Galway County Council

N6 Galway City Ring Road

Eco-hydrogeology Summary Report for Lough Corrib cSAC

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Contents

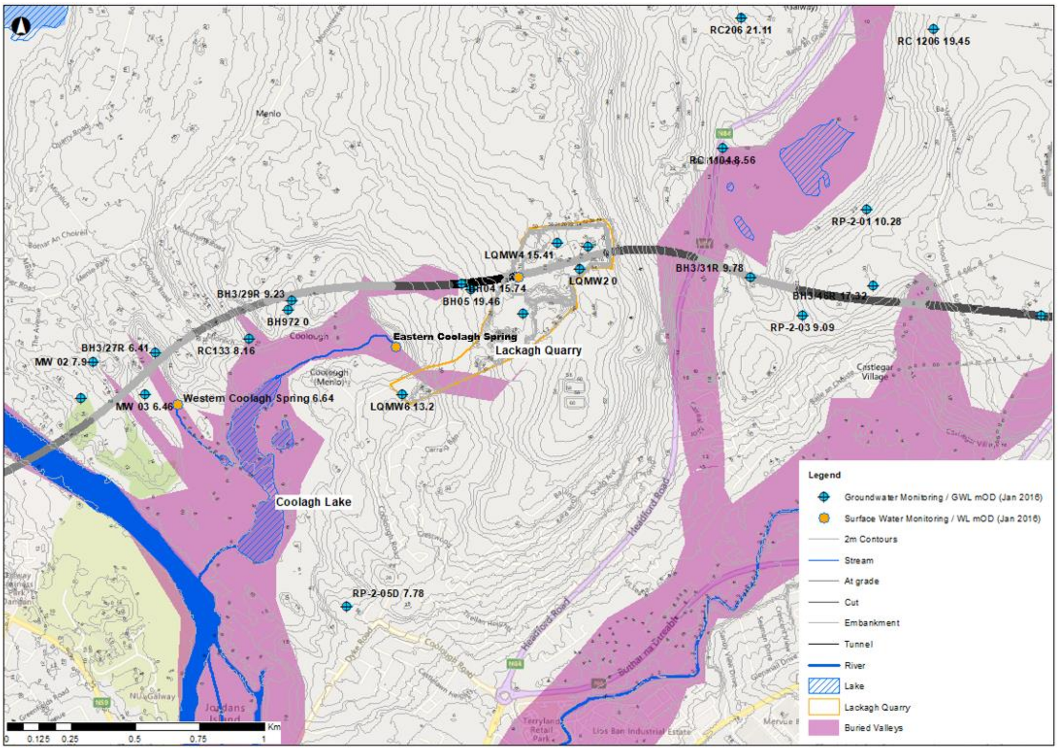
1 Introduction

Coolagh Lakes are located to the east of the River Corrib and are part of the Lough Corrib cSAC. The location of the Lough Corrib cSAC is presented in Plate 1 relative to the palaeochannels that have been identified in the wider area.

Plate 1: Lough Corrib cSAC

The River Corrib is a substantial river that is not dependent on groundwater. However, the Coolagh Lakes which is a tributary to the River Corrib, is mainly groundwater fed. Groundwater contributions are a combination of flow from a karst spring (Western Coolagh Spring) as well as from seepages around the periphery of the lakes. The location of Coolagh lakes and Western Coolagh Spring are shown on Plate 2.

Plate 2: Location of Coolagh lakes relative to Lackagh Quarry



Biodiversity assessments have identified that the habitats at the Coolagh Lakes are dependent on the lake water level and lake water quality. On this basis, the groundwater dependant terrestrial ecosystems (GWDTE) around the lake margins are dependent on the groundwater contribution to Coolagh Lakes. The hydrogeological setting and interaction between groundwater, the Coolagh Lakes and the River Corrib are explored in terms of both water level and water quality in this summary report.

The Geotechnical and Hydrogeological Appraisal of the Lackagh Tunnel (EIAR Appendix A.7.3 of the EIAR and Appendix F of the NIS) and Chapter 10 of the EIAR(Page 892) assessed whether construction dewatering activities or the operational presence of the tunnel may act as a barrier to flow and intercept or divert the groundwater flow supplying Coolagh lakes, with the risk of compromising the integrity of the habitats.

Extensive assessments were undertaken to ensure that the hydrogeological regime was fully understood so that any potential impacts could be assessed.

In order to assess the potential for any impacts, the 2 questions below about the hydrogeological regime needed to be understood and this summary assessment answers those:

1- Does the groundwater from Lackagh Quarry drain to Coolagh Lakes?

2- Define the groundwater catchment to Coolagh Lakes and by what flow mechanisms are the Lake water level and Lake water quality supported.

The nature of the groundwater dependant terrestrial ecosystems (GWDTE) at Coolagh Lakes are described below in Section 2 of this report. Section 3 outlines a summary of the data assessed. Section 4 summarises the hydrogeological conceptual model and explores the above two questions. Section 5 summarises the assessment of potential impacts.

Appendix A includes groundwater contour maps for winter (Appendix A-1) and summer (Appendix A-2) as well as three sets of Hydrographs. (Appendix A-3)

- Hydrograph i (Appendix A-3i) shows groundwater responses in Lackagh Quarry
- Hydrograph ii (Appendix A-3ii) shows groundwater responses related to a perched groundwater table from a shale bed
- Hydrograph iii (Appendix A-3iii) shows the groundwater levels recorded adjacent to Coolagh Lakes

This assessment includes both detailed and conceptual cross sections to aid the understanding of the area. The conceptual cross sections are presented in Section 3 below while the three detailed sections are presented in Appendix B. The cross sections comprise of:

- Appendix B Section A-A: Southwest to North east cross section from the River Corrib to Ballindooley Lough via the Coolagh lakes and Lackagh Quarry. (split over 4 drawings to allow sufficient detail)
- Appendix B Section B-B: A West east cross section through Lackagh Quarry along the alignment including the proposed Lackagh Tunnel
- Appendix B Section C-C: North South section through Coolagh Lakes showing the relationship between the lake level and groundwater level

2 Groundwater Dependent Qualifying Habitat at Coolagh Lakes (Lough Corrib cSAC)

The Coolagh Lakes and the associated fringing wetland habitat form part of the qualifying interests of Lough Corrib cSAC.

The Coolagh Lakes themselves correspond with the qualifying interest Annex I habitat Hard water lakes [3140]. The lakes in turn support an associated wetland complex of wet grassland (GS4), wet heath (HH3), fen (PF1 and PF2) and reed swamp (FS1); areas of which correspond with the qualifying interest Annex I habitat types *Molinia* meadow [6410], *Cladium* fen [*7210] and Alkaline fen [7230]. Other Annex I habitat present which also form part of the associated wetland habitat complex are Residual alluvial forests [*91E0], Hydrophilous tall herb [6430], Wet heath [4010] and Transition mires [7140].

The full complex of wetland habitats associated with the Coolagh Lakes, including the fringing reed swamp, fen, marsh, wet heath, wet woodland and wet grassland habitats intergrade with and support the structure and functions of the lake habitat.

Equally, the area, distribution and quality of these habitats are dependent upon water levels and the water quality in the Coolagh Lakes.

The hydrogeological regime, particularly the groundwater contribution, must be maintained so that the area, distribution and depth of the lake habitat and its constituent/characteristic vegetation zones and communities are not reduced.

Critically, maintaining the area and condition of all fringing habitat, and not just those qualifying interest Annex I habitats, is a key component of the conservation objectives for Hard water lake [3140] habitat in Lough Corrib cSAC.

An overview of where the qualifying interest Annex I habitat types of Lough Corrib cSAC are located in relation to the Coolagh Lakes are shown on Plate 9.1 of the NIS.

Figure 10.3.3 of the NIS illustrates the collective extent of the groundwater dependent qualifying interest habitats of Lough Corrib cSAC. It shows the extent of both the qualifying interest Annex I habitats and the other fringing habitats which provide a supporting role to the lake habitat itself.

The Fossitt classifications of the habitats associated with the Coolagh Lakes in the immediate vicinity of the proposed road development are shown on Figure 13.3 of the NIS.

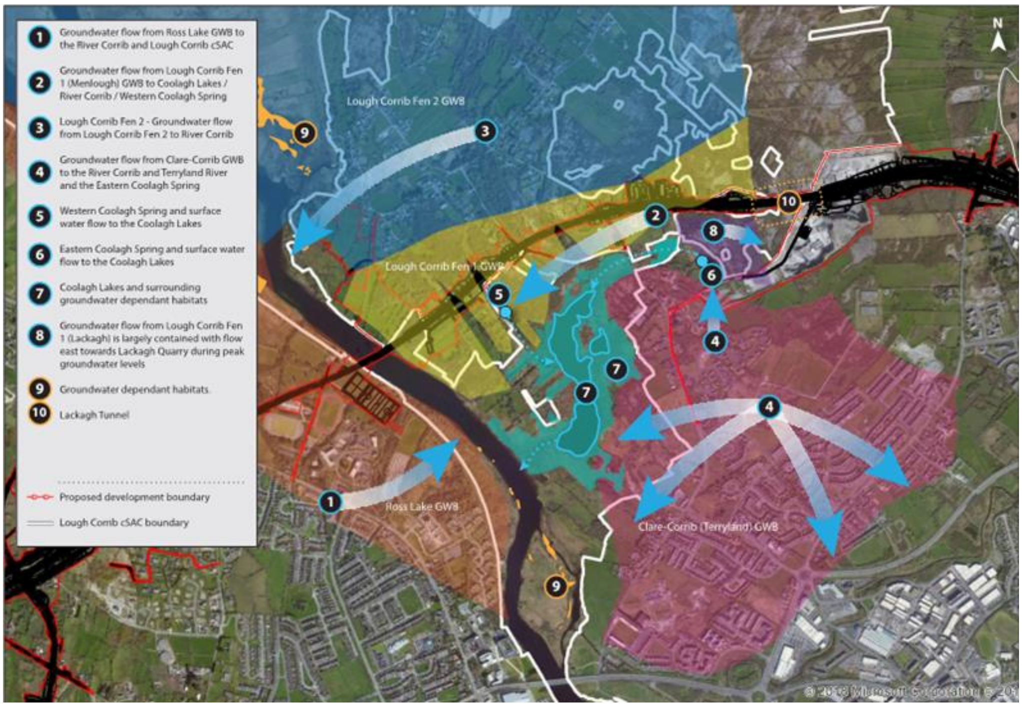
The Annex I classifications of the habitats associated with the Coolagh Lakes in the immediate vicinity of the proposed road development are shown on Figure 14.3 of the NIS.

3 Hydrogeology background

The ground investigations along the route of N6 Galway City Outer Bypass (2006 GCOB) and proposed road development identify four locations where the geology is interrupted by deep buried valleys (River Corrib, Coolagh Lakes/Lackagh Quarry, N84 Headford Road and N83 Tuam Road). These buried valleys locally interrupt the regional groundwater gradient and either impound and/or deviate the regional trend. The location of these relative to Coolagh Lakes and Lackagh Quarry are presented in Plates 1 above and Plate 3 below.

The hydrogeological study undertaken to inform the EIAR and NIS for the proposed road development identified 4 no. groundwater bodies (GWB) that contribute groundwater to the groundwater dependant habitats in the Lough Corrib cSAC. They are: 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 Plate 3 for ease of reference) illustrates those groundwater bodies that contribute groundwater to the Lough Corrib cSAC.

Plate 3: Generalised hydrogeology interactions with Lough Corrib cSAC



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. These features are shown on Plate 2 above.

Due to the thickness and low permeability of the fill sediment from its fines dominated nature, any groundwater contribution through the base of the lakes is unrealistic Other than Western Coolagh Spring 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 is a pond at the head of a drain, which has been named Eastern Coolagh Spring. Eastern Coolagh Spring is located within the thick clay deposits in the valley floor, approximately 35m away from limestone that rises steeply on the north and western sides from the valley floor. Although no flow is measurable at Eastern Coolagh Spring or immediately downstream of it, it is anticipated that groundwater in the surrounding subsoil will migrate to it as seepages. It is noted from walkover surveys that the margins of the lake remain permanently wet even during summer, indicating that constant groundwater seepage occurs at the limestone/buried valley interface around the lake periphery.

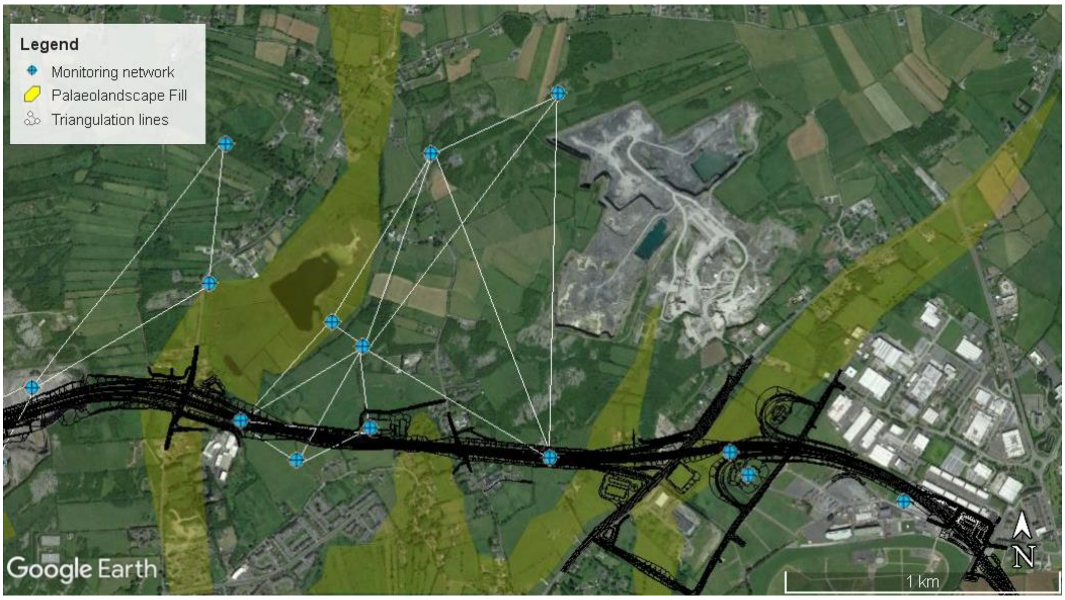
Manual groundwater level monitoring data is presented in Appendix A10.3 of the EIAR and summary groundwater data is presented in Table 10.8 of Chapter 10 of the EIAR and Table 3 of Appendix A of the NIS. This data has been presented in Appendix A of this report as groundwater level contours for Winter and Summer. Hydrographs are also presented in Appendix A3 to show the seasonal variation.

Regional groundwater level

The regional hydraulic gradient was developed for the limestone area using groundwater levels recorded in monitoring boreholes both upgradient and downgradient of the proposed road development, as well as groundwater levels measured along the proposed road development and the receiving water level at the River Corrib, Terryland River and Galway Bay.

A triangulation net was constructed across limestone groundwater bodies to provide a comprehensive assessment of gradient and flow direction. This allowed hydraulic gradients between monitoring points to be calculated and used to plot groundwater contours beyond the centreline and in the wider extent of the aquifer. The groundwater monitoring network allows groundwater flow directions to be calculated. An example of the triangulation net used is presented below in Plate 4.

Plate 4: Example of the triangulation net used (June 2016 water levels)



Based upon the gradient calculations and generation of groundwater contours (Refer to Appendix A-Figure 1 and Figure 2) the predominant groundwater flow of the regional groundwater system is towards the surface water features (the River Corrib and Terryland River).

In the limestone, 7 boreholes are located in the wider area. These include monitoring boreholes from 2006 GCOB (RC and MW) and the 4 monitoring boreholes designed to monitor surface water groundwater interaction (RP-02 series). In addition, the 3 Lackagh Quarry monitoring wells (LQMW series) and 3 surface water monitoring locations (SW-02 series) were also used to develop hydraulic gradients. The River Corrib (including the OPW gauge for the River Corrib at Dangan) and the Terryland River were used as receiving water for groundwater and where appropriate used to triangulate groundwater flow directions and gradients.

Groundwater levels are available for five monitoring wells in or adjacent to Lackagh Quarry ((LQMW04, LQMW05, BH04 and BH05) The hydrographs included in Appendix A i show the seasonal responses of groundwater levels for Lackagh Quarry. Water levels at the River Corrib, Western Coolagh Spring, Eastern Coolagh Spring are included for completeness. Cross Section A-A, B-B and C-C show the groundwater levels in the Lackagh Quarry and Coolagh lakes area

The Lackagh Quarry monitoring wells (LQMW 1-6) were originally installed when the quarry was operational, and no geological logs are available. LMQ1-3 were not included in the monitoring network as the groundwater levels recorded were identical to the level at LQMW4. LQMW4 was chosen as representative of all as it was in the best condition.

LQMW01, 02, 03 and 04 are in the quarry void. LQMW05 and LQMW06 are to the south-west, in the quarry yard area and quarry access road respectively. These locations are shown on Figures 1 and Figure 2 of Appendix A.

The geology of these wells was determined based the condition survey (which determined their depth), the geological mapping of the quarry and from boreholes drilled for the project.

Perched groundwater level

In additional to the regional groundwater system there is also local perching of the groundwater table at specific stratigraphic horizons. One horizon in particular, an argillaceous limestone observed in Lackagh Quarry, perches recharge in the Menlough/Lackagh Quarry area. The geometry of the ‘shale’ bed dips at 2 degrees with a strike of 288 degrees. Plate 5 (reproduced from Figure 3.15 of the Lackagh Tunnel Geotechnical and Hydrogeological report in Appendix A.7.3 of the EIAR and Appendix F of the NIS) illustrates this shale bed above the limestone. Cross sections A-A, B-B and C-C in Appendix B show the geometry of the shale horizon in the Lackagh Quarry and Coolagh Lakes area.

Plate 5: Shale bed in Lackagh quarry

The location of boreholes in Lackagh Quarry is presented in Appendix A – Figures 1 & 2. The seasonal variation of groundwater levels in Lackagh Quarry are presented in Appendix A Hydrograph (i), which is derived from Plate 10.5 in Chapter 10 of the EIAR and Appendix A.10.3 of the EIAR and Appendix F of the NIS.

This geological geometry of the shale bed controls perching of recharge in the local area between Menlough and Lackagh Quarry. The groundwater levels at 4 boreholes: BH05, LQMW05, LQMW06 and RP-5-S reflect the interaction of groundwater levels influenced by the shale bed. The location of these boreholes is presented in Appendix A – Figures 2 & 3. The hydrographs for these boreholes are presented in Appendix A Hydrograph (ii), which is derived using data from Plate 10.5 in Chapter 10 of the EIAR and Appendix A.10.3 of the EIAR and Appendix F of the NIS.

From mapping the geology at the wells, LQMW 04 is in the limestone aquifer below the shale horizon. As outlined above, the argillaceous limestone (also referred to as shale bed) observed in Lackagh Quarry, perches recharge in the Menlough/Lackagh Quarry area. LQMW05 is installed through the shale horizon into the lower aquifer and as such picks up both deeper and shallower groundwater. LQMW06 (by extrapolation of the geology geometry) is also installed through the shale horizon but on the opposite side of a buried valley to LQMW05. These monitoring locations are noted on Plate 3 above.

The geological logging of the five boreholes installed as part of the proposed road development along the alignment of Lackagh Tunnel was used to cross check this. These are shown in Plate 6 below (also refer below to Figure 5 in Appendix A of the Lackagh Tunnel Geotechnical and Hydrogeological Appraisal in Appendix A.7.3 of the EIAR and Appendix F of the NIS for completeness). Of these five boreholes, three (BH04, BH05 and BH06) were completed with piezometers.

BH04 and BH05 are located in the narrow strip of limestone that lies to the west of the quarry, between the quarry and the buried valley (refer to Plate 6 below). Both BH04 and BH05 also encountered the shale bed.

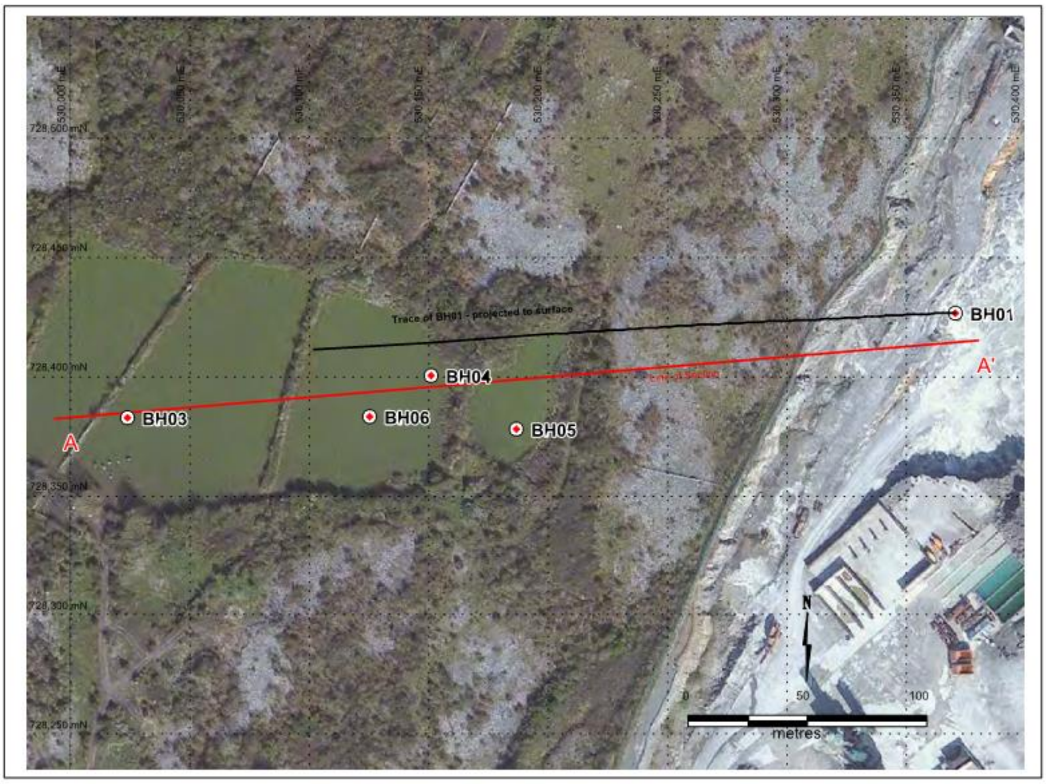
In borehole BH04, the shale was reported as mudstone with clay above and below it in a unit from 13.77mOD to 12.62mOD. In borehole BH05, a zone of core loss and clay occurred between 13.94mOD to 13.69mOD.

In both BH04 and BH05, the piezometer response zone is installed below the shale horizon.

- BH04: 9.49 to -2.83mOD
- BH05: 11.54 to -5.84mOD

Based on the geology encountered, whilst borehole BH04 has a significant thickness of shale and perches recharge above it, the shale horizon in borehole BH05 is weathered and will leak. As such, although shale bed perches recharge in the local area, there are locations where leakage occurs down to the regional groundwater table below and in these locations there will be localised recharge spikes in the regional groundwater table. These responses will be storm event related and temporary as the regional groundwater table equilibrates.

Plate 6: Locations of boreholes BH03, BH04, BH05 and BH06 (Source: Lackagh Tunnel Geotechnical and Hydrogeological Appraisal Appendix A Figure 5)



Peak groundwater levels in Lackagh Quarry

Peak flood levels were surveyed on the floor of Lackagh Quarry on 5 January 2016 at 15.69mOD. This peak flooding level represents the peak groundwater level.

The following groundwater levels were measured above this level and the reasons are outlined below:

- LQMW04 was manually measured on 11 January 2016 as 15.41mOD
- BH04 was manually measured on 5 January 2016 at 14.29mOD and on 11 January 2016 at 15.74mOD. The delayed peak response in BH04 represents equalisation in the unsaturated zone in the days after heavy rain
- BH05 was manually measured on 5 January 2016 at 19.46mOD and on 11 January 2016 at 16.66mOD. The equalisation from the recharge peak in BH05 would have caused the subsequent delayed peak response in nearby BH04

As stated in Section 2.1.5.1 above whilst the shale horizon forms a natural barrier in BH04, that barrier is weathered in BH05. As such, the higher groundwater levels in BH05 are a reflection of recharge from above the shale bed entering the monitoring borehole. The short-lived high groundwater levels in BH05 on January 5, 2016 are a recharge response and not representative of the regional groundwater table. Following rainfall, recharge will flow via multiple pathways through the thick unsaturated zone down to the regional water table. Where natural weathered gaps in the shale bed occur then these will leak recharge to the regional groundwater table below.

The hydrographs included in Appendix A ii show the seasonal responses of groundwater levels in wells that interact with the shale bed.

Water levels at Coolagh Lakes

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.

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. The hydrographs included in Appendix A iii show the seasonal responses of groundwater levels at the River Corrib, Western Coolagh Spring, Eastern Coolagh Spring and groundwater levels in wells around the periphery of Coolagh Lakes.

As mentioned, the level of the River Corrib influences the water level in the Coolagh Lakes so that generally the levels of both are comparable. However, as the River Corrib responds more rapidly than the groundwater levels (and Western Coolagh Spring) the River Corrib can rise slightly higher than the Coolagh Lakes during storm events (by up to 25cm). This can lead to water from the river entering the lower lake and mixing with the lake water. The rise of the level in the lower lake will cause impoundment in the upper lake but it is unlikely that river water will enter the upper lake due to the narrow connecting channel between lakes.

The hydrographs included in Appendix A iii show the seasonal responses of groundwater levels in wells that interact with the shale bed.

Water quality at Coolagh Lakes

Water sampling was undertaken during the hydrogeological study to characterise the groundwater quality across the study area. Groundwater samples were taken from Western Coolagh Spring and monitoring boreholes around the periphery of Coolagh Lakes (RC133, RP-205S&D and MW03). The waters from these monitoring boreholes and also from Western Coolagh Spring are confirmed as having a high alkalinity (>180mg/l total alkalinity $CaCO_3$), which is in line with the habitat description for Coolagh Lakes supporting alkaline fen. On this basis the fen is dependent on both the quality and quantity of groundwater.

Of the water samples taken from limestone, the total alkalinity from Western Coolagh Spring and borehole RC133 was slightly lower than other boreholes. It is likely that Western Coolagh Spring and RC133, which is adjacent to turlough K31, allow for faster flow through the aquifer which has the effect of a reduced limestone contact when compared to groundwater in either matrix or fracture flows (i.e. not sampled from karst systems). On this basis it would be expected that groundwater seeping from the margin of the limestone aquifer around Coolagh Lakes will be higher alkalinity than the water emergent from the karst system at Western Coolagh Spring. The hydrographs included in Appendix A iii show the seasonal responses of groundwater levels at the River Corrib, Western Coolagh Spring, Eastern Coolagh Spring and groundwater levels in wells around the periphery of Coolagh Lakes.

As discussed in water levels at Coolagh Lakes, there are times, particularly during storm events when the river water enters the lakes, this occurs when the river rises more rapidly than groundwater. On these occasions there will be a temporary natural fluctuation in water quality at the lower Coolagh Lake, with total alkalinity reducing due to mixing. Whilst, the upper lake can become impounded due to water level rise in the lower lake it is unlikely that a change in water quality at the upper lake occurs due to the restricted flow in the connecting channel between the two lakes.

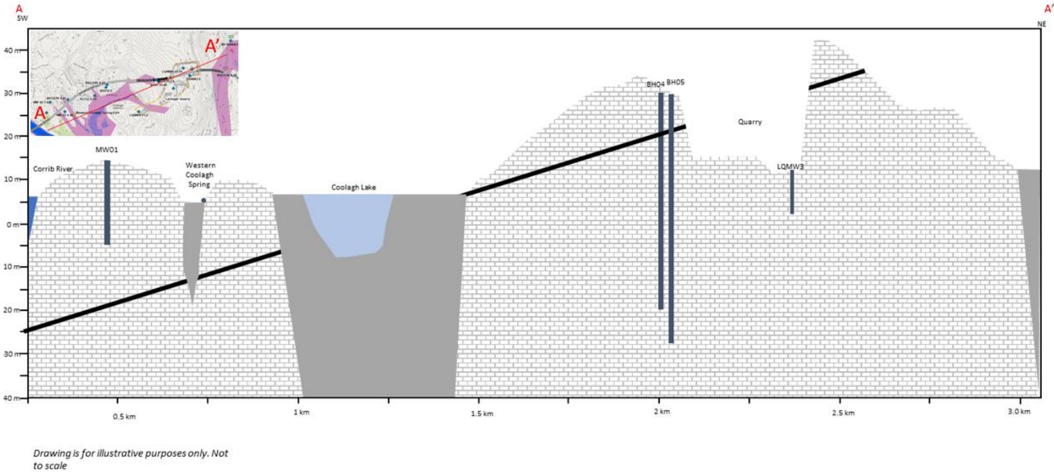
4 Hydrogeological Conceptual Model

The information presented in the above section allows a conceptual model to be developed for the area between Lackagh Quarry and Coolagh Lakes. This conceptual model is based on all monitoring ground investigation data presented in the EIAR and is framed against the two questions posed above which are key to informing any potential impact assessment.

As outlined above detailed cross sections have been prepared to illustrate the information available (refer to Appendix B Cross sections A-A, B-B and C-C in Appendix B).

A simple illustration of the conceptual hydrogeological model for Coolagh Lakes is presented in Plate 7 which is based on the information provided above and presented on the cross sections (Appendix B).

Plate 7: Conceptual model for Coolagh lakes



4.1 Does groundwater from Lackagh Quarry drain to Coolagh Lakes?

The hydrogeology at Lackagh Quarry has been complicated by the quarry itself. Prior to the quarry operation groundwater was clearly divided into two regimes, a regional groundwater regime and a perched groundwater regime. With the development of the quarry, the perched groundwater regime has been removed from the aquifer at Lackagh Quarry. Rainfall now directly recharges the regional aquifer via the floor of the quarry and inflows occur from above the shale bed.

The regional groundwater regime is shown by the monitoring data to be south westwards towards the River Corrib south of Coolagh Lakes, with the route being partially guided by the buried valleys that form barriers to groundwater flow. Refer to Appendix A Figures 1 and Figure 2 which show interpreted groundwater level contours for the Lackagh Quarry and Coolagh Lakes areas. These interpretations confirm that groundwater flows from the upland area north of Lackagh Quarry. This data also shows that the buried valley immediately west of Lackagh Quarry causes a bifurcation of the groundwater into two directions, part of the flow diverts west to the River Corrib and the other diverts flow south and then south westwards, via Lackagh Quarry and towards the River Corrib (south of Coolagh Lakes near Terryland).

Regarding the pre-quarrying groundwater flow directions: whilst the quarry has not changed the route of the regional groundwater flow, it has significantly altered the perched groundwater regime. Prior to the quarry, the perched groundwater would have flowed further west and would have contributed to Coolagh Lakes. Lackagh Quarry has severed the connection of the perched groundwater and drained these flows into the quarry void. As such, the perched groundwater regime of Lackagh Quarry is no longer connected to Coolagh lakes. The concept of the shale bed in the area of Lackagh Quarry is clearly shown in Cross sections A-A and B-B in Appendix B.

On the basis that the regional groundwater table drains away from Coolagh Lakes and the perched groundwater table has been intercepted by the quarry, then neither the regional nor perched water table at Lackagh Quarry drains to Coolagh Lakes. Therefore, groundwater from Lackagh Quarry does not drain to Coolagh Lakes. This regime will not be modified by the proposed road development and as such the groundwater at Lackagh Quarry will remain separate to Coolagh Lakes.

4.2 Define the groundwater catchment to Coolagh Lakes and by what flow mechanisms are the Lake water level and Lake water quality supported

Based on groundwater level monitoring and the description of the regional groundwater contours above, the catchment to Coolagh Lakes is limited to a reasonable small area that comprises of:

1- The catchment to Western Coolagh Spring (karst)

2- The seepages that emerge around the rock periphery of the Coolagh Lakes where the sediments fill the buried valley

On this basis the catchment can be divided into two flow types: (1) karst flow from the Western Coolagh Spring, which provides most of the volume to the lakes and (2) groundwater seepages from the surrounding limestone aquifer which keeps the margins wet and provides a year round supply of groundwater that is likely to be small in volume compared to Western Coolagh Spring but is very important in terms of the habitat in the marginal areas.

The catchment to the Western Coolagh Spring comprises the Lough Corrib Fen 1 (Menlough) GWB. The catchment for seepages to Coolagh Lakes comprises Lough Corrib Fen 1 (Menlough) GWB, Lough Corrib Fen 1 (Lackagh) GWB and the Clare-Corrib GWB. The catchment to Coolagh Lakes does not include Lackagh Quarry.

Cross sections C-C in Appendix B shows a section through Coolagh Lakes and confirms the high groundwater table around the periphery where limestone occurs. This high groundwater table provides source for constant seepage to the lakes all year round.

It is noted that prior to the quarry operations, the catchment would have included the perched groundwater regime at Lackagh Quarry, but it is important to recognise that the regional groundwater system at Lackagh Quarry has always been separate to Coolagh Lakes due to the buried valley that lies in between.

5 Impact assessment

The impact assessment for the habitats at Coolagh Lakes is considered in terms of potential for changes in the hydrogeological regime (water levels and flows) and the water quality during the construction and operation phases. The potential hydrogeological effects of the proposed road development on Lough Corrib cSAC are detailed in Section 9.1.4.3 of the NIS.

Assessment of potential changes to the hydrogeological regime is based on the conceptual model presented in Section 4. The hydrogeological conceptual model provides a robust assessment of the groundwater regime at Lackagh Quarry that confirms that groundwater flow in Lackagh Quarry, both the perched and regional groundwater flows, do not drain to Coolagh Lakes (Section 4.1). The regional groundwater regime at Lackagh Quarry is isolated from Coolagh Lakes by a substantial buried valley that lies between them and the perched groundwater has been intercepted by the quarry void.

On this basis, the assessment of potential impacts below focuses only on those design elements that lie within the catchment to Coolagh Lakes, which is clearly stated in Section 4.2. These design elements include viaduct foundations, infiltration basins and small scale works to existing roads in the local area.

Mitigation is applied to Lackagh Tunnel even though it is in a separate groundwater regime. The mitigation, enforcement of a no groundwater lowering in Lackagh Quarry rule, is applied in order to provide a belts and braces solution in recognition that Coolagh Lakes is a sensitive groundwater receptor and is included in the Schedule of Environmental Commitments.

5.1 Potential Impacts to the Hydrogeological regime from the proposed road development

The potential hydrogeological effects of the proposed road development on the Coolagh Lakes, and the associated groundwater dependent habitats that make up and support the qualifying interests of Lough Corrib cSAC, relate to the two types of groundwater contribution (1) the karst spring and (2) groundwater seepages around the periphery of the lakes. As was described in Section 3 above (Hydrogeology Background), Eastern Coolagh Spring is included as part of the seepage that supplies the margins of the lakes and is not a karst feature.

Western Coolagh Spring, which is a karst spring with conduit flow, is a discharge point from a karst system in the Lough Corrib Fen 1 (Menlough) GWB. The limestone seepages that occur around the periphery of the Coolagh Lakes are maintained by a high groundwater table in the limestone aquifer that is impounded by the buried valley upon which the Coolagh Lakes formed.

Assessment of the proposed road development assesses potential impacts on both the karst and seepage system that are important for groundwater contribution to Coolagh Lakes. The section below identifies those elements of the design that (1) have the potential to lower groundwater levels and (2) potential impacts that may cause a reduction in water quality.

Groundwater Lowering and Groundwater Quality

Those elements of the proposed road development in the catchment to Coolagh Lakes that have the potential to interact with groundwater during construction include bridge foundations and infiltration basins. All areas of cutting in limestone in this location are located above the regional water table. The following risk assessment is based upon the conceptual hydrogeological model for the area in Section 4 above, (which is summarised in Appendix A and Appendix F of the NIS):

Except for the potential for intercepting groundwater conduits when constructing the supporting piers for the Menlough Viaduct, the construction of the proposed road development will not affect the existing hydrogeological regime in terms of the quantity of water supply to the Coolagh Lakes or the frequency of flooding. To reiterate, groundwater dewatering during construction is not permitted within the design (see Section 5.1.1 of Appendix A of the NIS) in the catchments that drain to Coolagh Lakes.

In regard to the construction of the viaduct piers at Menlough, mitigation measures will ensure that flow in groundwater conduits will be maintained during construction of the Menlough Viaduct (refer to Section 10.5.3.3 of Chapter 10 of the EIAR (Page 892) and the CEMP in Appendix A.7.5 of the EIAR and Appendix C of the NIS).

The Clare-Corrib (Terryland) GWB overlaps with groundwater dependant habitats along the eastern edge of the Coolagh Lakes (Figures 10.3.7 and 10.3.8 of the NIS). Construction works at the Lackagh Quarry access road and along Bothar Nua and Sean Bothar have the potential to interact with groundwater. These works are small scale and do not include dewatering or require significant excavations.

As per all areas of the alignment, there is a risk that the accidental spillage of pollutants during construction could affect groundwater quality in the GWB, specifically the karst flows associated with Western Coolagh Spring, which in turn could affect the conservation objectives of the Lough Corrib cSAC at Coolagh Lakes and the supported fringing wetland habitats. These issues are assessed in Section 10.5.3.3 of Chapter 10 of the EIAR (Page 887) and managed by the CEMP (Appendix A.7.5 of the EIAR and Appendix C of the NIS). In the catchment of Coolagh Lakes, all runoff from construction drains to either infiltration basins or attenuation ponds (that themselves drain to the River Corrib), and hence the runoff risk to Coolagh Lakes is removed. The infiltration basins and attenuation ponds are designed to be used during both construction phase for site runoff and operational phase for road runoff and will be part of the initial works undertaken for the proposed road development.

The design of each infiltration basin is specific to the local hydrogeology, taking into account the unsaturated zone available and including placement of engineered appropriate subsoil to provide the required infiltration capacity. All infiltration basins include pre-treatment by hydrocarbon interceptor and containment areas to provide an appropriate holding time to contain accidental spillages. All infiltration basins will be excavated into bedrock, with an over excavation to accommodate the thickness of appropriate subsoil. The sides of the excavation will be lined to control groundwater infiltration so that all discharges drain through a constructed subsoil appropriately placed for the thickness of the unsaturated zone. The design of the infiltration basins, coupled with the inclusion of hydrocarbon interceptor and containment area, will provide a robust level of protection to prevent contamination of groundwater from the infiltration basins during construction and operation.

Risk has been identified of accidental spills during construction for those areas where limestone outcrops, such as those areas where the groundwater has extreme or high vulnerability (Figure 3.01 and 3.02 of Appendix A of the NIS) and in cuttings and excavations. Mitigation measures will ensure that groundwater quality is not affected during construction (refer to Section 10.5.3.1.2 of Chapter 10 of the EIAR (Page 887) and by the CEMP (Appendix A.7.5 of the EIAR and Appendix C of the NIS).

The drainage design (as described in Section 2, and Appendices A, F and D of the NIS) will ensure that groundwater quality will be maintained during operation, this includes inspection at maintenance intervals, with remediation actioned to ensure that karst features do not affect the functioning of the infiltration basins during operation. This will ensure that they continue to function as designed for the operational lifespan of the proposed road development (see Section 10.3.1.2 of the NIS).

5.2 Potential Affects to Lough Corrib cSAC Qualifying Interest Habitats from hydrogeological impacts

This section examines how the groundwater dependent qualifying interest habitats of Lough Corrib cSAC associated with the Coolagh Lakes would be affected by the potential hydrogeological impacts identified in Section 5.1.

These potential impacts are as follows and, in both instances, the risk of an impact occurring is highly unlikely:

- The potential of intercepting groundwater conduits in the Lough Corrib Fen 1 (Menlough) GWB when constructing the supporting piers for the Menlough Viaduct and the potential, and
- The potential of an accidental pollution event affecting groundwater quality in the Lough Corrib Fen 1 (Menlough) GWB, Lough Corrib Fen 1 (Lackagh) GWB and the Clare-Corrib GWB

Hard water lakes [3140]

As described above in Section 2, the conservation objectives for Hard water lakes [3140] includes the associated fringing lake habitats. Affecting water quality in the Coolagh Lakes and/or affecting the functioning or quality of the existing hydrogeological regime during construction (even though the risk of any perceptible effect is low) could affect the Annex I status of the lake thereby reducing habitat area and the distribution of this habitat type within Lough Corrib cSAC. These impacts could also affect the type, abundance and distribution of the typical species supported by the lakes, the vegetation composition and distribution, the area and condition of the fringing aquatic vegetation, lake substratum quality and water chemistry.

Based upon the hydrogeological assessment outlined in Section 5.1 above, there will be no changes to the groundwater regime in this area. Minor water quality impacts associated with construction may occur and mitigation measures have been proposed as robust preventative measures to specifically manage accidental spills and sediment runoff (refer to Section 5.3). No impacts have been identified for the operational phase of the proposed road development.

***Molinia* meadow [6410], *Cladium* fen [*7210] and Alkaline fen [7230]**

Affecting water quality in the receiving environment and/or affecting the functioning or quality of the existing hydrogeological regime could affect ecosystem functioning and the condition of areas of these habitat types such that their area and distribution is reduced within Lough Corrib cSAC. These impacts could also affect the vegetation composition and structure and the abundance and distribution of typical and locally distinctive species associated with QI habitats.

Introducing/spreading non-native invasive plant species could locally affect the extent, diversity, and vegetation composition or structure of these habitats within Lough Corrib cSAC.

The assessment of potential groundwater impacts on the site specific conservation objectives for *Molinia* meadow [6410], *Cladium* fen [*7210] and Alkaline fen [7230] habitats in Lough Corrib cSAC is presented in full in Table 9.16 of the NIS.

Based upon the hydrogeological assessment outlined in Section 5.1 above, there will be no changes to the groundwater regime in this area. Minor water quality impacts associated with construction may occur and mitigation measures have been proposed employed as robust preventative measures to specifically manage accidental spills and sediment runoff (refer to Section 5.3). No impacts have been identified for the operational phase of the proposed road development.

5.3 Mitigation Measures

It is reiterated that mitigation measures in Lackagh Quarry to not lower the groundwater level are included as a belts and braces approach even though Lackagh Quarry and Lackagh Tunnel do not drain to Coolagh Lakes.

The mitigation measures required to protect the existing groundwater regime supporting the groundwater dependent qualifying interest habitat of Lough Corrib cSAC, including those associated with the Coolagh Lakes, relate to potential groundwater quality impacts due to construction only. These potential impacts are mitigated by:

- Implementation of best practice construction practices and environmental controls to control the potential for, and respond to any, accidental groundwater pollution events on site as set out in the CEMP (Appendix A.7.3 of the EIAR and Appendix C of the NIS) – Section 10.3.1.1 of the NIS
- Application of the Karst Protocol to prevent groundwater impacts arising from encountering karst features on site during construction works – Section 10.3.1.2 of the NIS

These mitigation measures are robust and have been implemented successfully on other schemes and will be effective to ensure that the proposed road development does not adversely affect the integrity of Lough Corrib cSAC from hydrogeological impacts to the Coolagh Lakes.

6 Conclusion

Considering the design measures associated with the proposed road development, particularly those related to the Lackagh Tunnel, groundwater supply supporting groundwater dependant habitats in Lough Corrib cSAC will not be affected during operation.

The detailed mitigation strategy outlined above in Section 5 and described in Section 10.3 of the NIS will ensure that the proposed road development will not affect groundwater supply to the Coolagh Lakes during construction of the Menlough Viaduct and will not affect the quality of groundwater contributing to the Coolagh Lakes during construction and/or operation. These mitigation measures include the control and treatment of site run-off during construction, preventing groundwater impacts arising from encountering karst features on site during construction works and ensuring that, during operation, the drainage system and infiltration basins function as designed over the life of the proposed road development.

These mitigation measures will be implemented through the CEMP during construction (construction pollution risk) and by Galway County Council/TII over the operational lifespan of the proposed road development (maintenance) and will ensure that hydrogeological impacts do not occur.

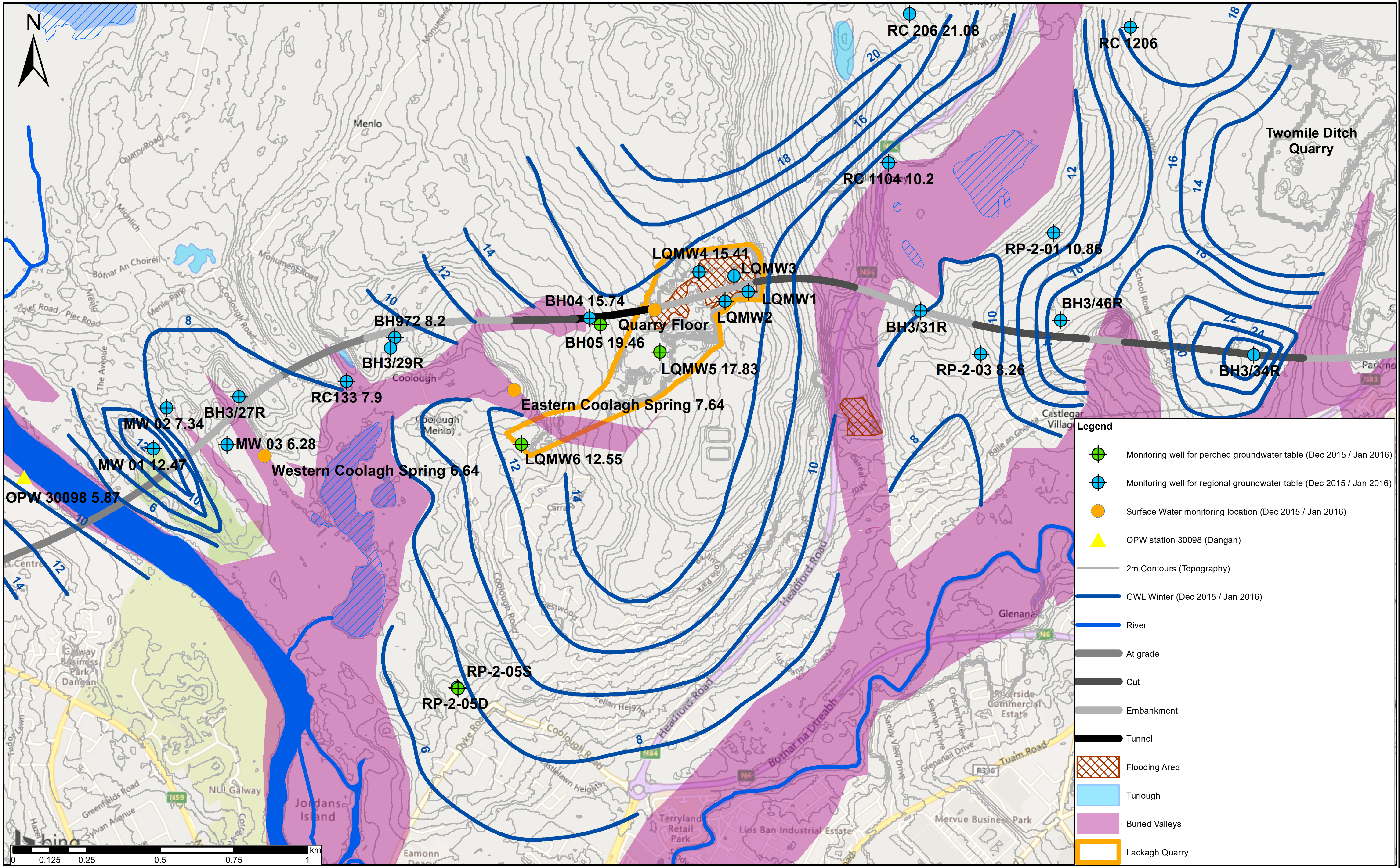
As a result, habitat degradation as a result of impacts on the existing groundwater regime will not occur or affect the conservation objective attributes and targets supporting the conservation condition of any groundwater dependent qualifying interest habitats and species of Lough Corrib cSAC, including those associated with the Coolagh Lakes. Therefore, there are no residual direct or indirect groundwater related impacts that could adversely affect the integrity of Lough Corrib cSAC.

Appendix A

Groundwater Monitoring and Hydrographs

A1

A3



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Scale:

Date: March 2020

All elevations mOD

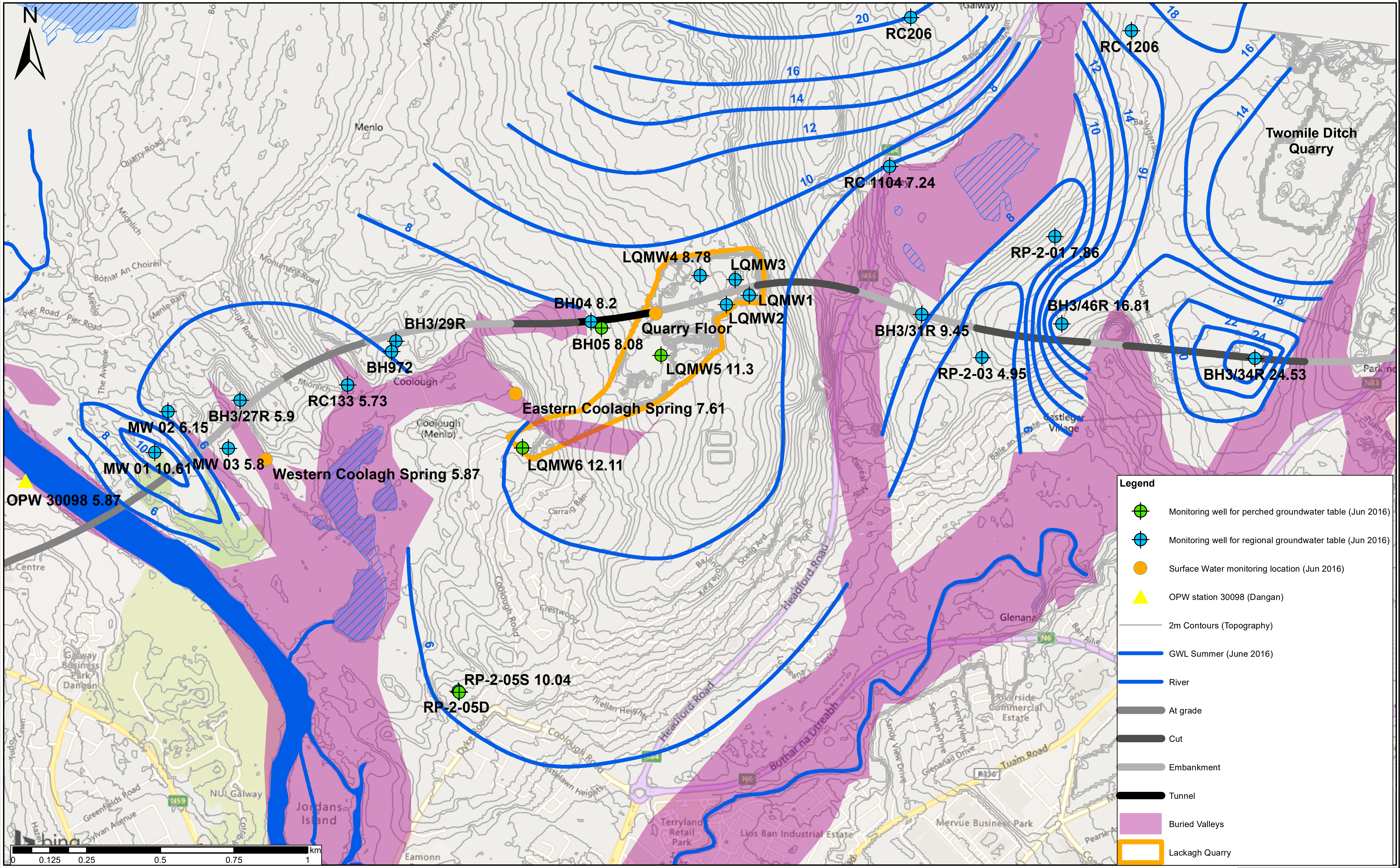
I1	04/03/2020	MK	LB	CB
Issue	Date	By	Chkd	Appd

Drawing Title
Winter Groundwater Levels

Drawing Status
For Information

Job No	Drawing No	Issue
233985-00	Appendix A-1	I1

A3



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Date: March 2020

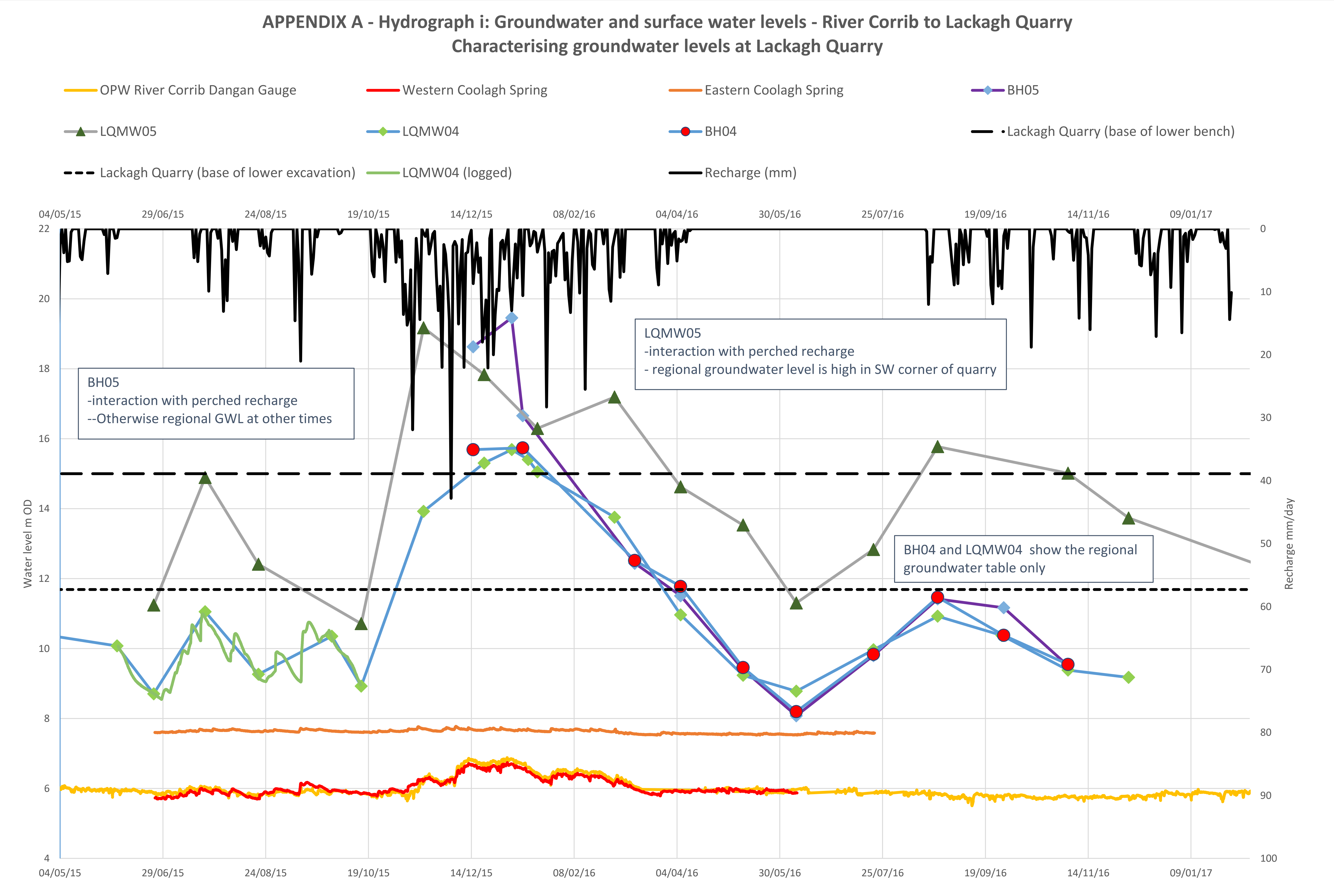
All elevations mOD

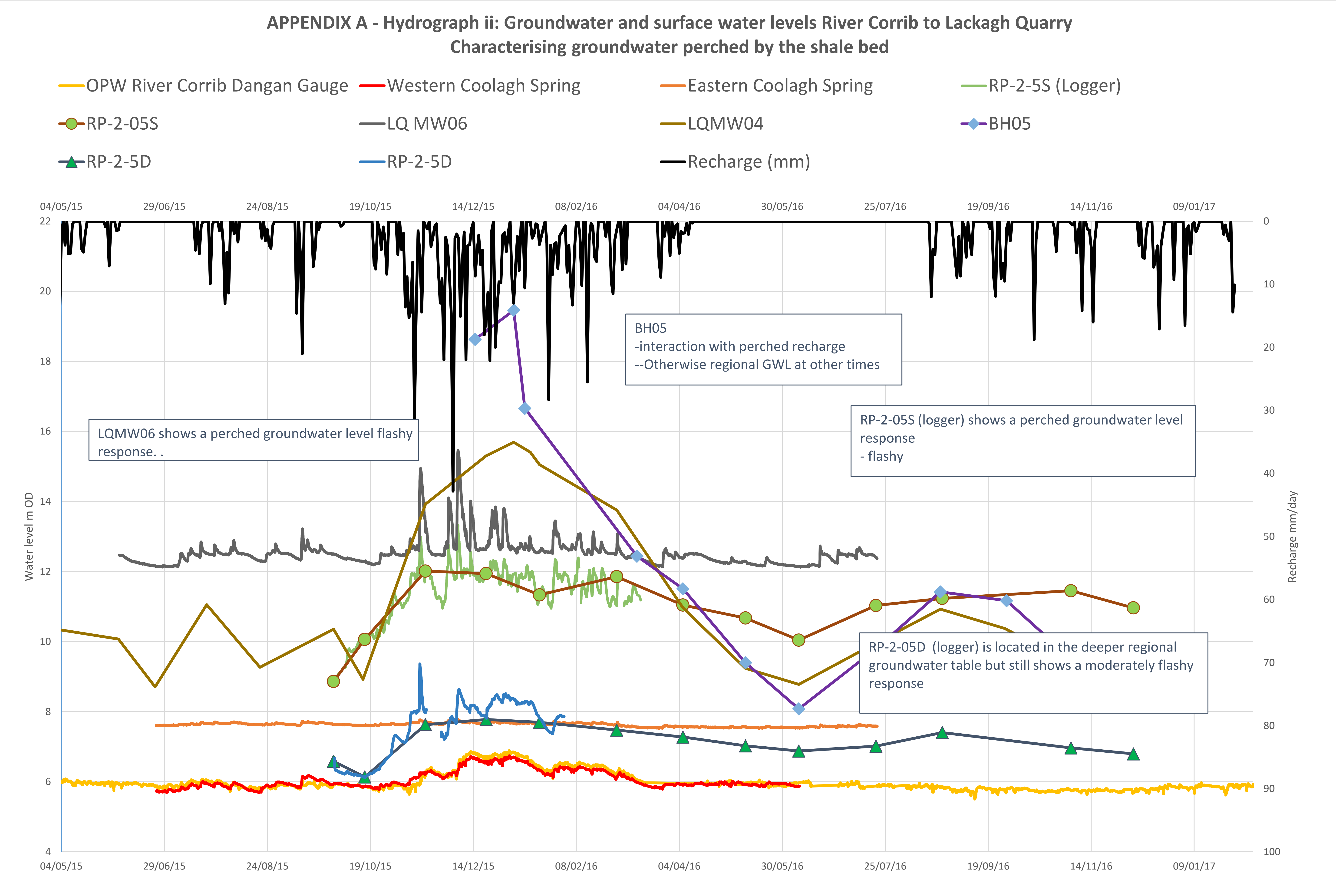
I1	04/03/2020	MK	LB	CB
Issue	Date	By	Chkd	Appd

Drawing Title
Summer Groundwater Levels

Drawing Status
For Information

Job No	Drawing No	Issue
233985-00	Appendix A-2	I1


APPENDIX A - Hydrograph i: Groundwater and surface water levels - River Corrib to Lackagh Quarry
Characterising groundwater levels at Lackagh Quarry
OPW River Corrib Dangan Gauge
Western Coolagh Spring
Eastern Coolagh Spring
BH05
LQMW05
LQMW04
BH04
Lackagh Quarry (base of lower bench)
Lackagh Quarry (base of lower excavation)
LQMW04 (logged)
Recharge (mm)
BH05
-interaction with perched recharge
--Otherwise regional GWL at other times
LQMW05
-interaction with perched recharge
- regional groundwater level is high in SW corner of quarry
BH04 and LQMW04 show the regional
groundwater table only
Water level m OD
Recharge mm/day
04/05/15
29/06/15
24/08/15
19/10/15
14/12/15
08/02/16
04/04/16
30/05/16
25/07/16
19/09/16
14/11/16
09/01/17


APPENDIX A - Hydrograph ii: Groundwater and surface water levels River Corrib to Lackagh Quarry
Characterising groundwater perched by the shale bed
OPW River Corrib Dangan Gauge
Western Coolagh Spring
Eastern Coolagh Spring
RP-2-5S (Logger)
RP-2-05S
LQ MW06
LQMW04
BH05
RP-2-5D
RP-2-5D
Recharge (mm)
BH05
-interaction with perched recharge
--Otherwise regional GWL at other times
LQMW06 shows a perched groundwater level flashy response. .
RP-2-05S (logger) shows a perched groundwater level response
- flashy
RP-2-05D (logger) is located in the deeper regional groundwater table but still shows a moderately flashy response
Water level m OD
Recharge mm/day
04/05/15
29/06/15
24/08/15
19/10/15
14/12/15
08/02/16
04/04/16
30/05/16
25/07/16
19/09/16
14/11/16
09/01/17
22
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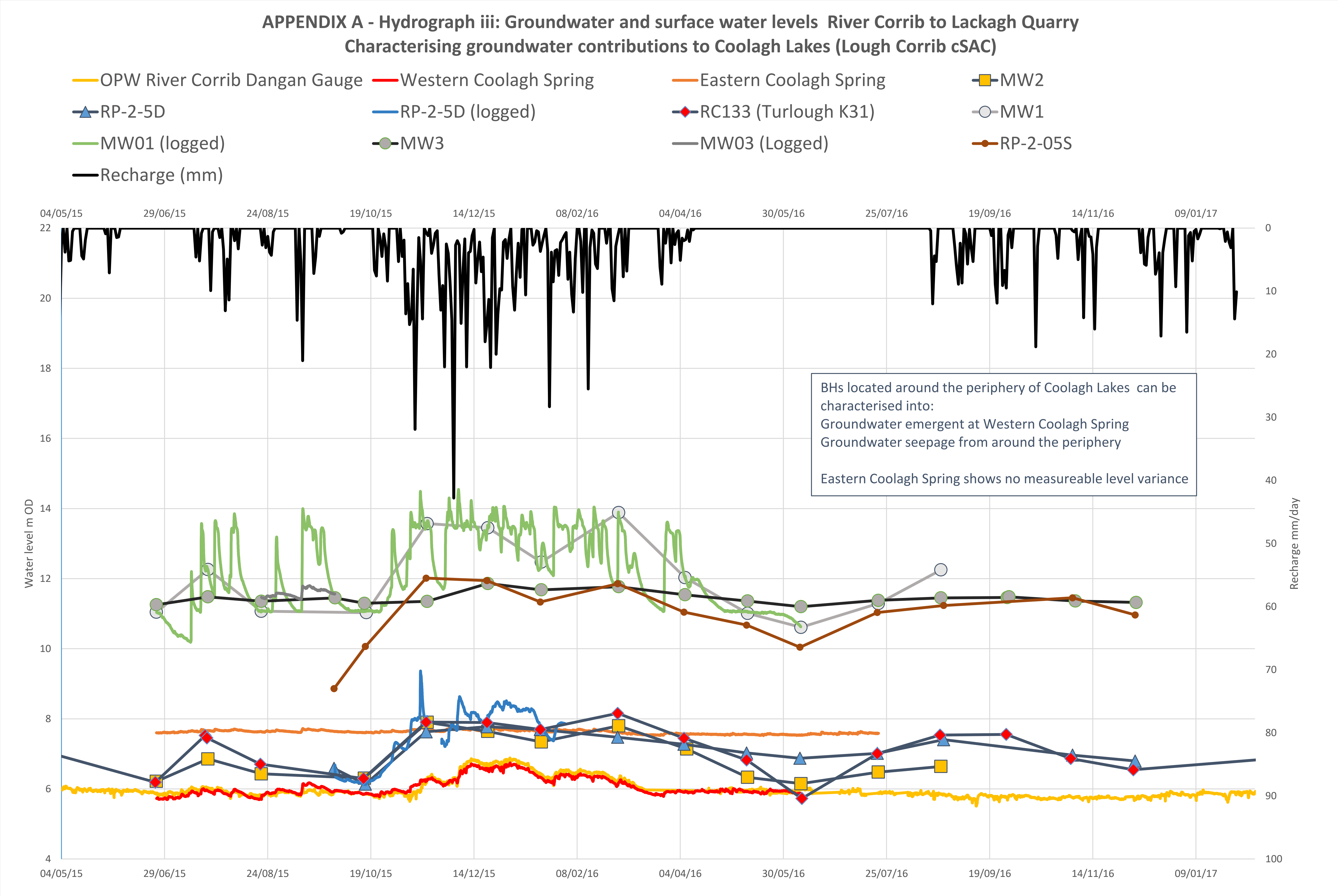
60
70
80
90
100

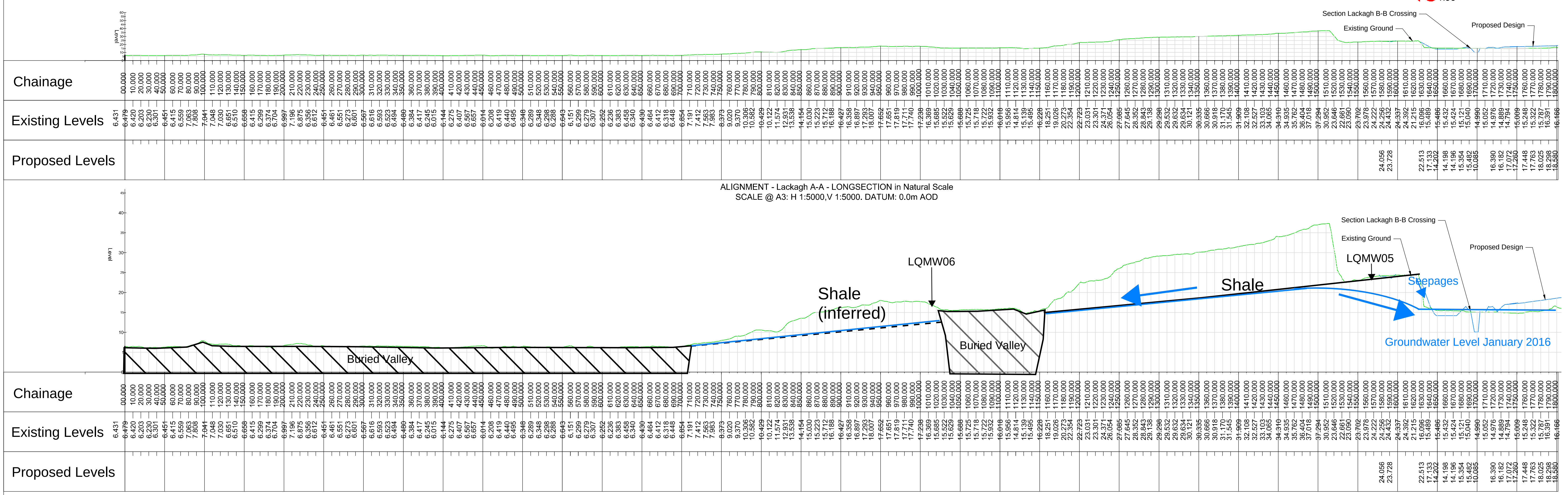


APPENDIX A - Hydrograph iii: Groundwater and surface water levels River Corrib to Lackagh Quarry
Characterising groundwater contributions to Coolagh Lakes (Lough Corrib cSAC)
OPW River Corrib Dangan Gauge
Western Coolagh Spring
Eastern Coolagh Spring
MW2
RP-2-5D
RP-2-5D (logged)
RC133 (Turlough K31)
MW1
MW01 (logged)
MW3
MW03 (Logged)
RP-2-05S
Recharge (mm)
BHs located around the periphery of Coolagh Lakes can be characterised into:
Groundwater emergent at Western Coolagh Spring
Groundwater seepage from around the periphery
Eastern Coolagh Spring shows no measureable level variance
Water level m OD
Recharge mm/day
04/05/15
29/06/15
24/08/15
19/10/15
14/12/15
08/02/16
04/04/16
30/05/16
25/07/16
19/09/16
14/11/16
09/01/17

Appendix B

Cross Sections

B1



ALIGNMENT - Lackagh A-A - LONGSECTION in Natural Scale
SCALE @ A3: H 1:5000,V 1:5000. DATUM: 0.0m AOD

ALIGNMENT - Lackagh A-A - LONGSECTION in 5x Exaggeration Scale
SCALE @ A3: H 1:5000,V 1:1000. DATUM: 0.0m AOD

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Scale: @A3 H 1:5000 , V - See Profile Scale

Date: March 2020

Issue	Date	By	Chkd	Appd
I2	05/03/2020	KJ	LB	EMC
I1	02/03/2020	KJ	LB	EMC

Drawing Title
Existing Ground & Proposed Design

Cross Section Lackagh A-A Sheet 1 of 2

Drawing Status
For Information

Job No	Drawing No	Issue
233985-00	**GCOB-SK-OH-037**	**I2**

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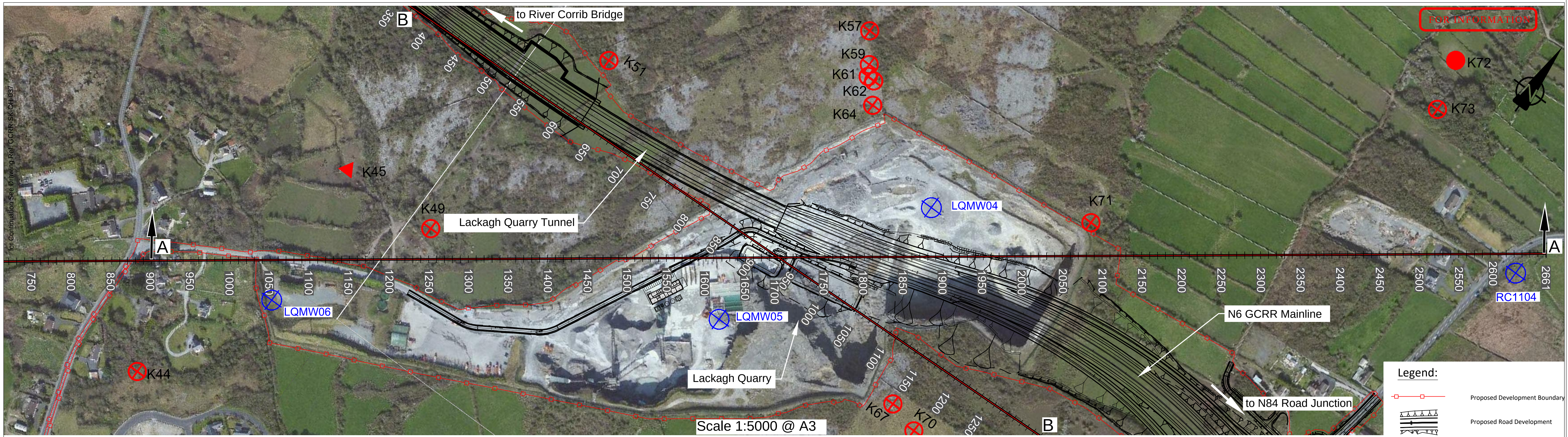

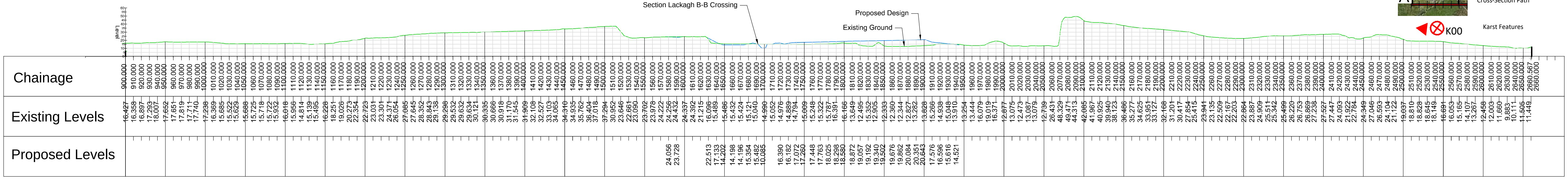

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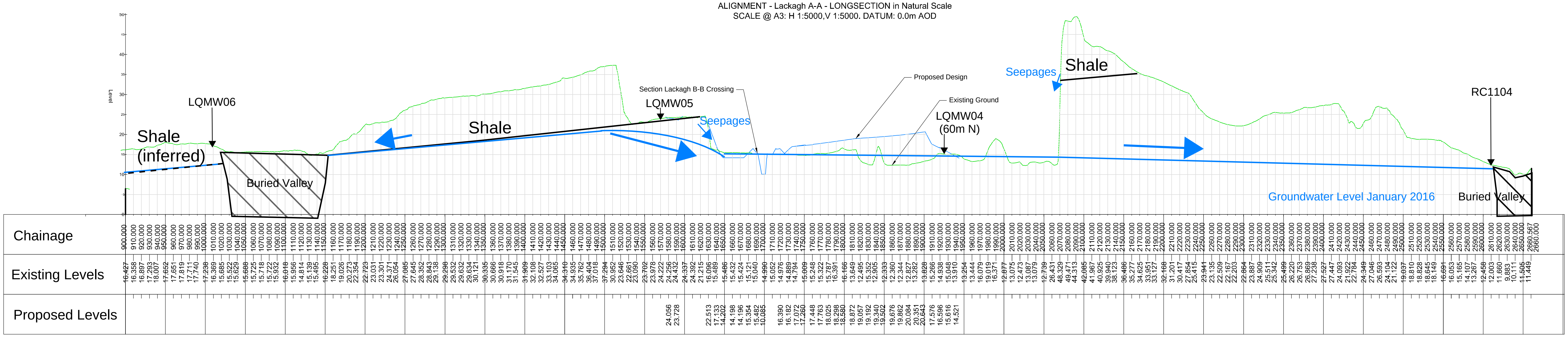

ALIGNMENT - Lackagh A-A - LONGSECTION in 5x Exaggeration Scale
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Issue	Date	By	Chkd	Appd
I2	05/03/2020	KJ	LB	EMC
I1	02/03/2020	KJ	LB	EMC

Drawing Title
Existing Ground & Proposed Design
Cross Section Lackagh A-A Sheet 2 of 2

Drawing Status
For Information

Job No	Drawing No	Issue
233985-00	GCOB-SK-OH-038	I2

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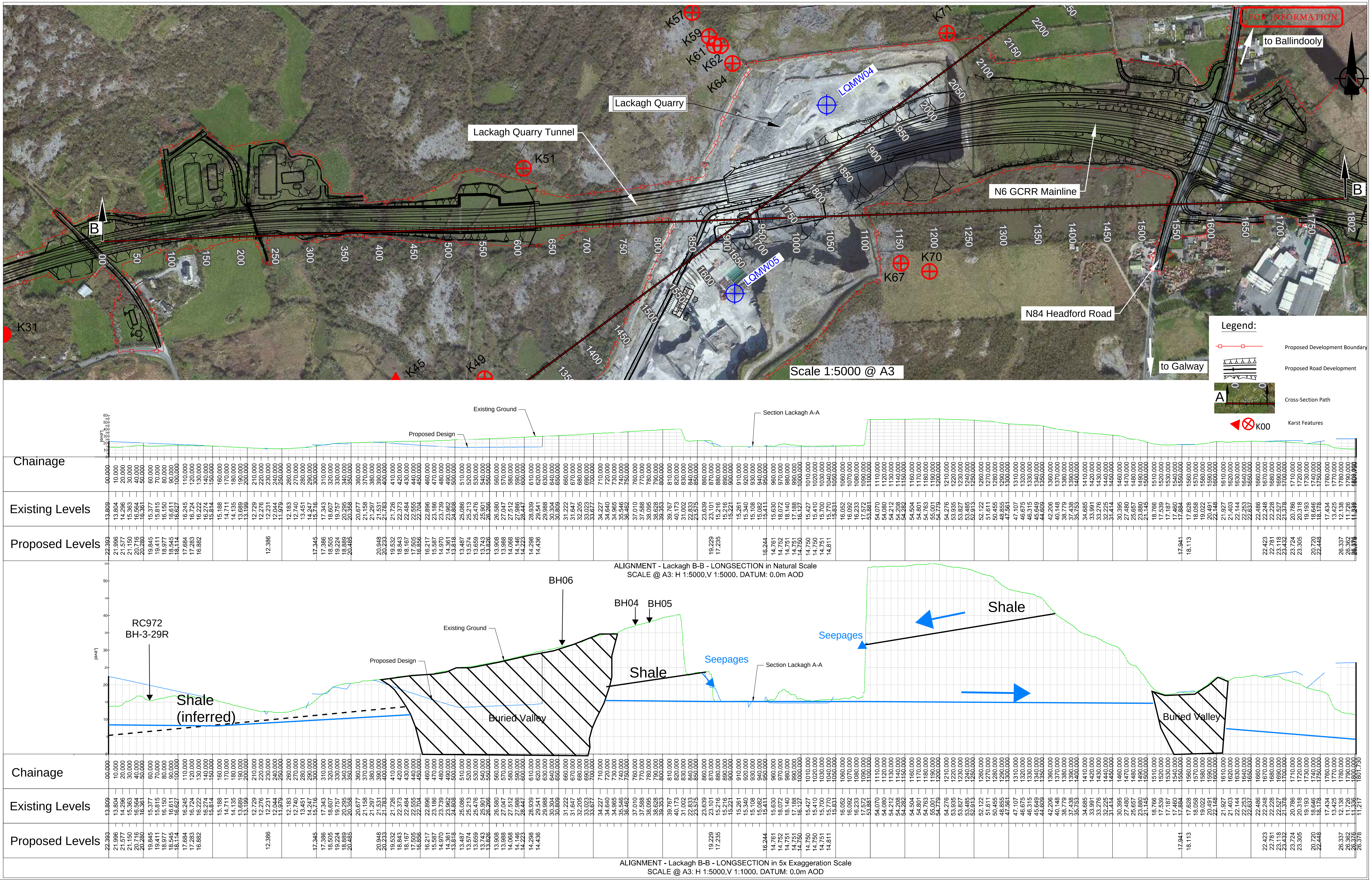

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Date: March 2020

Issue	Date	By	Chkd	Appd
I2	05/03/2020	KJ	LB	EMC
I1	02/03/2020	KJ	LB	EMC

Drawing Title
Existing Ground & Proposed Design
Cross Section Lackagh B-B

Drawing Status
For Information

Job No	Drawing No	Issue
233985-00	**GCOB-SK-OH-039**	**I2**

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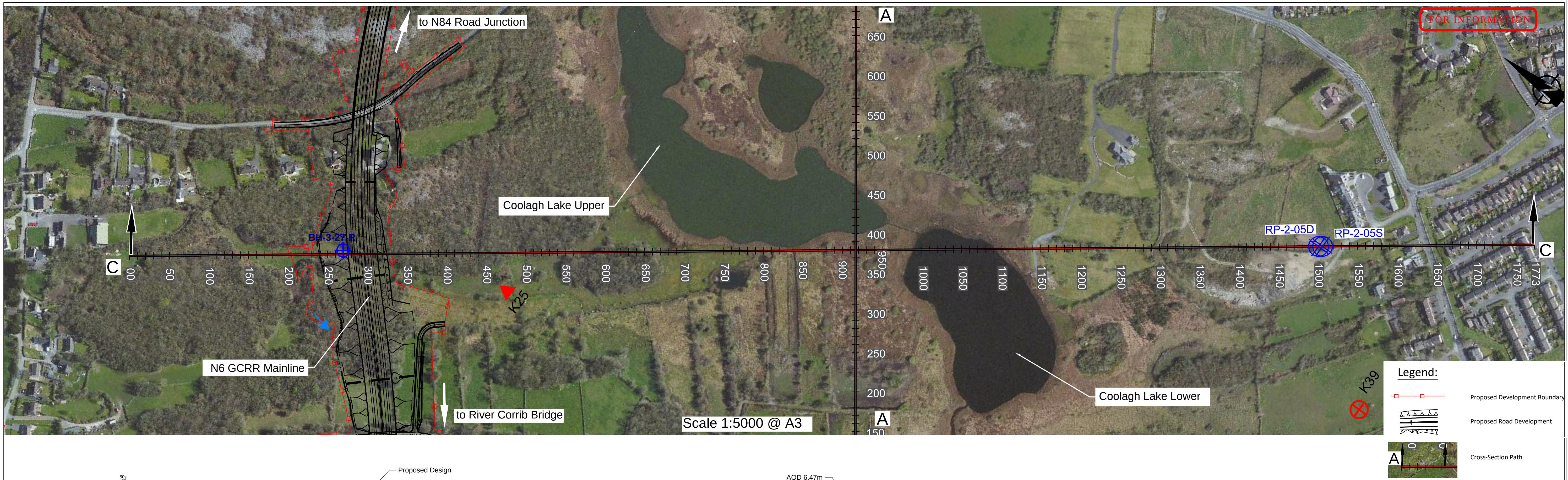

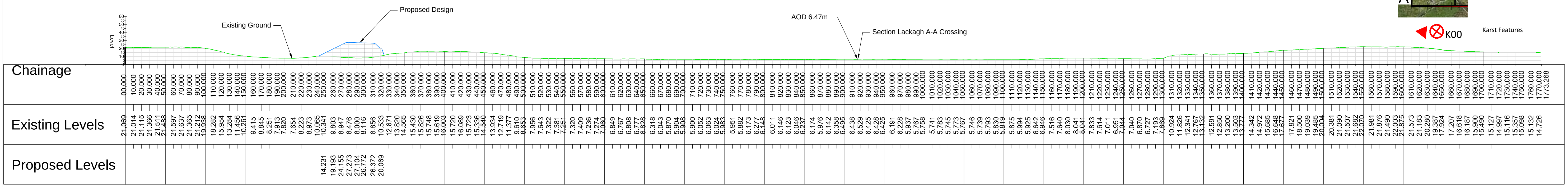

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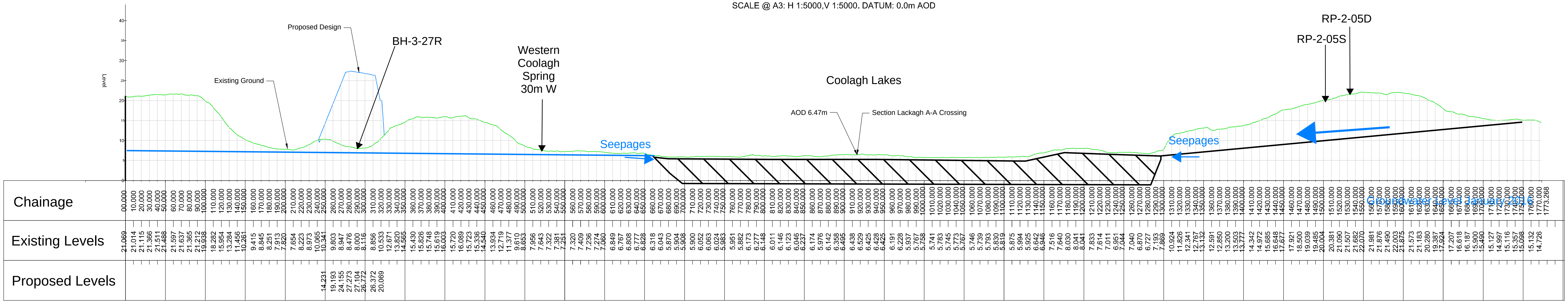

ALIGNMENT - Lackagh C-C - LONGSECTION in 5x Exaggeration Scale
SCALE @ A3: H 1:5000,V 1:1000. DATUM: 0.0m AOD

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Scale: @A3 H 1:5000 , V - See Profile Scale

Date: March 2020

Issue	Date	By	Chkd	Appd
I2	05/03/2020	KJ	LB	EMC
I1	02/03/2020	KJ	LB	EMC

Drawing Title

Existing Ground & Proposed Design

Cross Section Lackagh C-C

Drawing Status

For Information

Job No	Drawing No	Issue
233985-00	GCOB-SK-OH-040	I2

Do not scale