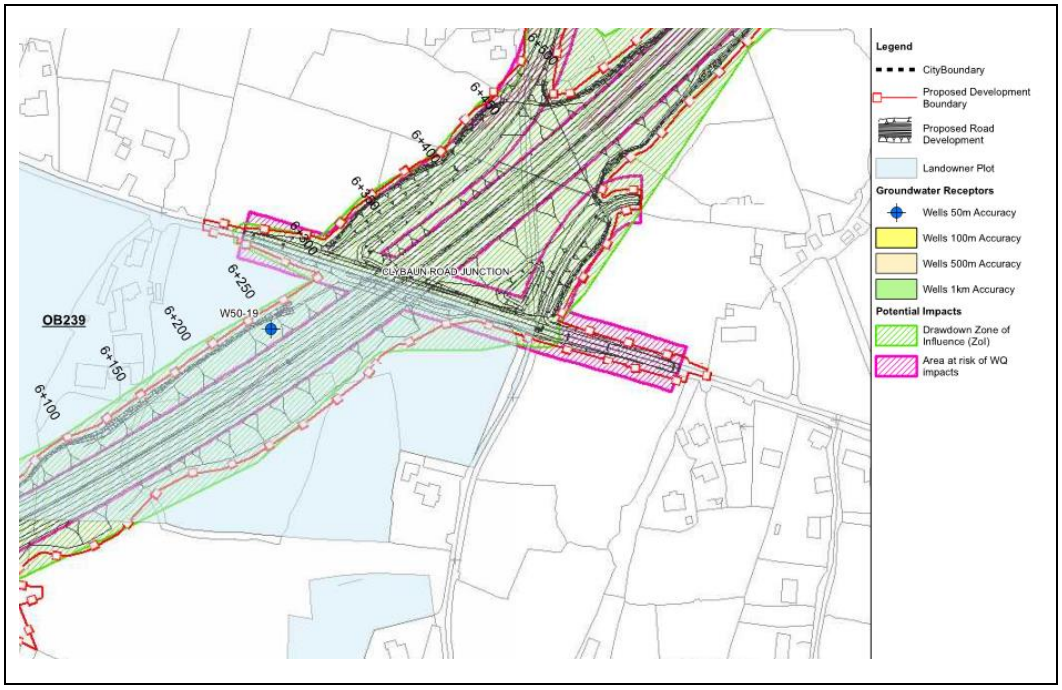
4.3.10 Submission/objection Ob_152 raises an issue in relation to spring/well (W50-16). Spring/well W50-16 is located in granite, located adjacent to earthworks EW02, which comprises of embankment with a short section of shallow cutting (Ref Figure 10.6.002 of the EIAR). The spring/well lies within the footprint of a side road and will not be retained. As part of the proposed road development the well will need to be decommissioned. Where wells are removed as part of the proposed road development then an alternative equivalent supply will be provided such as a replacement well.

Figure 1: Location of property in submission/objection Ob_152



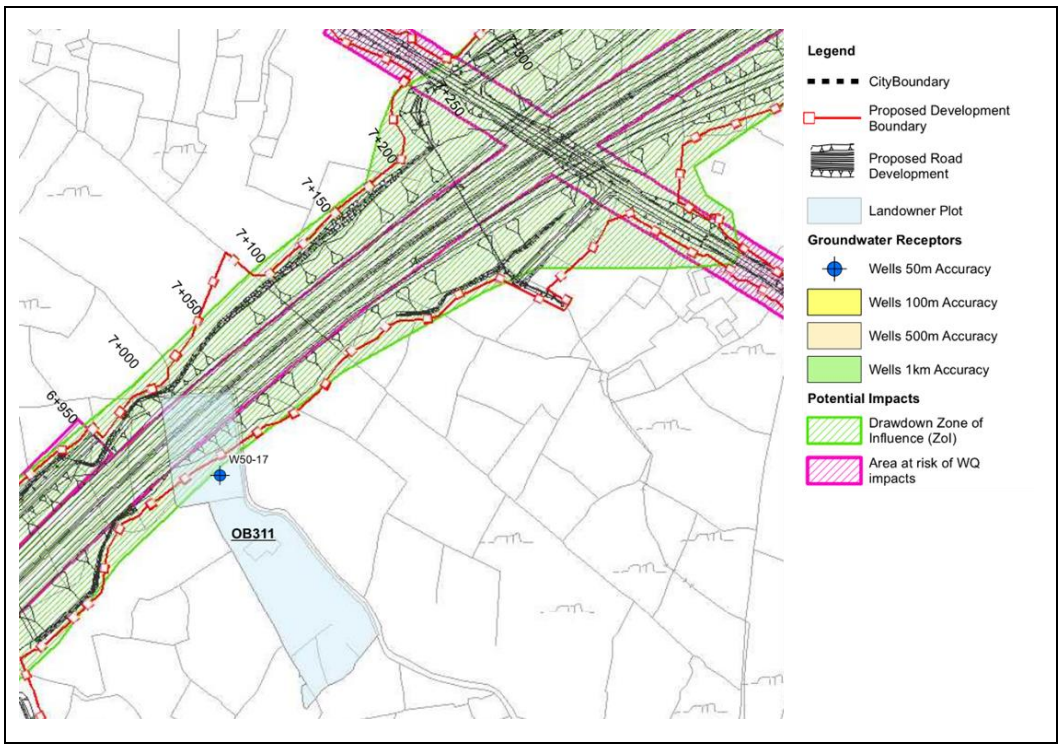
4.3.11 Submission Ob_239 raises an issue in relation to a well (W50-19). Well W50-19 is located in granite, adjacent to earthworks EW08, which comprises of embankment (Ref Figure 10.6.005 of the EIAR). The well lies within the footprint of the embankment and will not be retained. As part of the proposed road development the well will need to be decommissioned. Where wells are removed as part of the proposed road development then an alternative equivalent supply will be provided, such as a replacement well.

Figure 2: Location of property in submission/objection Ob_239



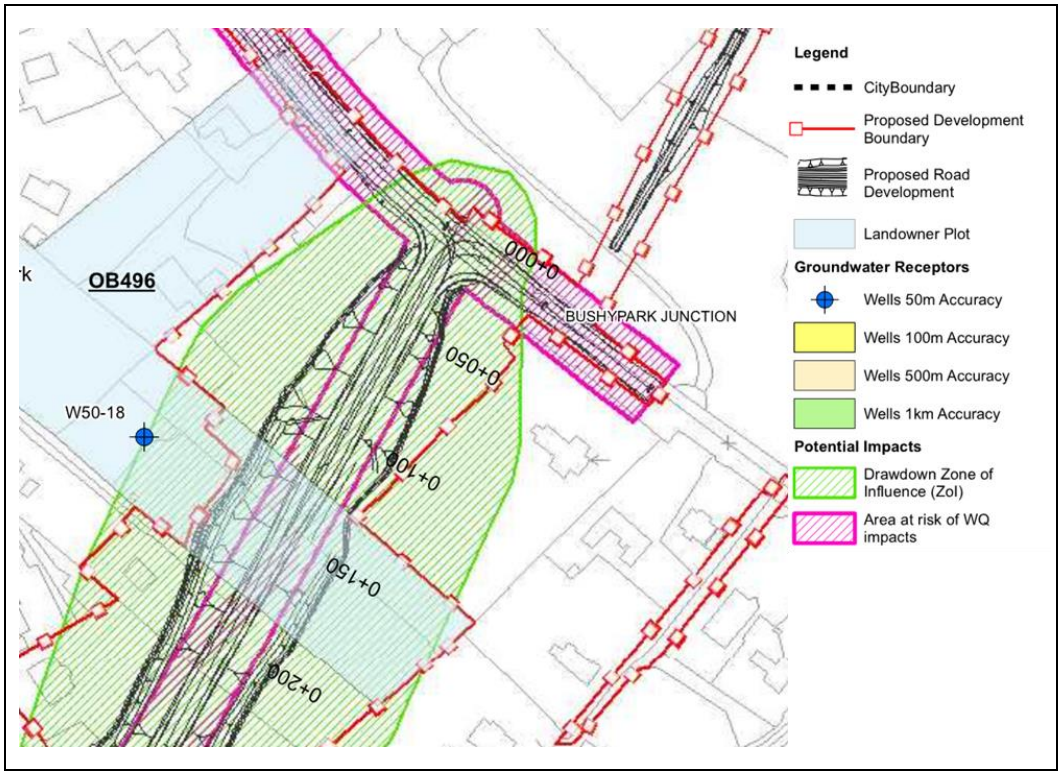
4.3.12 Submission Ob_311 raises an issue in relation to a well (W50-17). Well W50-17 is located in granite, adjacent to earthworks EW08, which comprises of embankment with a short section of shallow cutting (Ref Figure 10.6.005 of the EIAR). The well is on the margin of the zones for drawdown and water quality impacts. As part of the proposed road development the well will need to be decommissioned. Where wells are removed as part of the proposed road development then an alternative equivalent supply will be provided, such as a replacement well.

Figure 3: Location of property in submission/objection Ob_311



4.3.13 Submission Ob_496 raises an issue in relation to a well (W50-18). Well W50-18 is located in granite, adjacent to the N59 Link Road North. The well is the at the margins of the zones for drawdown impacts, both of which have been assessed on a conservative basis. As part of the proposed road development the well will need to be decommissioned. Where wells are removed as part of the proposed road development then an alternative equivalent supply will be provided, such as a replacement well.

Figure 4: Location of property in submission/objection Ob_496



4.3.14 In summary, extensive assessments were undertaken as part of the EIAR to establish the potential impacts on private wells from the proposed road development. Submissions/objections were received raising issues about four specific wells not identified in Chapter 10 of the EIAR. Specific assessments for those wells have been presented here. These identified the risks to those wells and any mitigation measures that will be implemented if necessary.

4.4 Potential Impacts to Private Commercial Wells

Issues

4.4.1 Submissions/objections have been received regarding the proposed removal of commercial wells as part of the proposed road development:

- Ob_602.1, Ob_602.2, Ob_698.1, Ob_698.2, Ob_699.1, Ob_699.2; Ob_704.1 and Ob_704.2: these submissions/objections state that Clada Group Ltd sources its water from its own private deep bored wells located at its production plant and the current well abstracts 50,000L of water in every shift. They state the proposed route will directly impact on the main source of water (the well) for the plant and that there are no alternative viable sources on company lands. They state this has been verified by testing a number of other boreholes on the land over the past number of years.
- Ob_691: This submission/objection queries the removal of commercial wells at the Galway Racecourse and the suitability of the proposed replacement wells.

Response

4.4.2 This response will deal solely with the hydrogeological elements of the submissions, which relate to the impact on one of their wells.

Clada Group Ltd Ob_602.1, Ob_602.2, Ob_698.1, Ob_698.2, Ob_699.1, Ob_699.2; Ob_704.1 and Ob_704.2

4.4.3 Well W50-12 is located in the western corner of the landholding, which is close to the boundary of two groundwater bodies (refer to Figure 10.7.108 of the EIAR). At the Clada site the limestone aquifer is deeply buried below clay deposits up to c.80m thick that are part of one of the main palaeolandscapes in the Galway City area. The hydrogeology at this site is described as part of the Ballindooley area in Section 10.3.1.2, Section 10.3.2.3 and Section 10.3.3.1 of Chapter 10 of the EIAR.

4.4.4 The proposed landtake for the N84 Headford Road Junction overlies the location of well W50-12. For this reason, this well will not be retained and will require to be decommissioned as part of the proposed road development.

4.4.5 As the existing well is producing water used in the food industry and for bottling it is required to meet the European Union Drinking Water Regulations (S.I. No. 122 of 2014) and the European Union (Natural Mineral Waters, Spring Waters and Other Waters in Bottles or Containers) Regulations (S.I. No. 282 of 2016).

4.4.6 The definitions of Natural Mineral Waters, Spring Waters and Other Waters in Bottles are defined in S.I No. 282 of 2016. The water source must satisfy the conditions of S.I. 282 of 2016 to be termed as ‘Mineral Water’, ‘Spring Water’ or ‘other waters in bottles or containers’. There are specific microbiological, treatment and bottling location requirements associated with Mineral Water and Spring Water, which are detailed in S.I. 282 of 2016. ‘Other water in bottles or containers’ are required to comply with water quality parameters and parametric values at the

point at which the waters are put into bottles or containers, as detailed in the Annex I to Drinking Water Directive (Council Directive 98/83/EC).

4.4.7 A replacement water source for the Clada Group Ltd. would need to meet the regulations that the existing water source satisfies.

4.4.8 Mitigation by way of a replacement well is unlikely to be sourced on the Clada Group Ltd site itself due to the significant depth of the overlying clay deposits which deeply bury the limestone aquifer. Therefore, in default of agreement between Galway County Council and the Clada Group Limited, compensation will be paid as part of the statutory compensation process, for the loss of this well which will allow Clada Group Limited to source an alternate offsite water supply that is of comparable quantity and quality. this is the only location at which it is not possible to provide an alternate source of abstraction, due to the existing geological conditions and is, therefore, the only location at which the payment of compensation is required.

Galway racecourse Ob_691

4.4.9 Three wells are in use at Galway racecourse to provide the water supply to buildings and stables. All three existing wells are located within the footprint of the proposed road development and replacement wells have been proposed as mitigation at the proposed location shown in Appendix A.15.2 of the EIAR. The proposed replacement wells lie within the same limestone aquifer but beyond the extent of drawdown and water quality impacts of the proposed road development, which are identified and shown on Figure 10.7.110 (construction) and Figure 10.8.110 (operation) of the EIAR. The replacement wells are subject to testing to confirm comparable groundwater quality prior to the current wells being decommissioned. Replacement wells will be designed to current guidance on wells specification for water supply.

4.4.10 In summary, the four commercial wells identified in the submissions/objections will be impacted by the proposed road development. Mitigation measures have been proposed to provide alternative replacement wells at the Galway Racecourse. Regarding the supply well at the Clada Group Ltd site, mitigation is unlikely by way of an onsite replacement supply well, and therefore financial compensation is proposed to allow Clada Group Ltd to source an alternate offsite water supply to provide water of comparable quantity and quality.

4.5 Possible impacts to water quality

Issue

4.5.1 Two submissions/objections, S_008 and S_36.2, raised issues regarding potential impacts to water quality:

- S_008: The submission/objection states that the proposed mitigation measures regarding accidental spillage, run off and foul waste from the construction compound will not produce for protection of ground water and surface water and any residual impacts that will protect public health.
- S_36.2: The submission/objection states that the further information submitted does not appear to have addressed potential impact on new intake location.

Response

4.5.2 Submissions/objections S_008 and S_36.2 relate to potential deterioration of groundwater quality from the proposed road development. Details of measures to be undertaken during construction to manage runoff and accidental spillages are detailed in the CEMP in Appendix A.7.5 of the EIAR. As provided in Section 4.2 above, those areas down gradient of the proposed road development where there is potential for deterioration in water quality have been identified and are shown in Figures 10.6.001 and 10.6.002 of the EIAR for construction. The extents of these areas differ for granite and limestone due to the faster way that groundwater can flow in Limestone. Both S_008 and S_36.2 are located on the limestone areas of the Galway area. With submission/objection S_008 relating to properties on the Ross Lake GWB and S_36.2 relating to groundwater contributions to the Terryland River from the Clare Corrib (Terryland) GWB.

4.5.3 With regard to S_008, the assessment of the Ross Lake GWB is presented in Section 10.3.2.2 of Chapter 10 of the EIAR, which considers how groundwater flow occurs in the limestone aquifer at that location. The Ross Lake GWB is a karst aquifer and was included in the karst mapping undertaken as presented in Figure 10.1.001 of the EIAR. Based on this assessment there are no known karst features in the location of the S_0008 residences.

4.5.4 With regard to S_36.2, the assessment of Clare Corrib (Terryland) GWB is presented in Section 10.3.2.3 of Chapter 10 of the EIAR. The EIAR assessment considers groundwater contributions to the Terryland River, which flows to the River Corrib, where the new Irish Water intake is located. As the Clare Corrib (Terryland) GWB is a karst aquifer this area was included in the karst mapping undertaken as presented in Figure 10.1.002 of the EIAR. Based on the assessment there are a number of karst features in the area, including the estavelles (springs) that the Terryland River rises from.

4.5.5 Procedures for managing karst are detailed in a specific karst protocol that forms part of the CEMP in Appendix A.7.5 of the EIAR. These measures are designed so that in the case that karst is encountered then there are measures in place to ensure that they are isolated from surface run-off and inspected by

hydrogeological/geotechnical specialists so that mitigation may be applied to prevent runoff and spillages entering the aquifer. Mitigation measures include backfilling with appropriate materials and sealing the feature from the surface. These measures will ensure that there will be no impacts on ground water and there will be no residual impacts on public health.

4.5.6 In summary, mitigation measures have been incorporated to manage any potential karst features intersected on the site. These mitigation measures will prevent accidental spillages or runoff migrating off site.

4.6 Potential Impacts to Private Wastewater Treatment Systems

Issues

4.6.1 Six submissions/objections, Clada Group Ltd. (Ob_602_698_699_704.1), S_008, S_062, S_063, S_066 and Ob_134 relate to concerns of groundwater level rise in domestic percolation areas for wastewater treatment systems. It is assumed that all wastewater treatment systems are reliant on treatment through percolation in the unsaturated zone:

- The Clada Group Ltd., submission notes that the site at Ballinfoile has a septic tank and a waste water treatment plant with sand polishing filter.
- S_008: The submission notes that the houses within the estate are serviced by septic tanks. This response refers only to groundwater aspects of the submission.
- S_062: The submission states that increased water tables may affect the percolation and water treatment systems on the property and the concern is raised that the percolation system will be lost. A query is raised as to whether soil samples have been collected to measure the properties of how the material currently allows percolation.
- S_063 and S_066: The submission states that water levels have not been collected at the house and notes the presence of percolation and septic tanks. It queries what is in place to ensure that it is not damaged.
- Ob_134: The submission states that alternations to the groundwater on the treatment of the foul water discharge from the existing effluent treatment system on site should be monitored and rectified. They request an EPA Site suitability assessment is undertaken before and after.

Response

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

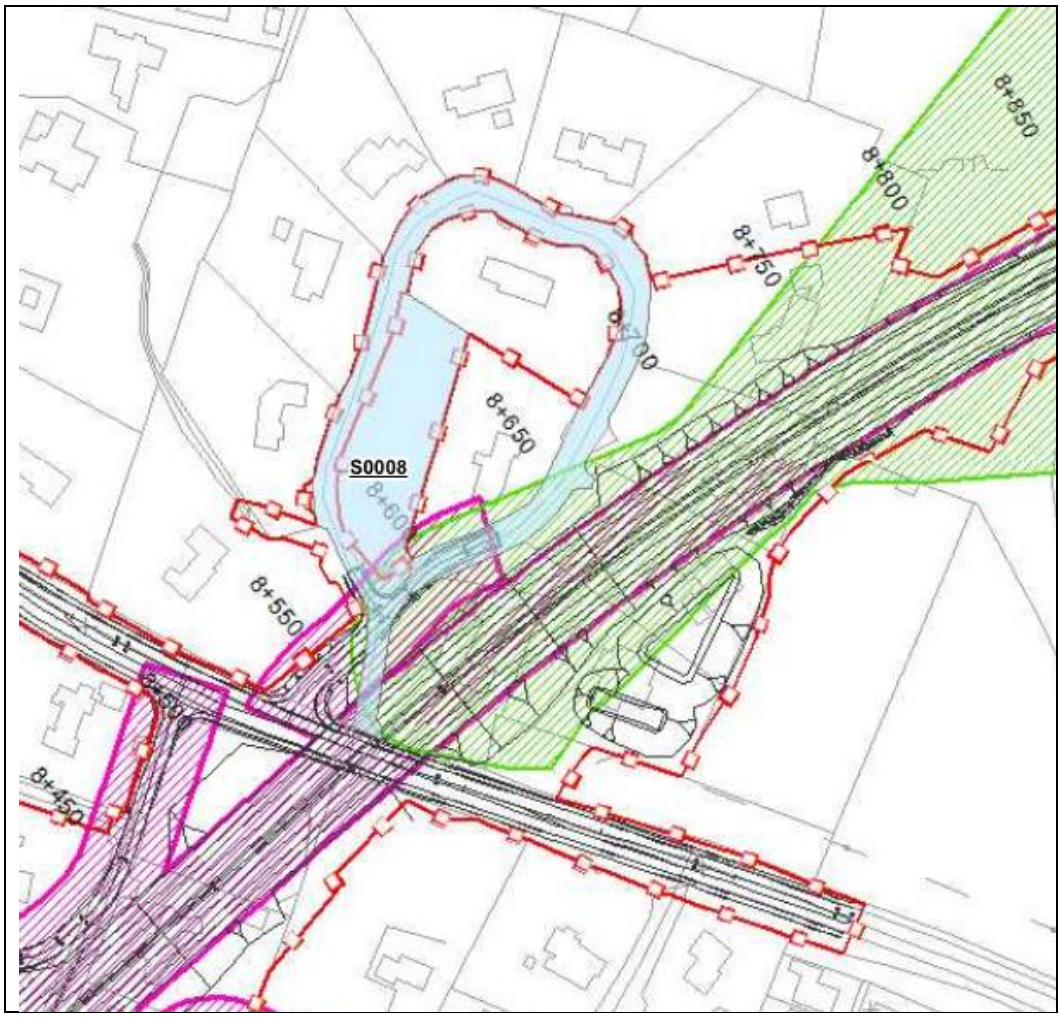
4.6.3 If groundwater levels were to rise beneath the base the of percolation area (i.e. the 'unsaturated zone' were to reduce), the treatment provided by the system would reduce and the groundwater quality would deteriorate. The areas where groundwater rise may occur due the proposed road development are limited to those areas either where infiltration basins are located (which is limited to the limestone area) or where the foundation of structures could divert flow paths. At these locations (infiltration basins and structures) there is a risk that groundwater levels may become slightly elevated during the winter when groundwater levels peak.

4.6.4 Groundwater rise and recharge is assessed extensively in Section 10.5.3 and 10.5.3.1. of Chapter 10 of the EIAR, however to provide clarity, those locations where submissions/objections were raised are illustrated in more detail below.

4.6.5 The Clada Group Ltd site at Ballinfoile includes a septic tank and sand polishing filter that are within the landtake of the proposed road development but outside of the construction footprint. The baseline hydrogeology of the area was assessed in Section 10.3.2.3 of Chapter 10 of the EIAR. As the water table will not be modified by the proposed road development at the Clada Group Ltd site there will be no impact to natural percolation relied on for the operation of the on site septic tank or sand polishing filter.

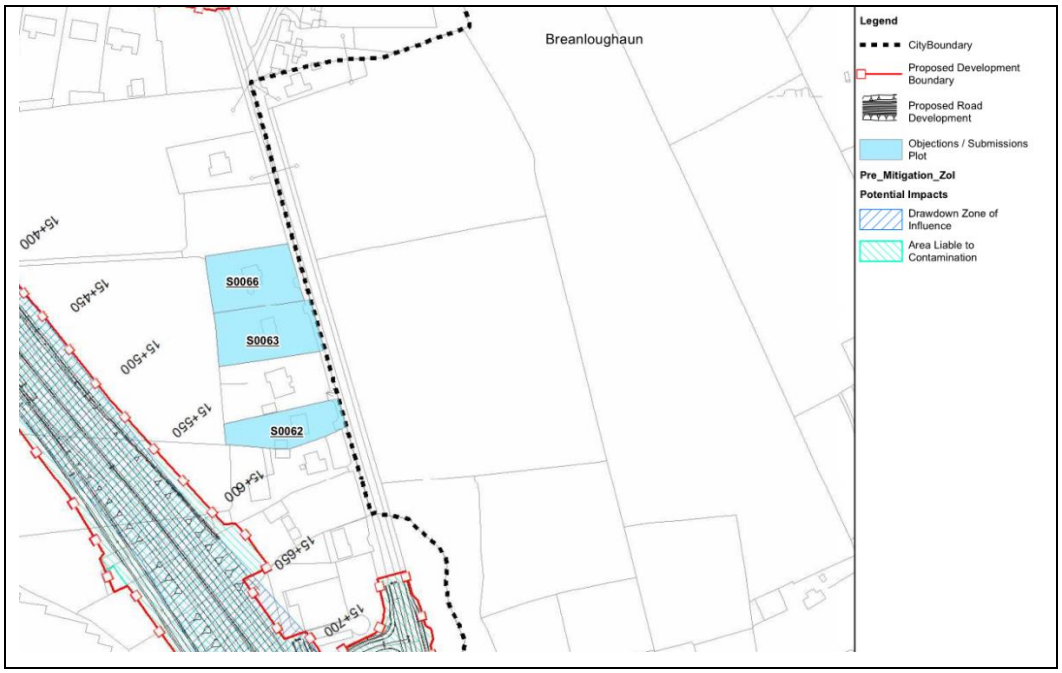
4.6.6 The percolation areas in relation to submission/objection S_0008 lie adjacent to earthworks EW13 which comprises of embankment, with an extent of drawdown occurring during construction (Figure 5). The location of the percolation area is close to the granite/limestone contact. The groundwater table will likely be slightly lowered in this area. As the groundwater table will lower in the area this impact will not reduce the operation of the percolation area and there will be no impact to the residence.

Figure 5: Location of properties in submission/objection S_0008



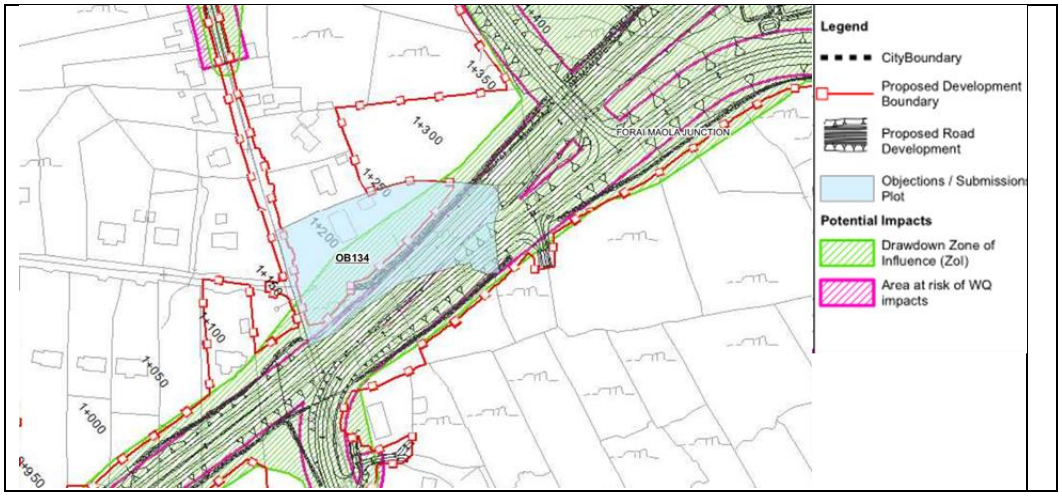
4.6.7 The percolation areas for the land in relation to submissions/objectionsS_062, S_063 and S_066 are shown below in Figure 6. These percolation areas lie adjacent to earthworks EW13 which comprises of embankment, with an extent of drawdown occurring during construction which reduces in size post construction. The location of the percolation area is close to the granite/limestone. The groundwater table will likely be slightly lowered in this area. As the groundwater table will lower in the area this impact will not reduce the operation of the percolation area and there will be no impact to the residence.

Figure 6: Location of properties in submission/objection S062, S063 & S066



4.6.8 The percolation area at the above residence lies adjacent to earthworks Ew02 which comprises of areas of embankment with shallow cutting (Figure 7). The location of the percolation area is within granite and will likely partially lie within a zone of drawdown. The groundwater table will likely be slightly lowered in this area. As the groundwater table will lower in the area this impact will not reduce the operation of the percolation area and there will be no impact to the residence

Figure 7: Location of properties in submission/objection OB134



4.6.9 In summary, the locations in question are adjacent to cuttings where groundwater is likely to be lowered. Lowering of the groundwater table will increase the thickness of the unsaturated zone (i.e. the dry area) beneath the percolation areas. The percolation areas need an unsaturated zone beneath them, so increasing the thickness of the unsaturated zone will have a positive impact on the operation. For this reason the percolation areas highlighted in the submissions/objections are not at risk from the proposed road development.

4.7 Potential Impact to a geothermal borehole

Issue

4.7.1 Two submissions, S_063 and S_066 raised a concern regarding a geothermal borehole. It should be noted that these relate to the same borehole:

- S_063 and S_066: The submission states that water levels have not been collected at the house and notes the presence of a geothermal system. It queries what is in place to ensure that it is not damaged.

Response

4.7.2 Geothermal systems are those where a heat pump is used to take heat from the ground and used to provide heat to a property. The system that this submission/objection refers to is a closed loop system which means that the pipe loop (which is filled with a fluid that conducts heat) is installed vertically in a drilled well.

4.7.3 The submission/objection queries what is in place to ensure that the system is not damaged by the proposed road development. The inference was that the effectiveness may be reduced if the groundwater level was drawn down at the location of the well.

4.7.4 This well was identified in Section 10.3.4.2 and assessed in Section 10.5.3.2 of Chapter 10 of the EIAR. Figure 10.7.110 and Figure 10.8.110 of the EIAR show that this well is located outside the zone of influence of the proposed road development – as described above, the ZoI is the area where the groundwater levels are reduced. This indicates that the geothermal well is outside the area where groundwater levels and will change and therefore will not be impacted by the proposed road development.

4.7.5 In summary, the geothermal well will not be impacted by the proposed road development.

4.8 Potential for Groundwater Flooding at Lackagh Quarry

Issue

4.8.1 An issue has been raised regarding the flood levels that can occur in Lackagh Quarry. The following submissions raised this point: Ob_584.1 Ob_584.2, S_074:

- Ob_584.1 and Ob_584.2: Raises concerns regarding flooding in Lackagh Quarry and contamination.
- S_074: Raises concerns regarding flooding in Lackagh Quarry.

Response

4.8.2 Chapter 10 of the EIAR confirms that groundwater flooding occurs seasonally in Lackagh Quarry during the winter groundwater high. The groundwater level data recorded in the project monitoring network is detailed in Section 10.3.2.3 of Chapter 10 of the EAIR and Section 4.2 of the NIS, the maximum and minimum groundwater levels recorded are presented along the proposed road development in Figure 10.6.008 of the EIAR. Monitoring of groundwater levels was undertaken in Lackagh Quarry over the period between 2015 and 2017. This monitoring period includes January 2016 where particularly high groundwater levels occurred and were recorded. The groundwater levels recorded during this monitoring period occurred with reports of groundwater flooding in limestone areas around County Galway and were caused by high rainfall associated with the 2015/16 storms Abigail, Desmond and Frank. The groundwater levels recorded in Lackagh Quarry during January 2016 are high and representative of peak events with a long return event. The OPW (Nicholson O. and Gebre F., 2016. Proceedings of the National Hydrology Conference 2016) and Met Eireann (Walsh S., 2016. Proceedings of the National Hydrology Conference 2016) describe the winter of 2015/106 as being exceptional, with river gauging stations in the River Corrib catchment of County Galway recording the highest or second highest levels on record.

4.8.3 The design of the proposed road development, including its construction, incorporates the full range of seasonal groundwater levels including extreme peak conditions (2015/2016) to ensure that the design is robust and does not alter the current groundwater regime.

4.8.4 Details of the material deposition areas are shown in Figure 7.301 and Figure 7.302 of the EIAR. These figures show that the material deposition areas in the lower floor area of Lackagh Quarry include design measures to accommodate the seasonal groundwater flooding. These measures include the use of only coarse material in the flood zone of the quarry as well as measures including the use of geotextiles to layer the material deposits so that any fine higher in the placed material do not migrate into the flood zone. Furthermore, as the material deposits will be vegetated after construction, infiltration of rainfall through the material deposit areas will include evapotranspiration reducing runoff.

4.8.5 In summary, the mitigation measures presented will prevent fines from being mobilised during storm events or due to flooding.

4.9 Potential for Structural Instability in areas of Groundwater Drawdown

Issues

4.9.1 An issue is raised in one submission, Ob_134, regarding the structural stability of a house where groundwater levels are reported to be lowered adjacent to cuttings:

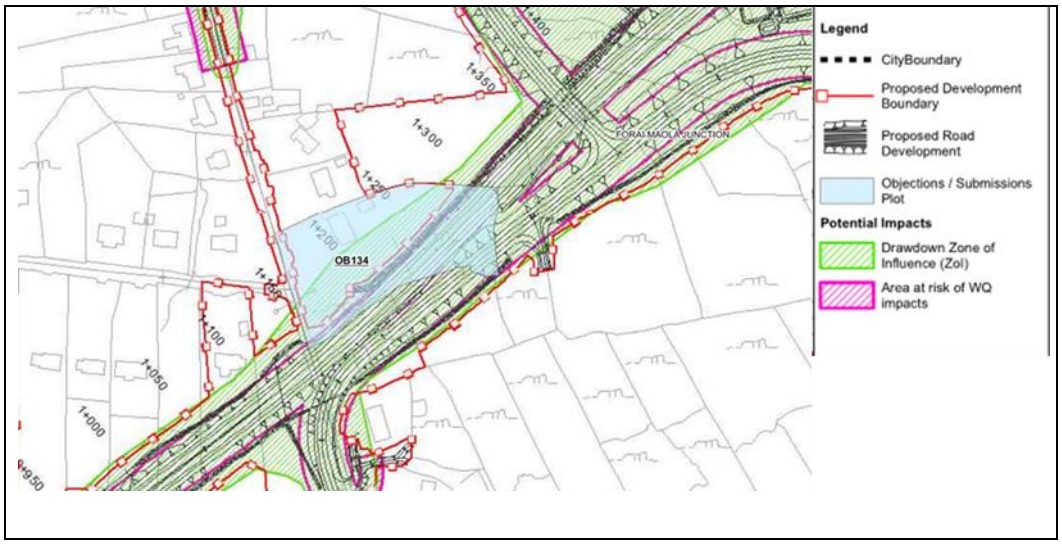
- Ob_134: The submission states that the dewatering zone of influence (the area where groundwater levels are lowered due to construction dewatering) extends to the gable of the dwelling and that changes in water level may impact the building foundations. They request a structural and photographic assessment be undertaken prior to construction dewatering.

Response

4.9.2 The submission raises the concern that the groundwater levels will drop beneath the property and cause instability. The way in which groundwater levels could fall due to construction and operation activities are outlined above in Section 4.2 above and assessed in detail in Table 10.17 in Section 10.4 of Chapter 10 of the EIAR. As outlined above, the location of the property relative to the zone of influence of any dewatering or large drainage run is the most important element to understand if there is likely to be a risk of groundwater levels falling.

4.9.3 The zone of dewatering is shown on the figure below relative to the property. It can be seen that this property is on the edge of the zone of influence of the drawdown (Figure 8). This means that in this area the groundwater levels may reduce but by a very small amount. For this reason a property condition survey will be undertaken in accordance with commitment C17.19 of Chapter 21 of the EIAR.

Figure 8: Location of property in submission/objection Ob_134



4.9.4 In summary, while it is unlikely groundwater levels may drop beneath this property to cause instability, a property condition survey will be undertaken to ensure that any changes that may occur can be identified and repaired if necessary.

4.10 Potential for Impacts to Lough Corrib cSAC and Hydrogeological Connections and Interactions

Issues

4.10.1 The following submissions raised this point: Development Applications Unit, Department of Culture, Heritage and the Gaeltacht submission S_018 (Dec 2018), S_18.2(Jan 2020) and S_074. For completeness, the hydrogeological context from the submission S_018.1 is extracted and presented below in 4.9.2 and 4.9.3

4.10.2 *"The application would benefit from clarity on the changes in hydrogeological regime the Lackagh Tunnel will have on the groundwater catchment area. Boreholes were drilled in the area, and groundwater level data collected, but spatial information is absent on directions of groundwater flow and hydraulic gradients. The tunnel is adjacent to the Lough Corrib Fen 1 (Lackagh) groundwater body (GWB) which contains groundwater-fed lakes and fens in the Lough Corrib SAC. The question of whether groundwater drainage associated with tunnelling construction work, during and post development, will not have an effect in Lough Corrib Fen 1 (Lackagh), may need interrogation. Whilst it is stated that the level of the tunnel will be below the groundwater table (and that "there will be no groundwater lowering within groundwater bodies that support groundwater dependant habitats within a European site"), it is also noted that groundwater seeps at the existing quarry face and base and that there are 'perched' water tables in local subsoil units above the limestone. The inclusion of 'water-tight' barriers is necessary for the operation, and this will divert groundwater flow. It is unclear what the hydrological connectivity between the groundwater dependent terrestrial*

ecosystems (GWDTEs) of the SAC are, particularly the habitats south of the proposed road.

4.10.3 *Following this, it is not clear how the GWDTEs in the Lough Corrib SAC are working 'hydrogeologically' and if flow paths may change post-construction. It appears that the lakes are underlain by significant thicknesses of low permeability substrate, with the fens developing on their margins, presumably due to artesian conditions and spring inputs (it is suggested the lake is fed by the [Western] Coolagh Spring), as indicated by the recorded alkaline conditions. The road will traverse the 'Lough Corrib Fen 1 (Menlough)' groundwater body. The road intercepts recharge and whilst the change in infiltration and aquifer loss is reported as minimal, it may be important considering the small catchment area(s) that appear to support the fen habitats. Further elucidation could be beneficial."*

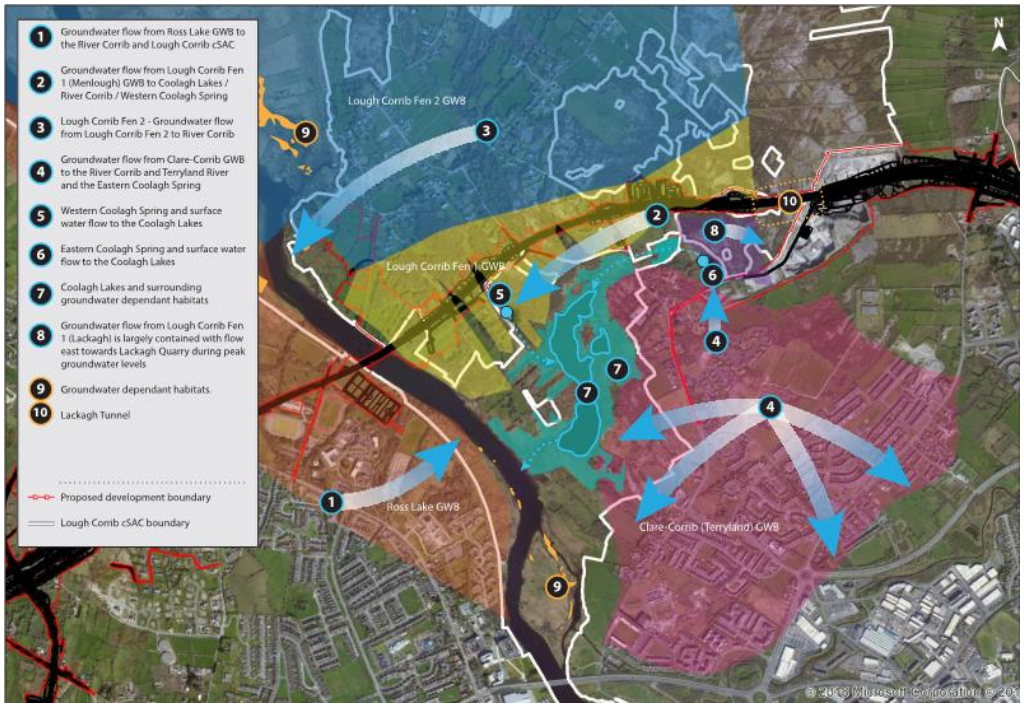
Response

4.10.4 These issues were addressed in Sections 4.12 and 4.13 of the RFI submitted to An Bord Pleanála the 30 August 2019. Further details are provided below in response to the submissions/objections.

4.10.5 The overall hydrogeological baseline environment supporting groundwater dependant habitats in Lough Corrib cSAC is summarised and illustrated in Section 5.2 of Volume 1 of the NIS - Executive Summary. A more detailed description is provided in Section 5.2 of Volume 2 of the NIS, which is supported by the full hydrogeological study, included as Appendix A of the NIS (refer to Section 4.2 for the baseline hydrogeological description of each of the groundwater bodies that contribute groundwater to wetland habitats within Lough Corrib cSAC). It is also presented in Section 10.3.3.2 of Chapter 10, Hydrogeology of the EIAR.

4.10.6 The hydrogeological study undertaken to inform the EIAR and NIS for the proposed road development identified those groundwater bodies that contribute groundwater within the groundwater dependant habitats in the Lough Corrib cSAC. There are four groundwater bodies (GWB): Ross Lake GWB, Lough Corrib Fen 1 (Menlough) GWB, Lough Corrib Fen 2 GWB and the Clare-Corrib GWB. The location of these GWB are explained and illustrated in Section 5.2 of the NIS. Plate 5.2 in the NIS (included below in Figure 9 for ease of reference) illustrates those groundwater bodies that contribute groundwater to the Lough Corrib cSAC. Figure 9 below is an extract from EIAR Figure 10.5.001 and 10.5.002 (NIS Figure 10.1.1 and 10.1.2 as well as NIS Appendix A 5.01 and 5.02)) which presents all delineated GWB catchment extents. Figure 10.3.1 to 10.3.8 of the NIS show the groundwater bodies that contribute to the Lough Corrib cSAC and includes the location of all Annex 1 GWDTE habitat.

Figure 9: Generalised hydrogeology interactions with European sites



4.10.7 The hydrogeological assessment for the Lough Corrib cSAC identified that only the Lough Corrib Fen 1 (Menlough) GWB contributes to Western Coolagh Spring, which is the main spring for Coolagh Lakes. Those other GWBs shown in Figure 9 above either contribute directly to the River Corrib (Ross Lake GWB and Lough Corrib Fen 2 GWB) or as in the case of Clare-Corrib (Terryland) GWB to the River Corrib, Terryland River and Eastern Coolagh Spring, which is a small potential spring.

4.10.8 The River Corrib is a substantial river that is not dependent on groundwater from those groundwater bodies presented in Figure 9. However, the Coolagh Lakes which is a tributary to the River Corrib receives a significant proportion of its flow from groundwater, specifically from Western Coolagh Spring and the Lough Corrib Fen 1 GWB. Biodiversity assessments have identified that the habitat around the margin of Coolagh Lakes are dependent on the lake water level and lake water quality. On this basis the GWTDE around the lake margins are dependent on the groundwater contribution to Coolagh Lakes, which is primarily dependant on the Western Coolagh Spring and the Lough Corrib Fen 1 (Menlough) GWB. The hydrogeological setting and interaction between Western Coolagh Spring, the Coolagh Lakes and the River Corrib are explored below.

4.10.9 The hydrogeological setting at Coolagh Lakes comprises of the lakes occurring in topographic depressions within an extent of thick, low permeability silt and clay subsoil deposits, which are bound to the north and east by limestone. The thick clay subsoils are part of the palaeolandscape in the limestone bedrock that have been infilled with fine grained sediment. A deep buried landscape at the eastern extent of the Lough Corrib Fen 1 (Menlough) GWB recorded a thickness of 106m of silty clay. The contact of the palaeolandscape is sharp and vertical, and not dissimilar to

that of the head of canyon or gorge. The Western Coolagh Spring is located at the margin of this significant palaeolandscape feature, where limestone crops out and encompasses the northern, eastern and southern margins of the Coolagh Lakes. The Coolagh Lakes fill the topographic depression where the deep subsoil deposits occur (refer to Figure 10 and Figure 11 below), which appear open to the west, where the lakes drain out to the River Corrib. Due to the thickness and fines dominated nature of the fill sediment, any groundwater contribution through the base of the lakes is very unlikely. There are no other karst springs around the periphery of the lakes. It is noted that the only other 'spring' feature associated with Coolagh Lakes, Eastern Coolagh Spring, is located within the thick clay deposits and not limestone. Eastern Coolagh Spring is recorded as a potential spring as no measurable flow or significant seasonal variation in level was recorded during the monitoring period.

4.10.10 Manual groundwater level monitoring data is presented in Appendix A10.3 of the EIAR and summary groundwater data is presented in Table 10.8 of Chapter 10 of the EIAR and Table 3 of Appendix A of the NIS. Continuously logged groundwater level data is presented in Plate 10.5 of Chapter and Plate 5 in Appendix A of the NIS. This data has been used to plot groundwater level contours for the Lough Corrib Fen 1 (Menlough) GWB for January 2016, April 2016 and June 2016, which are presented in Figures 10, 11 and 12 below show groundwater level contours for the Lough Corrib Fen 1 (Menlough) GWB. The groundwater contours are calculated based on data from seven groundwater monitoring wells (MW01, MW02, MW03, BH3/27, BH133, BH972, BH-3-29R) and the groundwater level continuously recorded at Western Coolagh Spring (WCS) and Eastern Coolagh Spring (ECS). This data confirms that groundwater flow in the central and eastern part of the GWB drains to Western Coolagh Spring, whilst the western part of the GWB drains to the River Corrib. This data confirms that the groundwater from the Lough Corrib Fen 1 (Menlough) drains to Western Coolagh Spring (WCS) and clearly identifies the range of groundwater levels through winter and summer.

Figure 10: Groundwater levels (mOD) and inferred contours for Lough Corrib Fen 1 (Menlough) GWB (January 2016)

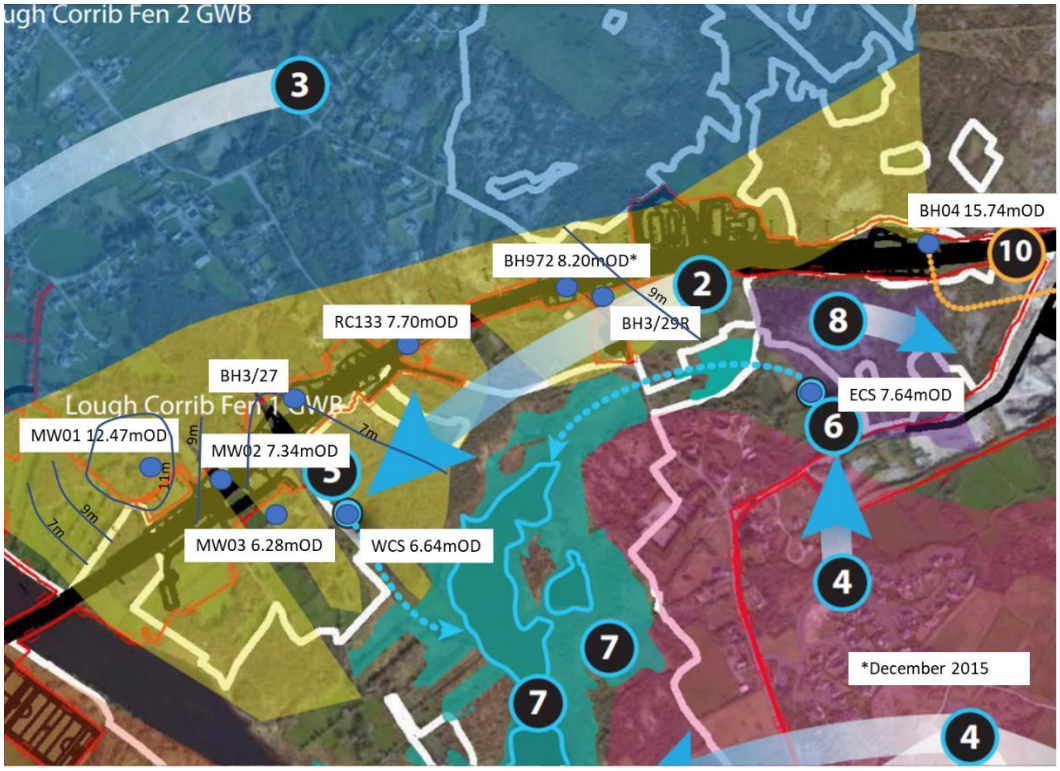


Figure 11: Groundwater levels (mOD) and inferred contours for Lough Corrib Fen 1 (Menlough) GWB (April 2016)

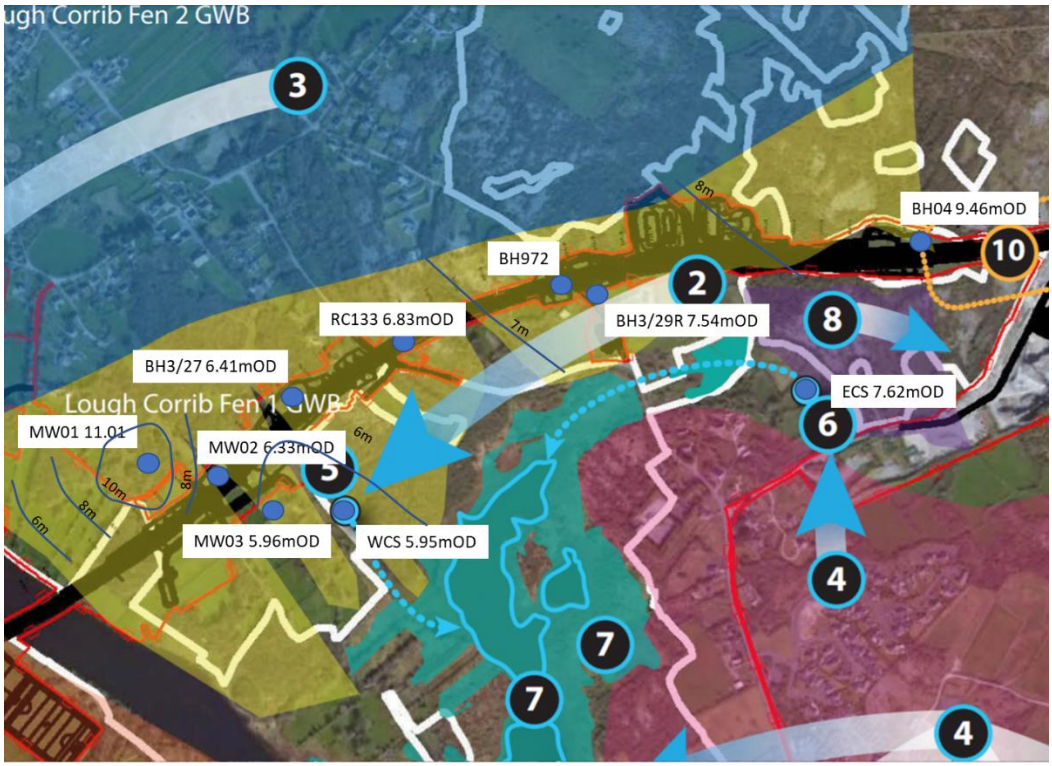
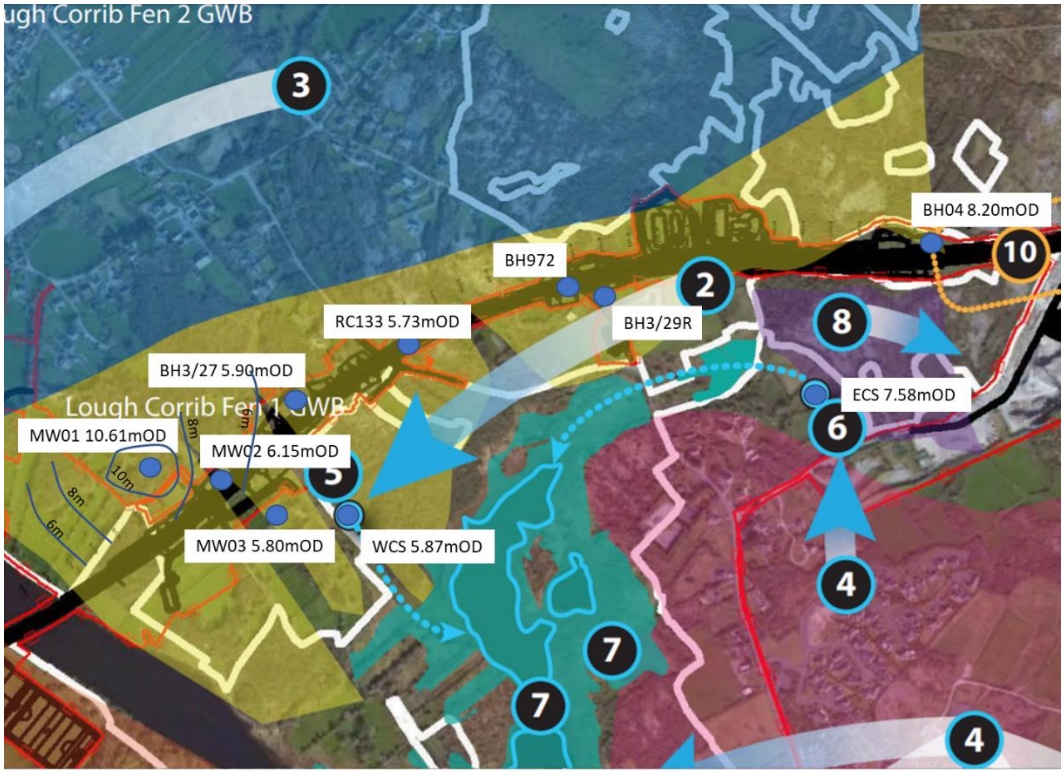


Figure 12: Groundwater levels (mOD) and inferred contours for Lough Corrib Fen 1 (Menlough) GWB (June 2016)



4.10.11 Plate 3 and 4 in Appendix A of the NIS (also included as Plate 10.3 and 10.4 in Chapter 10, Hydrogeology of the EIAR), is included below in Figure 13 and 14 of this statement of evidence for ease of reference, illustrate the 'workings' between groundwater and the Coolagh Lakes.

Figure 13: Schematic north south cross-section through Coolagh Lakes (groundwater high)

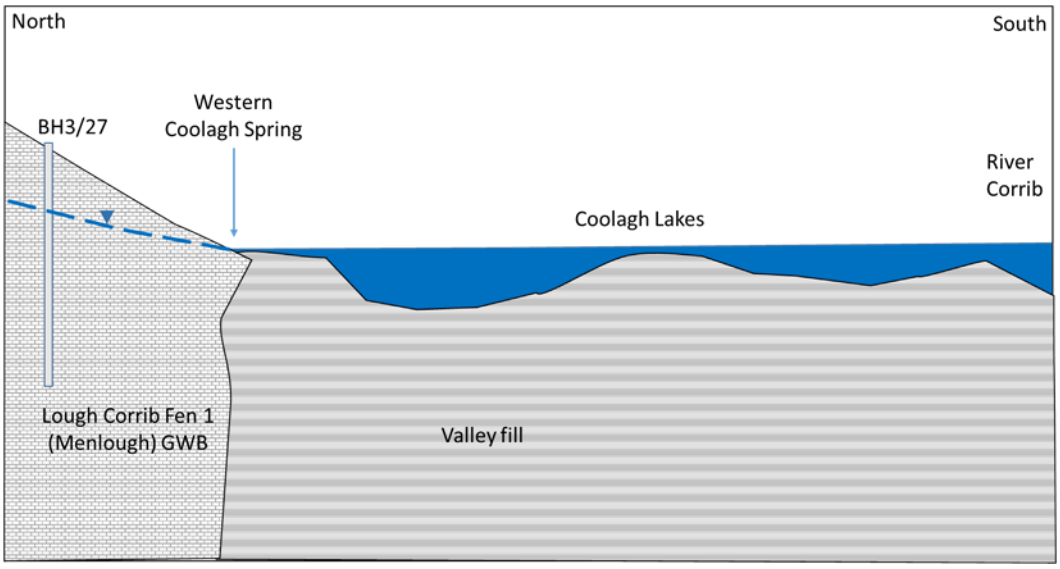
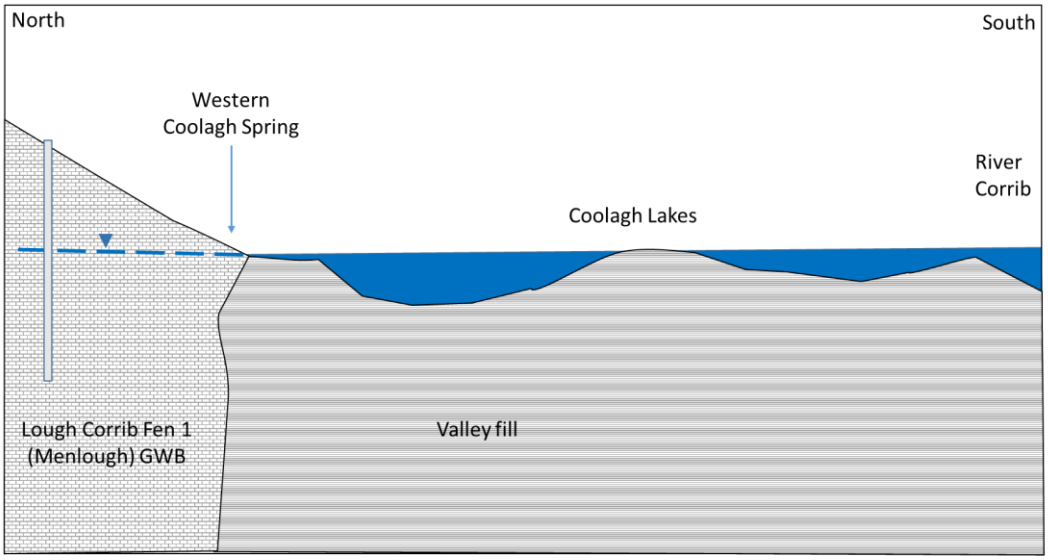


Figure 14: Schematic north south cross-section through Coolagh Lakes (groundwater low)



4.10.12 As described in Section 10.3.3.2 of Chapter 10 of the EIAR, the water level in the Coolagh Lakes is controlled by a combination of flow from Western Coolagh Spring and flow from the Coolagh Lakes to the River Corrib. When groundwater level rises in the Lough Corrib Fen 1 GWB the flow at Western Coolagh Spring increases, conversely when groundwater levels lower, the flow at the spring reduces. On this basis the flow at Western Coolagh Spring is seasonal, with peak flows occurring in the winter and flow reducing in the summer to the extent that flow ceases.

4.10.13 The groundwater levels within the Lough Corrib Fen 1 (Menlough) GWB are included in the water level database presented in Appendix A10.3 of the EIAR, which includes both groundwater levels recorded in monitoring boreholes, as well as the springs and Coolagh Lakes. This data is used to present the groundwater table seasonal maximum and minimum levels along the alignment of the proposed road development in Figure 10.6.007 and Figure 10.6008 of the EIAR and, which show the section through the Lough Corrib Fen 1 (Menlough) GWB from the River Corrib to Lackagh Quarry for the maximum and minimum groundwater levels recorded. The groundwater level data shows that the water table is slight in the winter and flat during the summer. Seasonally the fluctuation in the GWB is of the order of 2.5m (BH-3-27R, Western Coolagh Spring, BH133, BH972 BH-3-29R). During the summer the hydraulic gradient across the GWB is less than 1m/km and in the winter the gradient increases to 2m/km. Based on the very slight groundwater table gradient for summer and winter, this water level data has not been contoured but rather presented in profile form in Figure 10.6.007 and 10.6.008 of the EIAR to show the direction of flow and seasonal variation. It is noted that the eastern extent of the GWB is bound by the palaeovalley/palaeokarst feature encountered in BH03, BH04 and BH06.

4.10.14 As shown in Figure 9 the proposed road development traverses Lough Corrib Fen 1 (Menlough) GWB. Design and mitigation measures are included as part of the proposed road development specifically to protect groundwater levels from being lowered within the Lough Corrib Fen 1 (Menlough) GWB. These measures are set out in Chapter 21, Schedule of Environmental Commitments of the EIAR, in the Construction Environmental Management Plan (CEMP) in Appendix A.7.5 of the EIAR and in Lackagh Tunnel Geotechnical and Hydrogeological Appraisal Report included in Appendix A.7.3 of the EIAR and Appendix F of the NIS. These measures include: excavations associated with the Lackagh Tunnel will not permit dewatering of the bedrock aquifer or works below the groundwater table, and the karst inspection protocol The effective implementation of these measures will prevent groundwater levels being lowered during construction in the groundwater bodies that contribute groundwater to Lough Corrib cSAC and hence, as stated in Section 2.6.7 of the NIS, *"there will be no groundwater lowering within the groundwater bodies that support groundwater dependant habitats with a European site"*.

4.10.15 In summary, Coolagh Lakes are groundwater dependant being mainly fed from one significant spring, Western Coolagh Spring. The habitat around the periphery of Coolagh Lakes is identified as being water dependant. and as such the habitats at Coolagh Lakes are GWDTE, and are dependent of Western Coolagh Spring. Mitigation measures have been designed so that no active lowering of the groundwater table occurs within the catchment to Western Coolagh Spring. Karst specific measures incorporated into the construction design will ensure that groundwater flow paths will not change post-construction. Furthermore, the proposed road development will not pose any temporary or permanent barrier to groundwater movement in these groundwater bodies. The conclusions of this hydrogeological assessment have informed the ecological assessment as it relates to Appropriate Assessment (AA) and addressed in Section 4.4.3 of Aebhin Cawley's statement of evidence on AA.

4.11 Potential for impacts to Moycullen Bogs NHA

Issue

4.11.1 The following submissions/objections raise a point regarding the Moycullen Bogs NHA: Development Applications Unit, Department of Culture, Heritage and the Gaeltacht submission S_018 (Dec 2018), S_18.2(Jan 2020) and S_074.

4.11.2 Extract from Submission/objection S18.2 (Jan 2020): '*The Department reiterates it's concerns regarding the Moycullen Bog NHA, that dewatering of the Galway Granite batholith, within cutting areas during construction and operation of the proposed scheme, may result in lowering of the peatland water table with peat subsidence and consequent negative impact on the ecology of the Bog. The potential for such impacts needs to be assessed and mitigation measures proposed to address this matter as appropriate.'*

Response

4.11.3 The hydrogeology of the peatland water table has been assessed in detail in Section 10.3.3.1 of Chapter 10 of the EIAR and the impact assessment undertaken in Section 10.5.3of Chapter 10 of the EIAR.

4.11.4 The Moycullen Bogs NHA includes a number of isolated areas designated as NHA including, from west to east, Na Forai Maola Thair, Lough Inch, Tonabrocky and Letteragh and are shown on Figure 10.5.001 and Figures 10.7.104, 10.7.105, 10.7.106 10.8,104, 10.8.105 and 10.8.106 of the EIAR.

4.11.5 Those areas of the NHA at Na Forai Maola Thair and Lough Inch are either in a separate catchment or down gradient of the proposed road development and therefore are not at risk from groundwater drawdown induced from cuttings.

4.11.6 The NHA at Tonabrocky lies in a distinct sub catchment to that of the proposed road development. Tonabrocky and the proposed road development are separated by a surface watercourse, with the proposed road development being 450m distant from Tonabrocky at its closest and the proposed road development is on embankment in that section. Based on this assessment of the Moycullen Bogs NHA at Tonabrocky is not at risk from groundwater drawdown induced from cuttings.

4.11.7 The Moycullen Bogs NHA at Letteragh lies on high ground west of the River Corrib. The NHA lies on the catchment divide between groundwater that drains eastward and northwards to the River Corrib and groundwater that drains southward towards Galway Bay. In the granite area the surface water and groundwater catchments are the same.

4.11.8 The proposed road development in this location comprises of:

- the main alignment, which is in a deep cutting at Letteragh
- the N59 Link Road North, which is at grade or on embankment close to Moycullen Bogs and then in a shallow cutting just before the N59 Moycullen Road

4.11.9 The Letteragh cutting on the mainline is shown on Figure 10.6.006 (plan and profile) of the EIAR with minimum and maximum groundwater levels shown. The drawdown extents calculated for the Letteragh cutting and the N59 Link Road North are shown on Figure 10.7.106 (construction) and 10.8.106 (operation) of the EIAR. The maximum drawdown extent from the Letteragh and N59 Link Road North rock cuttings do not encroach to the NHA and drawdown from the rock cuttings remain greater than 200m distant from the NHA at Letteragh. Furthermore, as the Letteragh cutting initiates immediately east of the N59 Link Road North, the cutting lies within a separate sub catchment to the NHA at Letteragh. As presented in Section 4.1 above, the calculation to determine drawdown incorporates measures to ensure that it remains based on conservative assessment of the hydraulic tests undertaken in the study area.

4.11.10 It is noted that the area of the mainline of the proposed road development from the existing Clybaun Road to the proposed N59 Link Road North lies down gradient of the Moycullen Bogs NHA at Letteragh. This section of the proposed road development is on embankment (refer to Figure 10.6.006 of the EIAR) with no significant rock cuttings.

4.11.11 As part of the ground investigation undertaken in the area of the Letteragh cutting, boreholes were drilled to prove the depth to bedrock as well as a geophysical survey. This data confirms that the bedrock at the Letteragh cutting is either at or consistently close to surface. On this basis there is no evidence present to indicate that drawdown could extend further than indicated. Based on the assessment there is no risk to the Moycullen Bogs NHA at Letteragh from drawdown in the bedrock groundwater induced by the Letteragh cutting or N59 Link Road North cutting.

4.11.12 In summary, all areas of the Moycullen Bogs NHA are in separate catchments or sub-catchments to road cuttings for the proposed road development. Based on assessment of each cutting, the maximum drawdown reach will remain with its own sub-catchment extent and on this basis, the proposed road development will have no impact to the Moycullen Bogs NHA.

4.12 Corrigenda

4.12.1 There are a number of minor corrigenda to the assessment presented in Appendix A to the NIS and Chapter 10 of the EIAR, which are presented next to this Statement of Evidence. These corrigenda do not change the conclusions in relation to the Hydrogeology to the EIAR or the NIS.

5 Conclusion

5.1 The hydrogeological assessment, presented in Chapter 10 of the EIAR and Appendix A of the NIS, includes detailed consideration of groundwater features located within the study area, assessment of changes to the hydrogeological environment from design elements and mitigation measures proposed in respect of the proposed road development.

5.2 Responses to submissions/objections have provided further information and clarification on the assessments undertaken and documented in the application documentation. Submissions/objections have identified four additional domestic wells that were not identified in the EIAR and the assessment undertaken has been updated to include these wells, using the mechanism for assessing potential impacts to abstraction wells that is detailed in Chapter 10 of the EIAR.

5.3 Further clarity has been provided describing the interaction between groundwater and surface water at European sites, including the Lough Corrib cSAC, and NHA sites, including the Moycullen Bogs NHA at Letteragh. In particular, the issues raised in two submissions made by the Development Applications Unit of the Department of Culture, Heritage and the Gaeltacht have been responded to comprehensively.

5.4 Further clarity has been provided on the groundwater conditions at the site of the existing Galway Racecourse and Clada Water abstraction well. Financial compensation is proposed to allow Clada Group Ltd to source an alternate offsite water supply to provide water of comparable quantity and quality.

5.5 Other than the additional domestic wells identified, the issues raised in the submissions/ objections in relation to potential impacts on hydrogeology have been fully considered, and having considered those issues, the conclusions of the hydrogeological impact appraisal remain as set out in the EIAR.

Corrigendum to Hydrogeology

1 NIS – Appendix A Hydrogeology Assessment Report

NIS Appendix A Figure 7.01 appears in duplicate

NIS Appendix A Figure 7.01 (I1) (which is the duplicate) has been removed

NIS Appendix A Figure 8.01 and Figure 8.02 are (i) missing a legend and (ii) had colouring errors relating to Spiddal and Maam-Clonbur.

NIS Appendix A Figure 8.01 has had the following added:

- legend
- the Spiddal groundwater body colour included
- the Maam-Clonbur groundwater body colour included

Please note that Figure 8.02 should be read as being amended in line with Figure 8.01.

NIS Appendix A Figure 9.01 and Figure 9.02 are (1) missing a legend and (2) had colouring errors in regard to Spiddal and Maam-Clonbur.

NIS Appendix Figure 9.01 has had the following added:

- legend
- Spiddal groundwater body colour included
- Maam-Clonbur groundwater body colour included

Please note that Figure 9.02 should be read as being amended in line with Figure 9.01.

NIS Appendix A Plate 1 has one borehole label (RP-2-05D) in duplicate and one incorrect borehole label

- NIS Appendix A Plate 1 (Drawing No. GCOB-SK-D-702) has been amended to remove the duplicate borehole label ~~RP-2-05D~~
- NIS Appendix A Plate 1The reference to ~~B.H.3/18~~ should read B.H.3/29

2 EIAR – Chapter 10 Hydrogeology

EIAR Figure 10.5.001 and Figure 10.5.002 show the Spiddal and Maam-Clonbur groundwater bodies have been coloured incorrectly

EIAR Figure 10.5.001 has been amended to include the following:

- The Spiddal groundwater body is coloured correctly
- The Maam-Clonbur groundwater body is coloured correctly.

Please note that Figure 10.5.002 should be read as being amended in line with Figure 10.5.001.

EIAR Figures 10.7.101-106 show the Spiddal and Maam-Clonbur groundwater bodies have been coloured incorrectly.

EIAR Figure 10.7.101 has been amended to include the following:

- Spiddal groundwater body coloured correctly
- Maam-Clonbur groundwater body coloured correctly

Please note that Figures 10.7.102- 10.7.106 should be read as being amended in line with Figure 10.7.101.

EIAR Figures 10.8.101-106 show the Spiddal and Maam-Clonbur groundwater bodies are coloured incorrectly

EIAR Figure 10.8.101-106 has been amended to include the following:

- Spiddal groundwater body coloured correctly
- Maam-Clonbur groundwater body coloured correctly

Please note that Figures 10.8.102- 10.8.106 should be read as being amended in line with Figure 10.8.101.

The EIAR included the description of W50-10 as a domestic geothermal well when it is a domestic abstraction well.

Below are the list of locations where well W50-10 is referred to as a domestic geothermal well when it should be read as an agricultural/domestic supply:

1. Table 10.26 on page 929;
2. Table 10.27 on page 935.

Well W1000-02 was included in error. As it does not exist all references to W1000-02 should be read as deleted.

Consequently the following are the list of locations where well W1000-02 appeared in EIAR Chapter 10 tables should be read as deleted:

1. Table 10.16 on page 875;
2. Table 10.18 on page 890;
3. Table 10.20 on page 902;
4. Table 10.26 on page 929;
5. Table 10.27 on page 935.

W1000-02 appears in one sentence on Page 864 and the reference is deleted

With the above correction and an original type error, the adjusted count of private domestic wells in limestone is 18.

The Visean Undifferentiated Limestone is tapped into for ~~20~~ 18 private domestic wells. These comprise of W50-02, 03, 04, 05, 06, 07, 08, 10 and 11, W100-01, 02, 03, 04, 05 and 06, W500-01 and W1000-~~02,~~ 03 and 04.

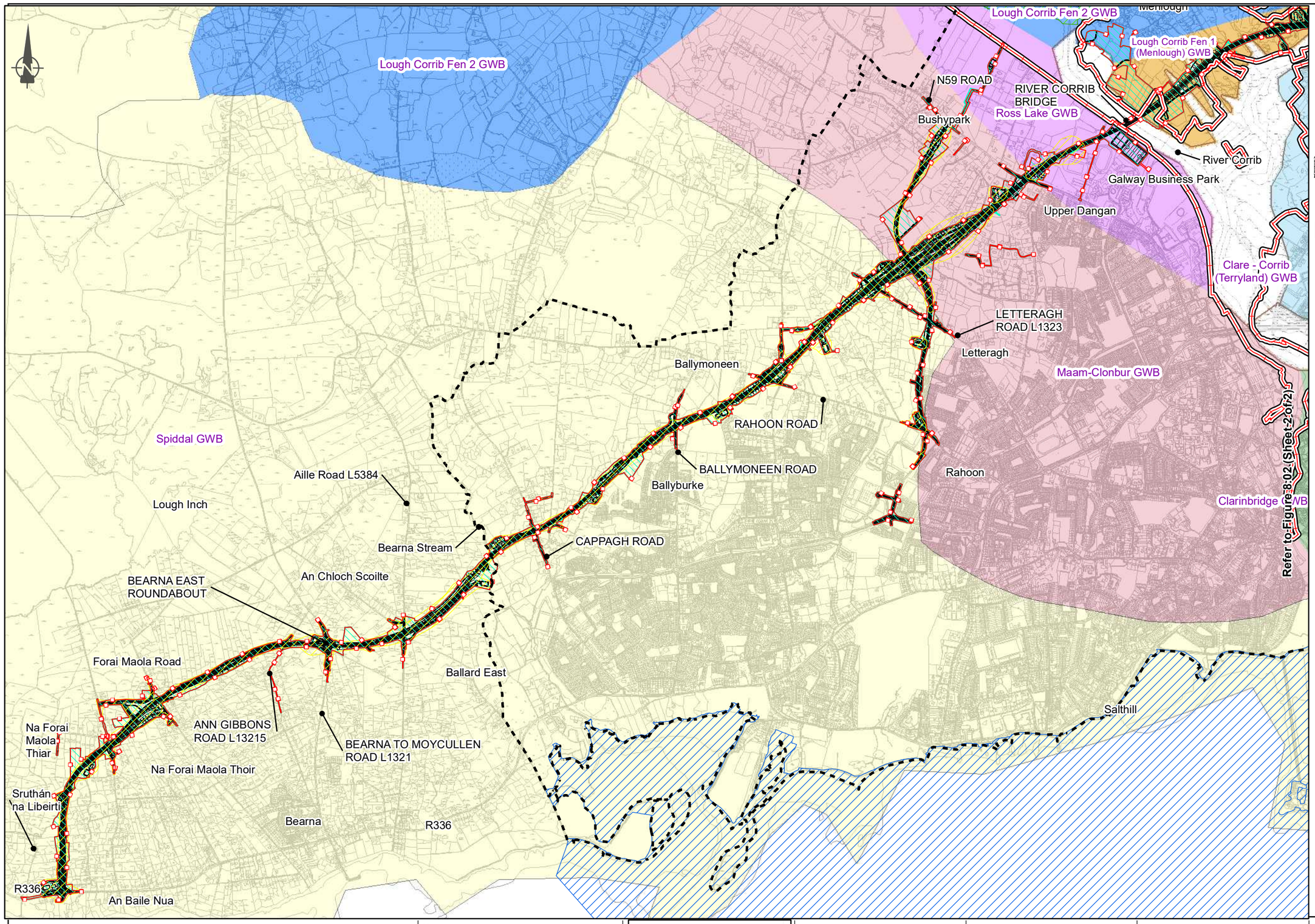
W1000-02 appears in one sentence on page 891 and the full sentence is deleted

~~One well (W1000-02) has a potential risk for water quality deterioration as it lies down gradient and within the 100-day TOT from the proposed road development.~~

W1000-02 appears in one sentence from Page 913 and the sentence is deleted

An impact assessment on abstraction wells was completed for the construction phase and is presented in **Section 10.5.3.1**. The same assessment is valid for the operation phase. It highlights that five wells (W50-10, W50-11, W50-12, W50-13 and W12-14) will be removed by the proposed road development at the construction phase. ~~One well (W1000-02) has been identified as lying downgradient and within the 100-day TOT from the proposed road development.~~

A3



FOR INFORMATION

Legend

- City Boundary
- Proposed Development Boundary
- Proposed Road Development

European Sites

- Lough Corrib cSAC
- City Boundary
- Inner Galway Bay SPA
- Lough Corrib SPA

Zone of Influence

- Construction phase potential drawdown impacts
- Construction phase potential WQ impacts

Groundwater Bodies (2017)

- Clare - Corrib (Terryland) GWB
- Clarinbridge GWB
- Maam-Clonbur GWB
- Lough Corrib Fen 1 (Menlough) GWB
- Lough Corrib Fen 2 GWB
- Spiddal GWB
- Ross Lake GWB
- Estimated extent of buried landscape

Clients: Comhairle Chontae na Gaillimhe Galway County Council; N6 Galway City Transport Project; An Roinn Iompair Turasóireachta agus Spóirt Department Transport, Tourism and Sport; Transport Infrastructure Ireland

Key Plan: Sheet 1, Sheet 2

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Scale: **1:25,000**

Date: **July 2018**

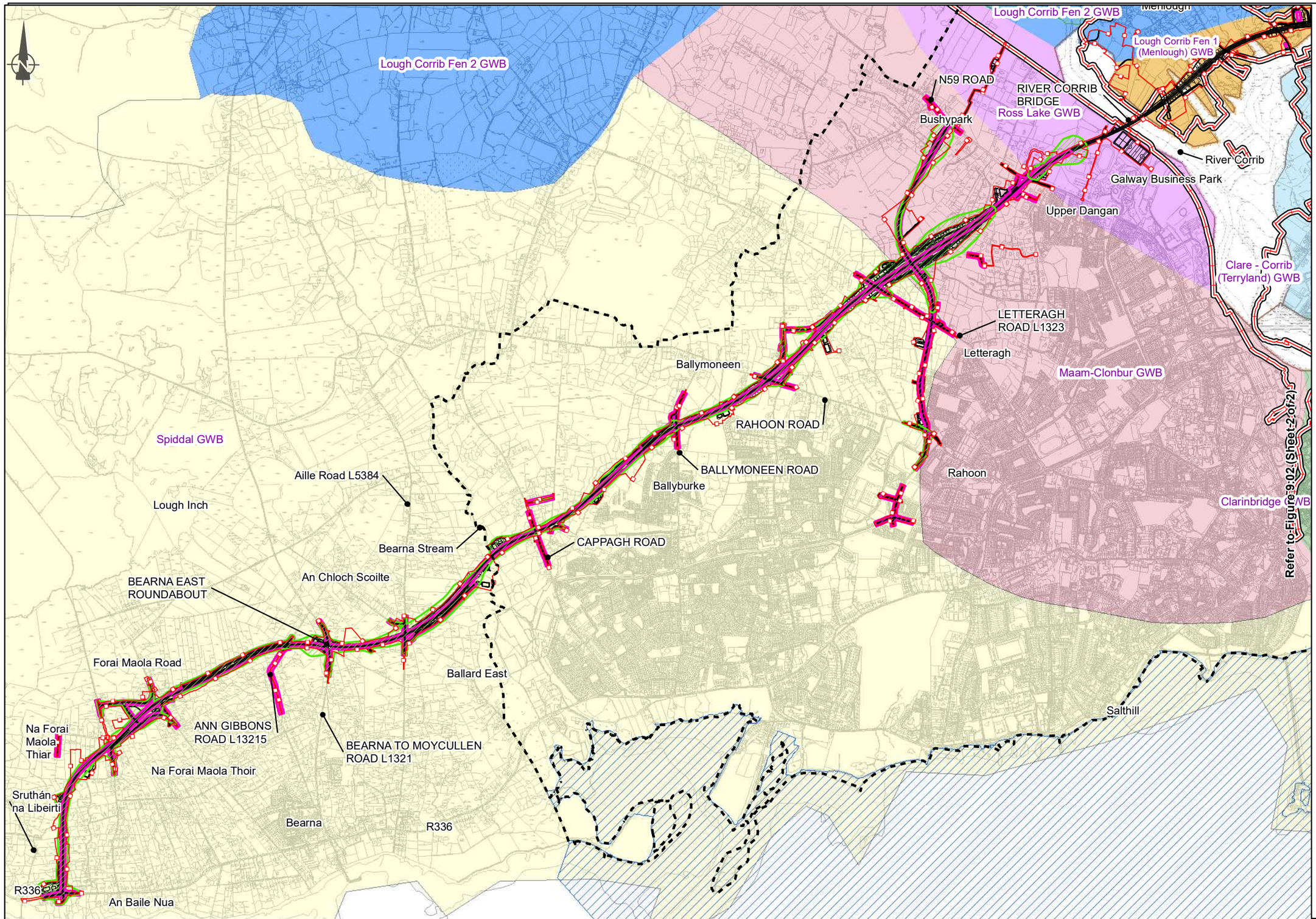
Issue	Date	By	Chkd	Appd
I2	19/02/2020	AG	LB	EMC
I1	26/07/2018	AO	LB	EMC

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	I2

A3



FOR INFORMATION

Legend

- City Boundary
- Proposed Development Boundary
- Proposed Road Development

Zone of Influence

- Operation phase potential drawdown impacts
- Operation phase potential WQ impacts

European Sites

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

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; N6 Galway City Transport Project; An Roinn Iompair Turasóireachta agus Spóirt; TII

Key Plan: Sheet 1, Sheet 2

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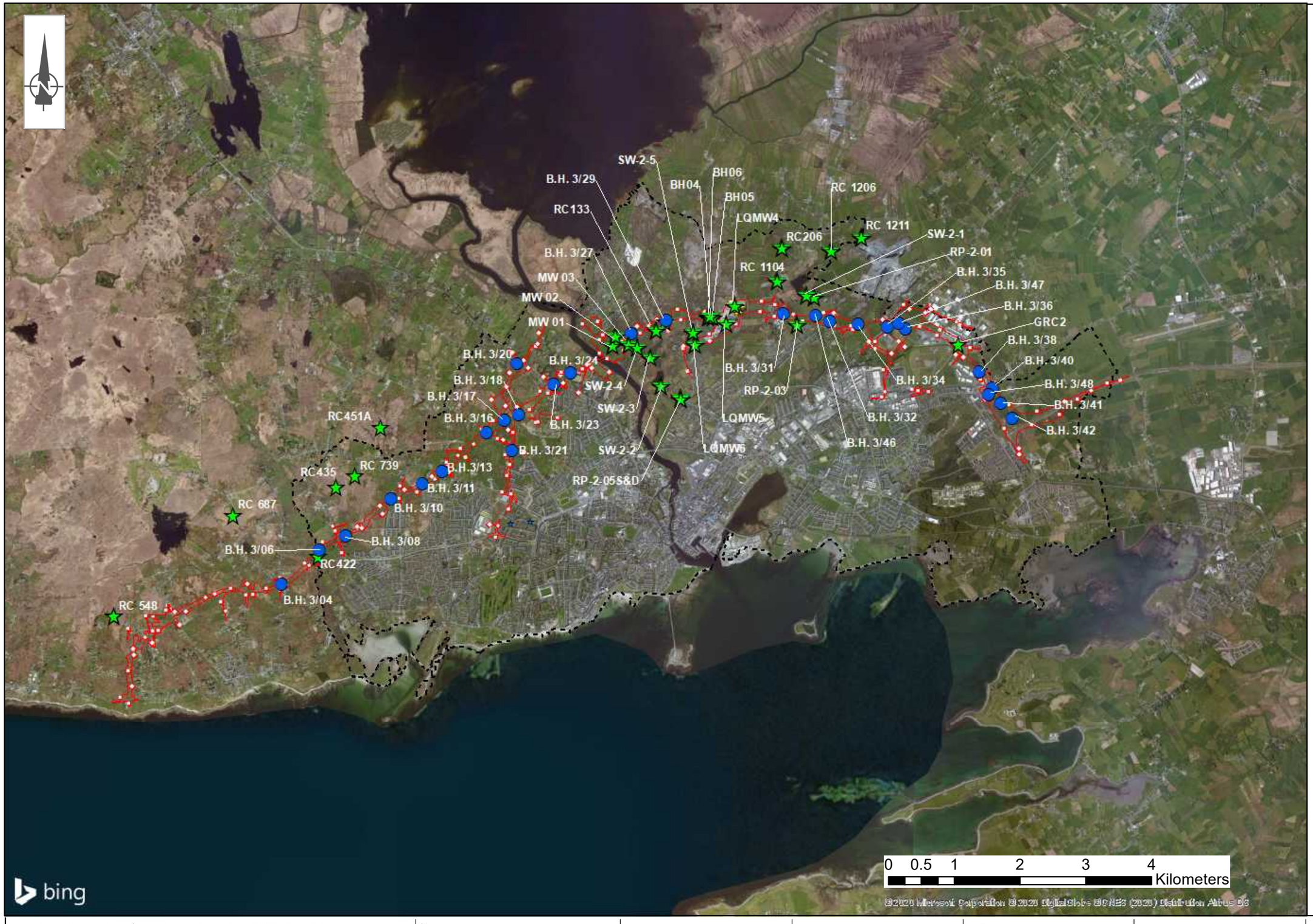
Issue	Date	By	Chkd	Appd
I2	19/02/2020	AG	LB	EMC
I1	26/07/2018	DM	LB	EMC

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	I2

A3



FOR INFORMATION

Legend

- City Boundary
- Proposed Development Boundary
- Phase 3 GI groundwater level monitoring
- Phase 2 GI groundwater level monitoring

Clients

Comhairle Chontae na Gaillimhe
Galway County Council

N6 Galway City Transport Project

An Roinn Iompair Turasóireachta agus Spóirt
Department Transport, Tourism and Sport

TII Bonneagar Iompair Éireann

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Date: **July 2018**

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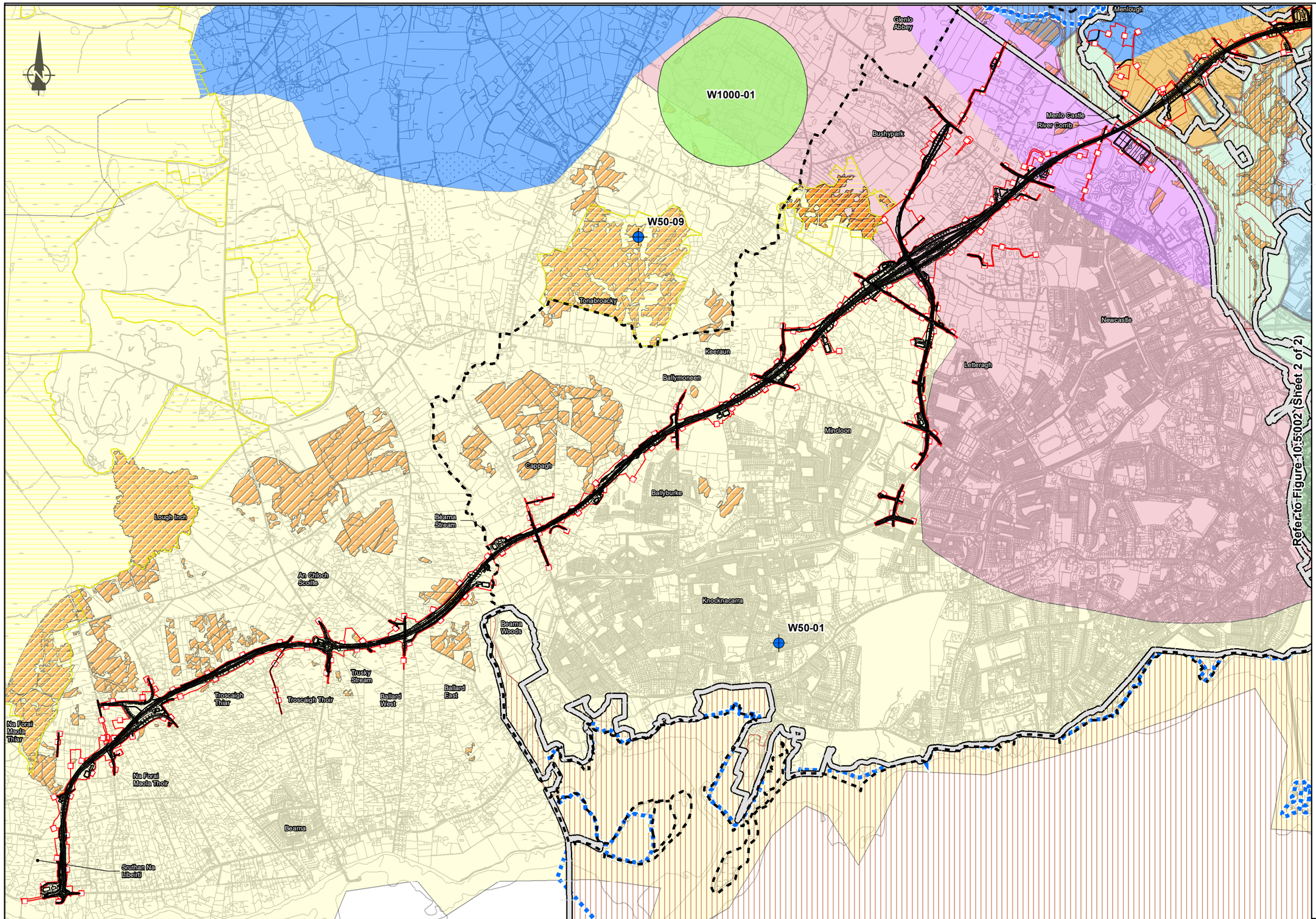
I2	19/02/2020	AG	LB	EMC
I1	26/07/2018	PC	LB	EMC

Locations of Monthly Monitored Groundwater Level Locations

Drawing Status
For Information

Job No	Drawing No	Issue
233985-00	GCOB-SK-D-702	I2

A3



EIA REPORT

Legend

- City Boundary
- Proposed Development Boundary
- Proposed Road Development
- candidate Special Area of Conservation
- Special Area of Conservation (SPA)
- National Heritage Areas (NHA)
- Potential Natural Heritage Areas (pNHA)

Groundwater Receptors

- Wells 50m Accuracy
- Wells 100m Accuracy
- Wells 500m Accuracy
- Wells 1km Accuracy
- Groundwater Depedant habitats

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

Palaeolandscapes

- Estimated Palaeolandscapes extents

Clients

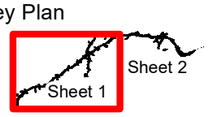
Comhairle Chontae na Gaillimhe Galway County Council

N6 Galway City Transport Project

An Roinn Iompair Turasóireachta agus Spóirt Department Transport, Tourism and Sport

TII Transport Infrastructure Ireland

Key Plan



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Date: **September 2018**

Issue	Date	By	Chkd	Appd
I2	19/02/2020	AG	MH	EMC
I1	28/09/2018	AG	MH	EMC

Drawing Title

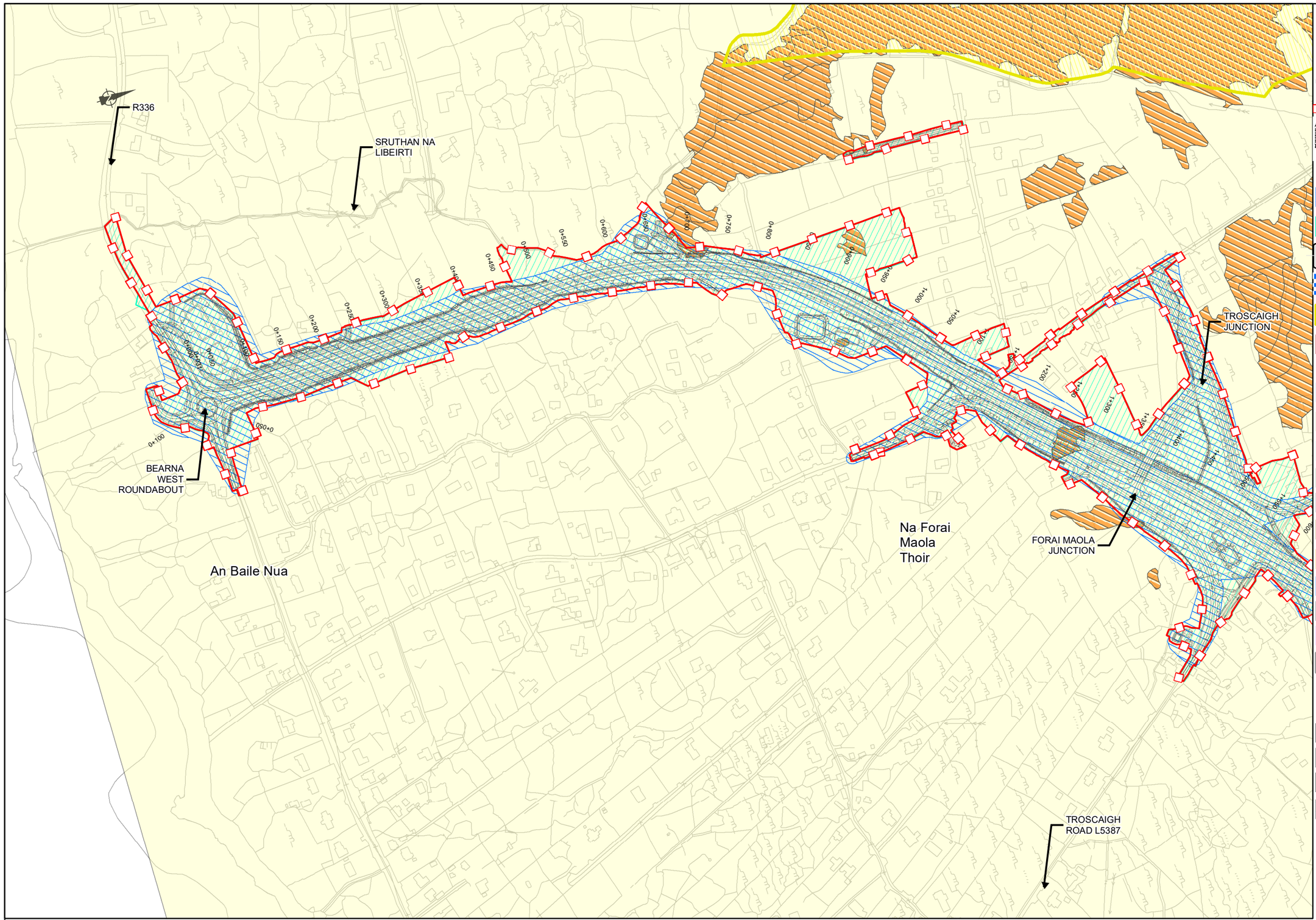
Groundwater Receptors Sheet 1 of 2

Drawing Status

For Information

Job No	Drawing No	Issue
233985-00	Figure 10.5.001	I2

A3



EIA REPORT

Legend

- City Boundary
- Proposed Development Boundry
- Proposed Road Development

Potential Impacts

- Drawdown Zone of Influence
- Area Liable to Contamination
- candidate Special Area of Conservation
- Special Areas of Conservation (SPA)
- National Heritage Areas (NHA)
- Potential National Heritage Areas (pNHA)

Groundwater Bodies (2017)

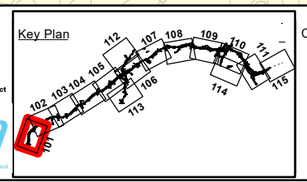
- Clare - Corrib (Terryland) GWB
- Clare-Corrib (Ballindooley East) GWB
- Clare-Corrib (Ballindooley West) GWB
- Clarinbridge GWB
- Maam-Clonbur GWB
- Lough Corrib Fen 1 (Lackagh) GWB
- Lough Corrib Fen 1 (Menlough) GWB
- Lough Corrib Fen 2 GWB
- Spiddal GWB
- Ross Lake GWB
- Estimatated Palaeolandscapes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

Groundwater Receptors

- Wells 50m Accuracy
- Wells 100m Accuracy
- Wells 500m Accuracy
- Wells 1km Accuracy
- Groundwater Dependant habitat
- Groundwater Seepage Points

Clients: Comhairle Chontae na Gaillimhe Galway County Council; N6 Galway City Transport Project; An Roinn Iompair Turasóireachta agus Spóirt Department Transport, Tourism and Sport; TII Transport Infrastructure Ireland

Key Plan



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Date: **February 2020**

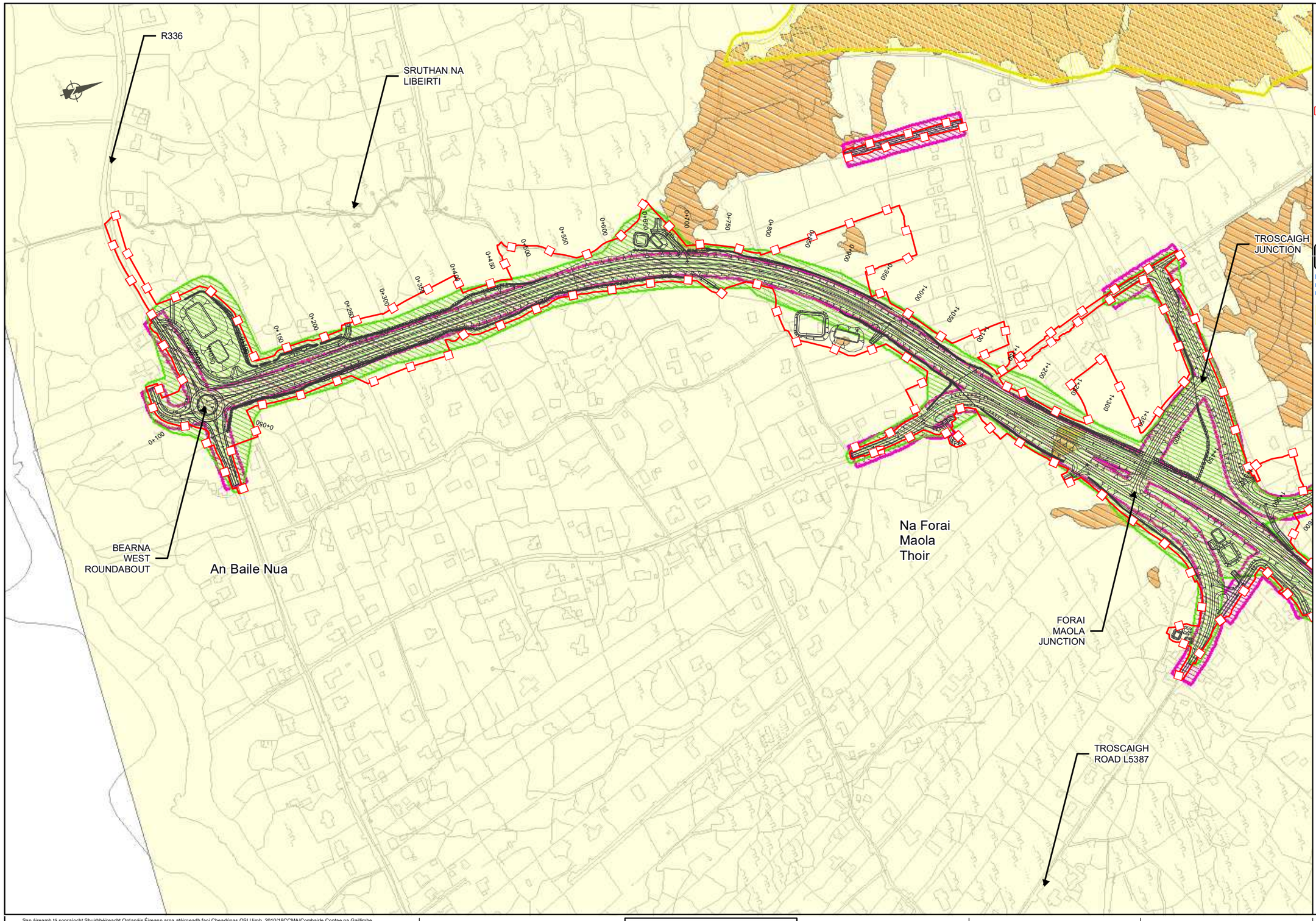
Issue	Date	By	Chkd	Appd
I2	19/02/2020	JOT	MH	EMC
I1	28/09/2018	KJ	MH	EMC

Drawing Title: **Construction Zone of Influence (ZoI) Sheet 01 of 15**

Drawing Status: **FOR INFORMATION**

Job No	Drawing No	Issue
233985-00	Figure 10.7.101	I2

A3



EIA REPORT

Legend

- CityBoundary
- Proposed Development Boundary
- Proposed Road Development

Potential Impacts

- Drawdown Zone of Influence (ZoI)
- Area at risk of WQ impacts
- candidate Special Area of Conservation
- Special Area of Conservation (SPA)
- National Heritage Areas (NHA)
- Potential Natural Heritage Areas (pNHA)

Groundwater Bodies (2017)

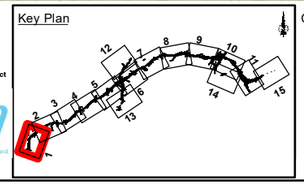
- Clare - Corrib (Terryland) GWB
- Clare-Corrib (Ballindooley East) GWB
- Clare-Corrib (Ballindooley West) GWB
- Clarinbridge GWB
- Maam-Clonbur GWB
- Lough Corrib Fen 1 (Lackagh)
- Lough Corrib Fen 1 (Menlough) GWB
- Lough Corrib Fen 2 GWB
- Spiddal GWB
- Ross Lake GWB
- Estimatated Palaeolandscapes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

Groundwater Receptors

- Wells 50m Accuracy
- Wells 100m Accuracy
- Wells 500m Accuracy
- Wells 1km Accuracy
- Groundwater Dependant Habitat
- Groundwater Seepage Points

Clients: Comhairle Chontae na Gaillimhe Galway County Council; N6 Galway City Transport Project; An Roinn Iompair Turasóireachta agus Spóirt; Transport Infrastructure Ireland

Key Plan



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Job Title: **N6 Galway City Ring Road**

Scale: **1:5,000**

Date: **September 2018**

Issue	Date	By	Chkd	Appd
I2	19/02/2020	AM	MH	EMC
I1	28/09/2018	KJ	MH	EMC

Drawing Title: **Operation Zone of Influence (ZoI) Sheet 01 of 15**

Drawing Status: **FOR INFORMATION**

Job No	Drawing No	Issue
233985-00	Figure 10.8.101	I2