Appendix A.7.7

BD02 Culverts and Underpasses

A.7.7

Galway County Council

N6 Galway City Transport Project

Culvert and Underpass Structures Preliminary Design Report

GCOB-4.04-020-013

Issue 3 | 23 October 2017

Job number 233985

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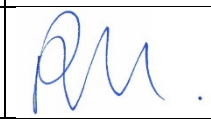
		Signature			
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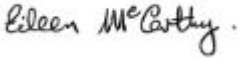
		Signature			
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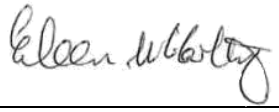
		Signature			
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1 Introduction

1.1 Design Brief given to the authors, including dates

This report has been produced by Arup, who have been appointed by Galway County Council to provide multi-disciplinary engineering consultancy services for the N6 Galway City Transport Project. Galway County Council, Galway City Council, Transport Infrastructure Ireland (formerly known as the National Roads Authority) and the National Transport Authority are collaborating in developing a solution to the existing transportation issues in Galway City and its environs. The solution will include a smart mobility component, public transport component and a road component. The road component of the solution is known as N6 Galway City Ring Road (GCRR).

1.2 Background information covering the origins for the need for the structure

The underpass and culvert structures are required as part of the proposed N6 Galway City Ring Road. These underpasses and culverts are required to maintain streams and watercourses, to provide mammal passage and to mitigate environmental impacts.

1.3 Previous studies and their recommendations

Previous studies and documents relevant to this Outline Structures Report are listed below.

- Galway County Council. Project Brief. Phase 1, Scheme Concept and Feasibility Studies (GC/14/11222, 2 May 2015).
- Galway County Council. Project Brief. Phase 2, Route Selection (GC/14/11222, 6 November 2015).
- GCOB-4.04-009 Route Selection Report, Issue 1, August 2015.
- Galway Transport Strategy, An Integrated Transport Management Programme for Galway City and environs, Technical Report, September 2016

2 Site and function

2.1 Site location

The structures are located at the chainages stated in Table 1 below, along the proposed road development.

2.2 Function of the structure and obstacles crossed

Underpass C10/01 is required to span over exposed limestone pavement (i.e. priority Annex I habitat) and provide wildlife passage under the proposed road development.

Hydraulic culverts and minor stream crossings facilitate the necessary drainage and watercourse provisions due to the proposed road development.

Along the scheme, there are a number of underpass structures needed to facilitate the movement of wildlife. In some cases such underpasses also serve as hydraulic culverts.

Table 1 Culverts and Underpasses

Name of structure	Chainage	Function	Other Requirements
C00/01	00+640	Combined Hydraulic Culvert + Mammal Underpass	-
C02/01a	02+740	Hydraulic Culvert	-
C02/01b	02+850	Combined Hydraulic Culvert + Mammal Underpass	-
C03/01	03+065	Combined Hydraulic Culvert + Mammal Underpass	-
C03/03	03+945	Combined Hydraulic Culvert + Mammal Underpass	-
C03/04	03+965	Combined Hydraulic Culvert + Mammal Underpass	-
C04/01	04+120	Combined Hydraulic Culvert + Mammal Underpass	Otter Ledge
C04/02	04+915	Combined Hydraulic Culvert + Mammal Underpass	Otter Ledge
C06/00	06+460	Mammal Underpass	-
C06/01	06+850	Combined Hydraulic Culvert + Mammal Underpass	-
C07/00	07+100	Mammal Underpass	-

Name of structure	Chainage	Function	Other Requirements
C07/02a	07+225	Combined Hydraulic Culvert + Mammal Underpass	-
C08/01a	08+450	Mammal Underpass	-
C08/02	08+650	Mammal Underpass	-
C08/04	08+620	Mammal Underpass	-
C08/05	08+580	Mammal Underpass	-
C09/01	09+530	Mammal Underpass	-
C09/02	09+545	Mammal Underpass	-
C09/03	09+560	Mammal Underpass	-
C09/04	09+575	Mammal Underpass	-
C09/05	09+590	Mammal Underpass	-
C09/06	09+790	Mammal Underpass	-
C09/07	09+920	Mammal Underpass	-
C10/01 - environmental underpass	10+040	Environmental underpass spanning over exposed limestone pavement	-
C12/02	12+380	Mammal Underpass	-
C12/03	12+410	Mammal Underpass	-
C12/04	12+440	Mammal Underpass	-
C13/01	12+980	Mammal Underpass	

2.3 Choice of location

The structures location was chosen based on the location of the proposed road development relative to location of necessary crossings for the culverts and underpass structures.

2.4 Site description and topography

Table 2 Site description and topography.

Name of Structure	Site description and Topography	Archaeology at Structure	Ecology at Structure
Culvert C00/01	Culvert to allow existing stream to cross proposed road development and to facilitate the passage of wildlife, proposed road development on embankment.	Area of Archaeological Potential listed in Chapter 13 of the EIS as AAP 1 – Liberty Stream A townland boundary listed in Chapter 13 of the EIS as TB 2 – Liberty Stream (Also AAP 1)	Ecological constraint Annex Code 4030 (Fosset Code HH1) in vicinity of structure. Fossett Code GS3/HD1, Local Importance (Higher Value). Culvert to provide bat passage.
Culvert C02/01a	Culvert to allow existing stream to cross Bearna to Moycullen Road L1321, proposed road development on embankment.	Area of Archaeological Potential listed in Chapter 13 of the EIS as AAP 2 – Trusky Stream	An Ecological Constraint of Local (High) Importance listed in Chapter 8 of the EIS as EC09 is impacted by the structure C02/01a. The habitat is buildings and artificial surfaces, scrub and a wet grassland under Fossit Code BL3, WS1 and GS4.
Culvert C02/01b	Culvert to allow existing stream to cross proposed road development and to facilitate the passage of wildlife, proposed road development on embankment.	Area of Archaeological Potential listed in Chapter 13 of the EIS as AAP 2 – Trusky Stream A townland boundary listed in Chapter 13 of the EIS as TB 6 – Former site of townland boundary including a portion of stream	Fosset Code WS1/HD1/GS4/GS3, Local Importance (higher value). Culvert to provide bat passage.
Culvert C03/01	Culvert to allow existing stream to cross proposed road development and to facilitate the passage of wildlife, proposed road development on embankment.	A townland boundary listed in Chapter 13 of the EIS as TB 7 – Stone Wall	Fosset Code GS4/WS1/ER1, Local Importance (higher value). Culvert to provide bat passage.
Culvert C03/03	Culvert to allow existing stream to cross proposed road development and to facilitate the passage of wildlife, proposed road development on embankment.	None	Fosset Code GS4, Local Importance (higher value). Culvert to provide bat passage.

Name of Structure	Site description and Topography	Archaeology at Structure	Ecology at Structure
Culvert C03/04	Culvert to allow existing stream to cross proposed road development and to facilitate the passage of wildlife, proposed road development on embankment.	None	Fosset Code GS4, Local Importance (higher value). Culvert to provide bat passage.
Culvert C04/01	Culvert to allow existing stream to cross proposed road development and to facilitate the passage of wildlife, proposed road development on embankment.	Area of Archaeological Potential listed in Chapter 13 of the EIS as AAP 3 – Barna Stream A townland boundary listed in Chapter 13 of the EIS as TB 10 – Barna Stream	Fosset Code FW1/WS1/HD1, Local Importance (higher value). Culvert to provide bat and otter passage.
Culvert C04/02	Culvert to allow existing stream to cross proposed road development and to facilitate the passage of wildlife, proposed road development on embankment.	Area of Archaeological Potential listed in Chapter 13 of the EIS as AAP 4 - Stream A townland boundary listed in Appendix 13 of the EIS as TB 12 - Stream (AAP 4) and field boundary (boundary completely overgrown)	Ecological constraint Annex Code 4030 (Fosset Code HH1/HH3) in vicinity of structure. Ecological constraint Annex Code 4010 (Fosset Code HH1/HH3) in vicinity of structure. Fossett Code FW1, Local Importance (higher value). Fossett Code GS4, Local Importance (lower value). Culvert to provide bat, badger and otter passage.
Culvert C06/00	Culvert to facilitate the passage of wildlife, proposed road development on embankment.	None	Fossett Code GA1, Local Importance (lower value). Fossett Code BL3, Local Importance (lower value). Culvert to provide bat passage.
Culvert C06/01	Culvert to allow existing stream to cross proposed road development and to facilitate the passage of wildlife, proposed road development on embankment.	Area of Archaeological Potential listed in Chapter 13 of the EIS as AAP 5 - Stream and boggy hollow Archaeological Heritage site as listed in Chapter 13 as AH 2 - Bullaun Stone	Fossett Code GA1, Local Importance (lower value). Fossett Code GS4, Local Importance (lower value). Fossett Code WL2/HD1/GS4, Local Importance (lower value). Culvert to provide badger passage.

Name of Structure	Site description and Topography	Archaeology at Structure	Ecology at Structure
Culvert C07/00	Culvert to facilitate the passage of wildlife, proposed road development on embankment.	Previously Unrecorded Sites/ Structures of Cultural Heritage Merit listed in Chapter 13 of the EIS as CH33 - Very well built stone walled laneway, marked on the 1841 first edition map.	Fossett Code GA1/GS1, Local Importance (lower value). Culvert to provide bat passage.
Culvert C07/02a	Culvert to allow existing stream to cross proposed road development and to facilitate the passage of wildlife, proposed road development on embankment.	None	Fossett Code GA1/GS4, Local Importance (lower value). Fossett Code FW4, Local Importance (higher value). Culvert to provide bat passage.
Culvert C08/01a	Culvert to facilitate the passage of wildlife, proposed road development on embankment.	None.	Fosset Code Residential. Fosset Code BL3, Local Importance (lower value). Culvert to provide bat passage.
Culvert C08/02	Culvert to facilitate the passage of wildlife, proposed road development on embankment.	A designated landscape listed in Chapter 13 as DL 7 - Dangan Cottage, Dangan House, Dangan Nunnery, Mary Ville demesnes.	Fosset Code Residential. Fosset Code BL3, Local Importance (lower value). Culvert to provide bat passage.
Culvert C08/04	Culvert to facilitate the passage of wildlife, proposed road development on embankment.	None.	Fosset Code Residential. Fosset Code GS2. Culvert to provide bat passage.
Culvert C08/05	Culvert to facilitate the passage of wildlife, proposed road development on embankment.	A designated landscape listed in Chapter 13 as DL 7 - Dangan Cottage, Dangan House, Dangan Nunnery, Mary Ville demesnes.	Fosset Code Residential. Local Importance (lower value). Culvert to provide bat passage.
Culvert C09/01	Culvert to facilitate the passage of wildlife, proposed road development on embankment.	A designated landscape listed in Chapter 13 as DL 8 - Menlo Castle demesne.	Fosset Code WD1, Local Importance (higher value). Culvert to provide bat and badger passage.
Culvert C09/02	Culvert to facilitate the passage of wildlife, proposed road development on embankment.	A designated landscape listed in Chapter 13 as DL 8 - Menlo Castle demesne.	Fosset Code WD1, Local Importance (higher value). Culvert to provide bat and badger passage.

Name of Structure	Site description and Topography	Archaeology at Structure	Ecology at Structure
Culvert C09/03	Culvert to facilitate the passage of wildlife, proposed road development on embankment.	A designated landscape listed in Chapter 13 as DL 8 - Menlo Castle demesne.	Fosset Code WD1, Local Importance (higher value). Culvert to provide bat and badger passage.
Culvert C09/04	Culvert to facilitate the passage of wildlife, proposed road development on embankment.	A designated landscape listed in Chapter 13 as DL 8 - Menlo Castle demesne. Previously Unrecorded Sites/ Structures of Cultural Heritage Merit listed in Chapter 13 of the EIS as CH46 - Possible circular enclosure identified during AP analysis and marked as a possible feature of the 1895-1900 mapping.	Fosset Code WD1, Local Importance (higher value). Culvert to provide bat passage.
Culvert C09/05	Culvert to facilitate the passage of wildlife, proposed road development on embankment.	A designated landscape listed in Chapter 13 as DL 8 - Menlo Castle demesne. Previously Unrecorded Sites/ Structures of Cultural Heritage Merit listed in Chapter 13 of the EIS as CH46 - Possible circular enclosure identified during AP analysis and marked as a possible feature of the 1895-1900 mapping.	Fosset Code WD1, Local Importance (higher value). Culvert to provide bat passage.
Culvert C09/06	Culvert to facilitate the passage of wildlife, proposed road development on embankment.	A designated landscape listed in Chapter 13 as DL 8 - Menlo Castle demesne.	Fosset Code GS2/WN2, Local Importance (higher value). Fosset Code GS1, Local Importance (lower value). Culvert to provide bat passage.
Culvert C09/07	Culvert to facilitate the passage of wildlife, proposed road development on embankment.	None.	Fosset Code WN2, Local Importance (higher value). Fosset Code GS1, Local Importance (lower value). Culvert to provide bat passage.

Name of Structure	Site description and Topography	Archaeology at Structure	Ecology at Structure
C10/01	Culvert to facilitate the passage of wildlife and to span over exposed limestone pavement, proposed road development on embankment.	None	Ecological constraint Annex Code 8240 in vicinity of structure. Fossett Code ER2, International Importance. Culvert to provide bat and badger passage.
Culvert C12/02	Culvert to facilitate the passage of wildlife, proposed road development on embankment.	Area of Archaeological Potential listed in Chapter 13 of the EIS as AAP 10 - Boggy pasture – margins of Lough an Dúlaigh	Ecological constraint Annex Code 6410 (Fossett Code GS4) in vicinity of structure. Fossett Code GA1, local importance (lower value) Culvert to provide bat passage.
Culvert C12/03	Culvert to facilitate the passage of wildlife, proposed road development on embankment.	Area of Archaeological Potential listed in Chapter 13 of the EIS as AAP 10 - Boggy pasture – margins of Lough an Dúlaigh	Fosset Code GA1, Local Importance (lower value). Culvert to provide bat passage.
Culvert C12/04	Culvert to facilitate the passage of wildlife, proposed road development on embankment.	Area of Archaeological Potential listed in Chapter 13 of the EIS as AAP 10 - Boggy pasture – margins of Lough an Dúlaigh	Fosset Code GA1, Local Importance (lower value). Culvert to provide bat passage.
Culvert C13/01	Culvert to facilitate the passage of wildlife, proposed road development on embankment.	Archaeological Heritage site as listed in Chapter 13 as AH 24 - Redundant record – Non antiquity Area of Archaeological Potential listed in Chapter 13 of the EIS as AAP 11 - Boggy hollow (AH 24) Built Heritage (BH) sites located within the receiving environment listed in Chapter 13 of the EIS as BH12 - Thatched cottage (An Caisleán Gearr)	Fosset Code GA1/GS1/GA2/BL3, Local Importance (lower value). Culvert to provide bat passage.

2.5 Vertical and horizontal alignments

Proposed Road Development mainline alignment

Horizontal and vertical alignment varies along the route at differs at each of the culvert and underpass structures.

A design speed of 85km/h was utilised for the Type 1 Single Carriageway from the R336 to Ballymoneen Road.

A design speed of 100km/h was utilised for the Dual Carriageway and Urban Motorway from the Ballymoneen Road to the N6 interchange at Coolagh.

2.6 Cross sectional dimensions on the alignments

With respect to the proposed road development mainline, a Type-1 Single Carriageway is proposed for the section west of Ballymoneen Road Roundabout and a Type-1 Dual Carriageway for the section east of the Ballymoneen Road Roundabout.

The Type 1 single carriageway cross-section proposed from R336 Coast Road to Ballymoneen Road in accordance with TII Publications DN-GEO-03036 (Cross Sections and Headroom) is:

• Eastbound Verge Width (minimum)	3.0m	
• Eastbound Hard Shoulder	2.5m	
• Carriageway Width	7.3m	(2x3.65m lanes)
• Westbound Hard Shoulder	2.5m	
• Westbound Verge Width (minimum)	3.0m	
	18.3m	

The Type 1 Dual Carriageway cross-section proposed from the Ballymoneen Road to the existing M6 tie-in at Coolagh in accordance with NRA DMRB TD 27/11 is:

• Eastbound Verge Width (minimum)	3.0m	
• Eastbound Hard Shoulder	2.5m	
• Eastbound Carriageway Width	7.0m	(2 x 3.5m lanes)
• Central Reserve Width (including 2 x0.5m Hard Strips)	2.6m	
• Westbound Carriageway Width	7.0m	(2 x 3.5m lanes)
• Westbound Hard Shoulder	2.5m	
• Westbound Verge Width (minimum)	3.0m	
	27.6m	

The dimensions above exclude any additional width required for sightline visibility, which varies depending on the alignment at each structure's location.

The cross section dimensions at the structures is given in **Table 3**, **Table 4**, and **Table 5** below.

Table 3 Dimensions on bridge deck at C10/01

Name of Structure	Carriageway Width [2] (m)	Raised Verge Width (m) - Left [1]	Raised Verge Width (m) - Right [1]	Parapet width (m) – Left[1]	Parapet width (m) – Right[1]
C10/01	Varies 24.1min	Varies 0.6min	Varies 0.6min	0.5	0.5

[1] When considered in the direction of increasing chainage.

[2] Carriageway width measures from outer edge of hardshoulders (includes central reserve)

Table 4 Cross section at hydraulic culverts and mammal underpasses box structures

Name of Structure	Clear Width (m)	Clear Height (m)	Bed Depth (m)
C00/01	2.5	1.35	0.30
C02/01a	2.1	1.8	0.30
C02/01b	2.5	2.5	0.30
C03/01	2.5	1.2	0.30
C03/03	2.5	2.5	0.30
C03/04	2.5	2.5	0.30
C04/01	5.0	2.5	0.30
C04/02	3.1	2.5	0.30
C06/00	2.5	2.5	n/a
C06/01	2.5	2.5	0.30
C07/00	2.5	2.0	n/a
C08/01a	2.5	2.5	0.15
C08/02	2.5	2.5	0.70
C08/04	2.5	2.5	n/a
C08/05	2.5	2.5	n/a
C13/01	2.5	1.5	n/a

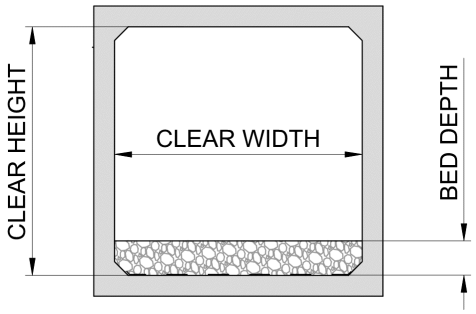


Figure 1 Cross section at hydraulic culverts and mammal underpasses box structures

Table 5 Cross section at environmental buried arch structures

Name of Structure	Clear Width (m)	Minimum Rise (m)	Bed Depth (m)
C07/02a	2.5	2.5	0.30
C09/01	5.0	4.0	n/a
C09/02	5.0	4.0	n/a
C09/03	5.0	4.0	n/a
C09/04	5.0	4.0	n/a
C09/05	5.0	4.0	n/a
C09/06	2.5	2.5	n/a
C09/07	2.5	2.5	n/a
C12/02	2.5	2.5	n/a
C12/03	2.5	2.5	n/a
C12/04	2.5	2.5	n/a

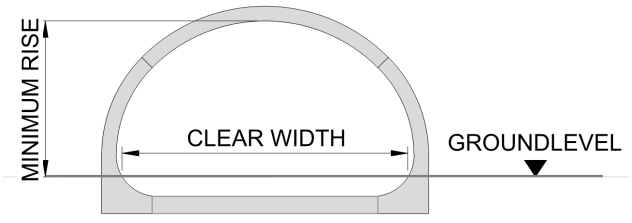


Figure 2 Cross section at environmental buried arch structures

2.7 Conflicting underground and overground services

All the utility providers have been consulted during the preliminary design process. The existing services in the vicinity of the proposed structures are outlines in **Table 6** below.

Table 6 Existing services

Name of Structure	Existing Services
C00/01	None
C02/01a	100mm Watermain Eir
C02/01b	None
C03/01	None
C03/03	110kV ESB Overhead
C03/04	110kV ESB Overhead
C04/01	None
C04/02	None
C06/00	250mm Watermain (will be decommissioned in design proposals) Overhead Eir (will be decommissioned in design proposals)
C06/01	None
C07/00	None
C07/02a	None
C08/01a	Decommissioned watermain and underground ESB connection
C08/02	Utilities associated with house demolition
C08/04	Utilities associated with house demolition
C08/05	Utilities associated with house demolition
C09/01	None
C09/02	None
C09/03	None
C09/04	None
C09/05	None
C09/06	None
C09/07	None
C10/01	None
C12/02	None
C12/03	None
C12/04	None

Name of Structure	Existing Services
C13/01	None

2.8 Geotechnical summary

The geotechnical summary for the Accommodation Underpass structure (Category 2) is provided in **Table 7** below.

Table 7 Geotechnical summary

Name of Structure	Chainage	Average Depth to Groundwater (m)	Average depth to Rockhead	Ground Conditions	Karst Risk
C10/01 – Environmental underpass	10+050	3.5	1.4	Soft sandy gravelly CLAY Firm sandy gravelly CLAY Medium strong to very strong typically non-intact LIMESTONE	High

For the remaining structures, the geotechnical information is available in the scheme factual reports[1].

It should be noted that at the culvert structures noted below, (not covered in **Error! Reference source not found.**6) the following geotechnical risks have been identified:

- C09/06 – Menlough Castle – High karst risk due to anomalies in geophysics profile GP3/06 (@Ch. 9+730 to 9+780)
- C12/02, 03, 04 – Ballindooly Lough – High karst risk coupled with deep soft overburden deposits, >20m (GP3/10 @ Ch. 12+300 to 12+390)
- C13/01 – Castlegar School Road – Paleolandscape/karst coupled with deep firm overburden deposits (likely based on trend of GP3/12 and BH3/32R)

Due to the high potential for karst features at these structure locations, piled foundations or other measured may be necessary. Additional ground investigation is recommended at these locations to further assess this risk.

2.9 Hydrology and hydraulic summary

For the culverting of existing streams, Section 50 consent has been obtained under the 1945 Arterial Drainage Act from the OPW. Please refer to Appendix C which includes a copy of the hydraulic assessment report.

[1] N6 Galway City Outer By-Pass Contract 1 GI Menlough to Garraun North 2003
N6 Galway City Outer By-Pass Contract 2 GI Gortatleva to Menlough 2003
N6 Galway City Outer By-Pass Contract 3 GI Forramoyle West to Gort 2004
N6 Galway City Outer By-Pass Detailed Design Ground Investigation 2006
N6 Galway City Transport Project – Phase 2 Ground Investigation Contract 1 2015
N6 Galway City Transport Project – Phase 3 Ground Investigation Contract 1 2016
N6 Galway City Transport Project – Phase 3 Ground Investigation Contract 2 2016

2.10 Archaeology summary

The archaeology summary is provided in Table 2 above.

2.11 Environmental summary

The locations of the otter and badger underpasses are based on the analysis of field survey results. Mitigation measures and culvert sizes have been designed in combination with the scheme ecologists. Otter passage facilities are located on watercourses crossed by the proposed road development where otters were recorded during the field surveys or, in the absence of results from the field surveys, on watercourses where there are otter records elsewhere within the catchment. Badger underpasses are sited to reconnect severed badger territories and commuting routes along habitat features. In terms of sizing and design, otter and badger underpass facilities are as per the relevant TII Guidelines.

The location of bat underpasses is based upon analysis of the survey results, including surveys at the crossing points of the proposed road development and important landscape features for bats, as they relate to the bat species recorded and habitat severance impacts identified (e.g. affecting commuting routes , foraging habitat or existing connectivity between roosting sites). The sizing of bat underpasses was determined in consideration of the target species' requirements, in that regard, based upon the findings of current published literature.

There are a small number of salmonid rivers interacting with the N6 GCRR. Inland Fisheries Ireland have been consulted regarding the requirements for fish passage at these locations.

Further information with regard to the environmental (ecology) requirements at the relevant structures is provided in Table 2 above.

2.12 Sustainability

Concrete is selected as the primary structural material for the underpass and culvert structures. Concrete has a high durability performance and requires little maintenance during the design life (120yrs), where the product is appropriately specified and executed. Portland cement replacements such as ground granulated blast-furnace slag (GGBS) will be used where appropriate.

All underpasses and culverts are of integral construction. This form of construction minimises the inspection and maintenance requirements compared to non-integral forms of construction.

All structures can be readily demolished at the end of the service life of the bridge, and much of the structural materials (concrete, steel etc.) can be recycled and reused.

3 Structure and aesthetics

3.1 General description of recommended structures

3.1.1 Hydraulic Culverts and Mammal Underpasses

Buried reinforced concrete structures are recommended for the culverts and underpasses. The structural form will be box or arch as indicated in **Figure 3** and **Figure 4**.

The choice adopted depends on the requirements of the structure. The drawings included in Appendix A.

These forms of structure are structurally efficient, achieve the performance requirements and are an economic solution to construct and maintain.

Figure 3 Box Structure

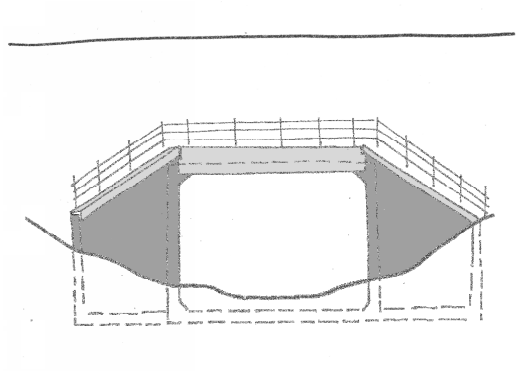
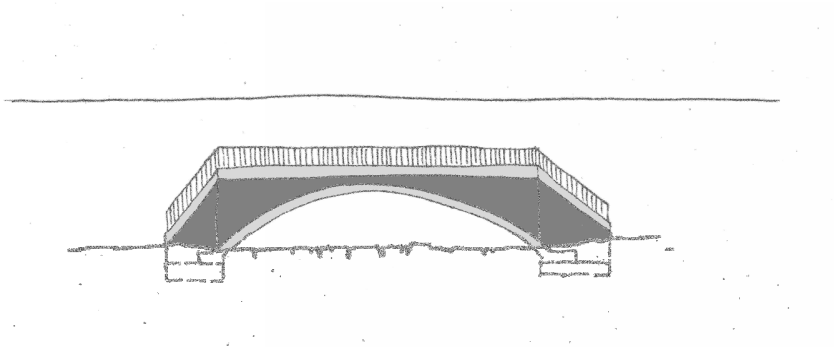


Figure 4 Arch Structure



Hydraulic Culverts

For the structures used for watercourse crossings, a buried box or buried arch structure is proposed. At locations where the cover to the top of the structure is greater than 7m, a buried arch structure is proposed, for the remaining structures a buried box configuration is selected. [refer to Drawing GCOB-1700-D-GEN-011]

All hydraulic culverts have a base slab and a bed depth allowance, as given in **Table 4** and **Table 5**. The culverts have been sized based on the required hydraulic capacity outlined in the Section 50 application process i.e. capacity 1% AEP Return

Period Storm plus an allowance for climate change. In addition to this at some locations, the hydraulic capacity of the culverts are oversized and have been increased in size to incorporate mammal passage requirements for example bats, badgers and otters.

Mammal Underpasses.

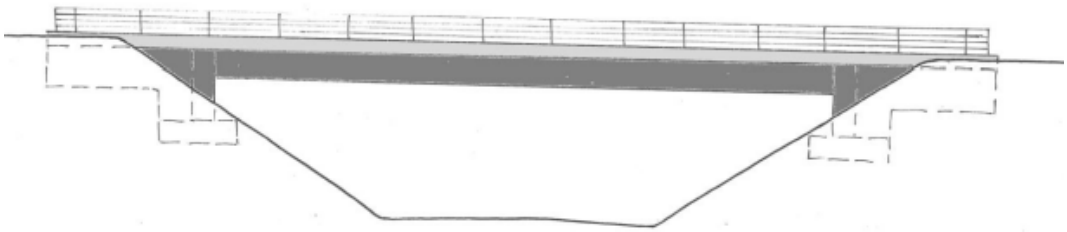
The mammal underpass structures are for facilitating the passage of wildlife. Typically, the required width is 2.5m and where the cover is greater than 7m a buried arch structure (with base slab) is proposed, and elsewhere a buried box structure is adopted. See Drawing GCOB-1700-D-GEN-011 for details.

At structures C09/01 to C09/05, a series of arch culverts is provided with a span of 5m and internal height of 4m, to ensure appropriate permeability through the embankment at this location

3.1.2 Environmental Underpass

At chainage 10+050, structure C10/01 is required to span over exposed limestone pavement and to facilitate the passage of wildlife. This structure has a span of approximately 20m and consists of precast prestressed beams and insitu deck and reinforced concrete abutments. The typical arrangement is given in **Figure 5** below and on Drawing GCOB-1700-D-C10-01-001.

Figure 5 Structure C10/01



3.2 Aesthetic considerations

For the culverts and underpasses, smooth concrete finishes are to be provided at the exposed faces, and appropriate detailing, such as drip checks and coping elements used to improve the weathering performance of the structure.

3.3 Proposals for the recommended structure of family of structures

3.3.1 Proposed category

The proposed category is given in **Table 8** below.

3.3.2 Span arrangements

Table 8 Span arrangements

Name of Structure	Structural Form (m)	Clear Span (m)	Category classification
Culvert C00/01	Buried RC box	2.5	0
Culvert C02/01a	Buried RC box	2.1	0
Culvert C02/01b	Buried RC box	2.5	0
Culvert C03/01	Buried RC box	2.5	0
Culvert C03/03	Buried RC box	2.5	0
Culvert C03/04	Buried RC box	2.5	0
Culvert C04/01	Buried RC box	5.0	1
Culvert C04/02	Buried RC box	3.1	1
Culvert C06/00	Buried RC box	2.5	0
Culvert C06/01	Buried RC box	2.5	0
Culvert C07/00	Buried RC box	2.5	0
Culvert C07/02a	Buried RC arch	2.5	0
Culvert C08/01a	Buried RC box	2.5	0
Culvert C08/02	Buried RC box	2.5	0
Culvert C08/04	Buried RC box	2.5	0
Culvert C08/05	Buried RC box	2.5	0
Culvert C09/01	Buried RC arch	5.0	1
Culvert C09/02	Buried RC arch	5.0	1
Culvert C09/03	Buried RC arch	5.0	1
Culvert C09/04	Buried RC arch	5.0	1
Culvert C09/05	Buried RC arch	5.0	1
Culvert C09/06	Buried RC arch	2.5	0
Culvert C09/07	Buried RC arch	2.5	0
C10/01	Single Span Integral Bridge	20.0	2
Culvert C12/02	Buried RC arch	2.5	0
Culvert C12/03	Buried RC arch	2.5	0
Culvert C12/04	Buried RC arch	2.5	0

Name of Structure	Structural Form (m)	Clear Span (m)	Category classification
Culvert C13/01	Buried RC box	2.5	0

3.3.3 Approaches including run-on arrangements

The approach embankments will be constructed using a compacted acceptable material with Clause 6N material behind end walls.

3.3.4 Substructure

For the hydraulic culverts and mammal underpasses, the proposed structure is a buried box/arch and the substructure is integrated with the superstructure. Refer to section 3.3.6 for further details.

At Structure C01/01 a reinforced concrete abutment, integral with the superstructure is proposed.

3.3.5 Foundation type

Typically, spread foundations will be used at the underpass and culvert structures. However, where there is soft material or karst features, alternative foundations, such as piles, may be necessary. Refer to Section 2.8 and Section 7.1 for further details.

3.3.6 Superstructure

With the exception of underpass C10/01, the reinforced concrete box/arch frame structures are adopted. Typically, reinforced concrete headwalls and wingwalls will be used at the ends of the structure. However, at some locations the underpass/culvert may be terminated within a structure retaining the N6 embankment, in which case, this retaining structure will also function as the headwall and wingwall for the underpass/culvert structure.

It is likely that some or all the structural elements will be constructed using pre-cast concrete.

At structure C10/01 a precast prestressed beam with insitu deck superstructure, integral with reinforced concrete abutments on pad footings is proposed.

3.3.7 Articulation arrangements, joints and bearings

The proposed underpasses / culverts are integral buried structures with no expansion joints or bearings. Movement joints will be required along the length of the structure and at the connection to the wingwalls.

3.3.8 Parapet

At all buried structures, a safety barrier with containment level of at least N2 will be provided on both verges of the mainline over the structure. Pedestrian

protection will be provided at headwalls and wingwalls in accordance with TII DN-STR-03011 (NRA BD 52).

At C10/01 a 1250mm high H2-W4 parapet, with mesh infill, will be provided at the edge of the bridge structure. The approach and departure safety barrier and transitions will be H2 containment. Inspection and Maintenance

None of the proposed underpass or culvert structures have expansion joints or bearings. The head walls and wing walls will be inspected from land adjacent to the walls. The underside of the roof and the exposed portions of the walls can be inspected from the beneath.

Waterproofing systems, joints, parapets etc shall be designed for Working Life Category 2 (replaceable structural parts, up to 50 years design working life).

All other elements of the structure shall be designed for Working Life Category 5 (≥120 years design working life).

4 Safety

4.1 Traffic management during construction including land for temporary diversions

Detailed traffic management proposals will be developed at detail design stage by the appointed Contractor in consultation with their Designers and the consent for the diversions and or road closures will be sought from the appropriate local authority.

4.2 Safety during construction

The Designer will take account of the General Principles of Prevention, as specified in the Schedule 3 of the Safety, Health and Welfare at Work Act 2005, liaise with the Project Supervisor appointed by the Client for the Design Process and the Project Supervisor appointed for the Construction Stage and carry out all other duties as required by Clause 15 of the Safety, Health and Welfare at Work (Construction) Regulations 2013 (S.I. No. 291 of 2013).

The Project Supervisor for the Design Process will comply with all the requirements outlined in Clauses 11, 12, 13 & 14 of the Safety, Health and Welfare at Work (Construction) Regulations 2013 (S.I. No. 291 of 2013).

4.3 Safety in use

Safety barriers in accordance with TII DN-REQ-0303 (NRA TD 19) will be used to protect vehicles on the mainline from the embankment at the buried underpasses and culvert locations. The safety barrier will be located within the verge at the top of the embankment in advance of the approach end and extending past the departure end of the structure.

At Structure C10/01 parapets will be provided across the length of the structure and on the approach and departure in accordance with TII DN-STR-03011 (NRA BD 52).

Pedestrian protection will be provided at the top of headwalls and wingwalls in accordance with TII DN-STR-03011 (NRA BD 52).

4.4 Lighting

No lighting is proposed in the proposed culverts or underpasses.

5 Cost

5.1 Budget Estimate in current year, including whole life cost

Table 9 Budget Estimate

Name of structure	Structure cost Excl. VAT
C00/01	228000
C02/01a	79040
C02/01b	187200
C03/01	115200
C03/03	124800
C03/04	132000
C04/01	159600
C04/02	236160
C06/00	153600
C06/01	153600
C07/00	141600
C07/02a	242400
C08/01a	124800
C08/02	88800
C08/04	110400
C08/05	100800
C09/01	277200
C09/02	286000
C09/03	277200
C09/04	278528
C09/05	281600
C09/06	192000
C09/07	168000
C10/01	699400
C12/02	280800
C12/03	259200
C12/04	230400
C13/01	136800

The cost estimate values given in **Table 9** are based on the cost rate per square metre of structure area given in **Table 10** below. An accuracy range of -10% to +15% is considered to be applicable to the budget cost for this stage of the design.

Table 10 Basis of cost estimate

Structure Type	Rate (Euro/m2)
Box culverts: span ≤ 5m	800
Arch Structures: span <7.5m	800
Prestressed Beam Deck Bridge	1300

6 Design Assessment Criteria

6.1 Normal Loading

Permanent Actions in accordance with IS EN 1991-1-1:2002 and the associated National Annex.

The structure will be designed for Load Models LM1 and LM2 in accordance with IS EN 1991-2:2003 and the associated National Annex.

6.2 Abnormal Loading

Load Model 3 up to and including SV196 (where applicable) will be considered in accordance with IS EN 1991-2:2003 and the associated National Annex.

6.3 Footway live loading

Where applicable, a footway loading shall be in accordance with Clause 5.3.2.1 of IS EN 1991-2:2003. A nominal q_{fk} = 5kN/m2 will be adopted.

6.4 Provision for exceptional abnormal loads

No exceptional abnormal loads are proposed.

6.5 Any special loading not covered above

Not applicable.

6.6 Heavy or high load route requirements and arrangements being made to preserve route

Not applicable.

6.7 Minimum headroom provided

No local access underpasses.

6.8 Authorities consulted and any special conditions required

Consultation with relevant authorities is on-going. The following groups have been contacted as part of the scheme:

Transport Infrastructure Ireland (TII)

Galway County Council (GCoC)

Galway City Council (GCiC)

Land and home owners

Utility companies (ESB, Gas, Eir, etc.)

Office of Public Works

National Parks and Wildlife Service

Inland Fisheries Ireland

7 Ground Conditions

7.1 Description of the ground conditions and compatibility with proposed foundations

The ground conditions for the Environmental Underpass structure (C10/01) is provided in **Table 11** below. For the remaining structures reference should be made to the scheme ground investigation reports.

Table 11 Ground Conditions

Name of Structure	Foundation Type	Soil / Rock at Formation Level	Safe Bearing Pressure (kN/m^2)	Formation depth above (+)/ below (-) egl (m)	Depth to Rockhead egl (m)
C10/01 – Environmental underpass	Pad	Soil	308	1.0	1.4

8 Drawings and Documents

8.1 List of all documents accompanying the submission

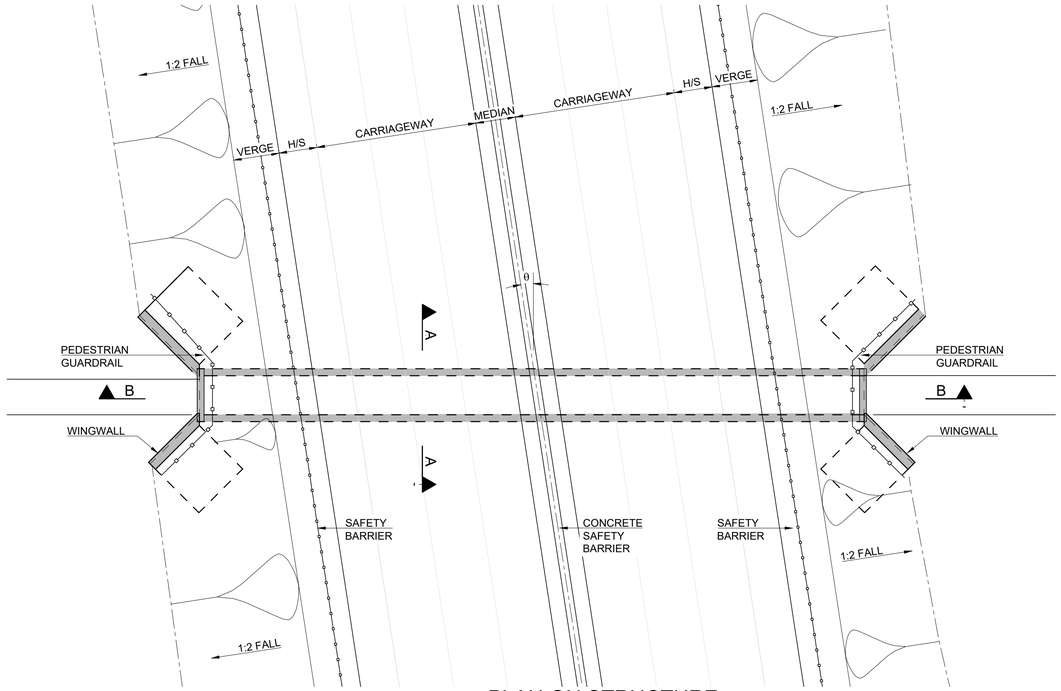
Table 12 Drawings

Drawing Number	Drawing Title
GCOB-1700-D-GEN-011	Culverts & Underpasses: Buried Box and Arch Structures
GCOB-1700-ST-C09-1 to 5-001	Culverts & Underpasses: Structures C09/01-C09/05 Sheet 1
GCOB-1700-ST-C09-1 to 5-002	Culverts & Underpasses: Structures C09/01-C09/05 Sheet 2
GCOB-1700 ST-C10-01-001	Culverts & Underpasses: Structure C10/01

Appendix A

Drawings

DESIGN REPORT



PLAN ON STRUCTURE

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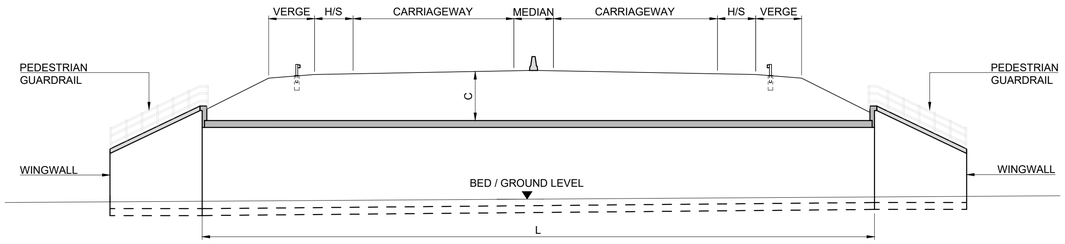

SECTION B-B

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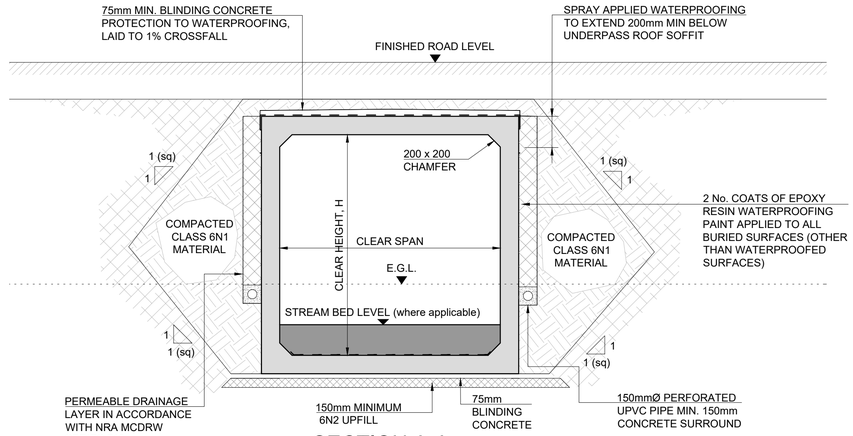
Reference	Name	Chainage	Strucuture Type	Clear Span, S [m]	Length, L [m]	Structural Depth, SD [m]	Clear Height, H [m]	Approximate cover, C (m)	Skew Angle, θ (deg)
C00/01	Culvert C00/01	00+670	Buried RC box	2.5	95.0	0.25	1.35	2.2	65
C02/01a	Culvert C02/01a - Tusky Stream	02+800	Buried RC box	2.1	38.0	0.25	1.80	2.6	16
C02/01b	Culvert C02/01b - Tusky Stream	02+850	Buried RC box	2.5	78.0	0.25	2.50	2.7	30
C03/01	Culvert C03/01	03+070	Buried RC box	2.5	48.0	0.25	1.20	0.6	4
C03/04	Culvert C03/04	03+965	Buried RC box	2.5	55.0	0.25	1.20	2.9	19
C03/03	Culvert C03/03	03+945	Buried RC box	2.5	52.0	0.25	1.20	3.1	19
C04/01	Culvert C04/01 - Bearna Stream	04+120	Buried RC box	5.0	35.0	0.35	2.50	0.9	15
C04/02	Culvert C04/02	04+915	Buried RC box	3.1	82.0	0.25	2.50	1.7	59
C06/00	Culvert C06/00	06+450	Buried RC box	2.5	64.0	0.25	2.50	4.2	31
C06/01	Culvert C06/01	06+850	Buried RC box	2.5	64.0	0.25	2.50	3.6	53
C07/00	Culvert C07/00	07+100	Buried RC box	2.5	59.0	0.25	2.00	1.6	11
C07/02a	Culvert C07/02a	07+225	Buried RC arch	2.5	101.0	0.25	2.50	7.7	0
C08/01a	Culvert C08/01a	08+450	Buried RC box	2.5	52.0	0.25	2.50	4.3	0
C08/02	Culvert C08/02	08+650	Buried RC box	2.5	37.0	0.25	2.50	1.9	0
C08/04	Culvert C08/04	08+580	Buried RC box	2.5	46.0	0.25	2.50	4.6	0
C08/05	Culvert C08/05	08+620	Buried RC box	2.5	42.0	0.25	2.50	2.7	0
C09/06	Culvert C09/06	09+790	Buried RC arch	2.5	80.0	0.25	2.50	10.9	0
C09/07	Culvert C09/07	09+920	Buried RC arch	2.5	70.0	0.25	2.50	14.2	0
C12/02	Culvert C12/02	12+375	Buried RC arch	2.5	117.0	0.25	2.50	12.6	0
C12/03	Culvert C12/03	12+410	Buried RC arch	2.5	108.0	0.25	2.50	10.5	0
C12/04	Culvert C12/04	12+435	Buried RC arch	2.5	96.0	0.25	2.50	8.8	0
C13/01	Culvert C13/01	12+980	Buried RC box	2.5	57.0	0.25	1.50	3.9	0



SECTION A-A

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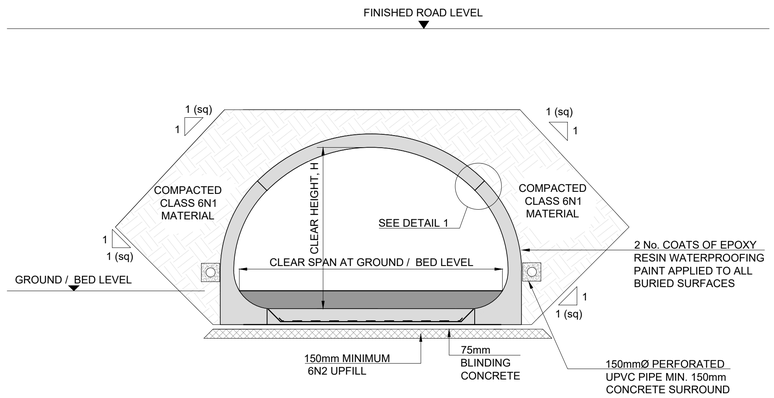
BURIED BOX



SECTION A-A

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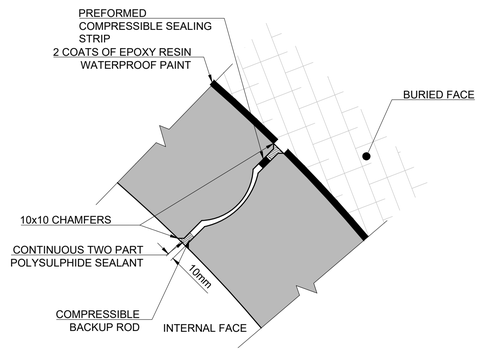
BURIED ARCH



DETAIL 1

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NOTES:

1. ALL DIMENSIONS ARE SHOWN IN MILLIMETRES UNLESS NOTED OTHERWISE.
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Job Title: N6 Galway City Ring Road

Scale: AS SHOWN @ A1

Date: July 2016

Issue	Date	By	Chkd	Appd
I3	02/08/2017	LM	PM	EMC
I2	30/06/2017	LM	PM	EMC
I1	11/07/2016	PD	PM	EMC

Drawing Title: Culverts □ Underpasses
Buried Box and Arch Structures

Drawing Status: **For Information**

Job No	Drawing No	Issue
233985	GCOB-1700-D-GEN-011	I3

Do not scale

DESIGN REPORT

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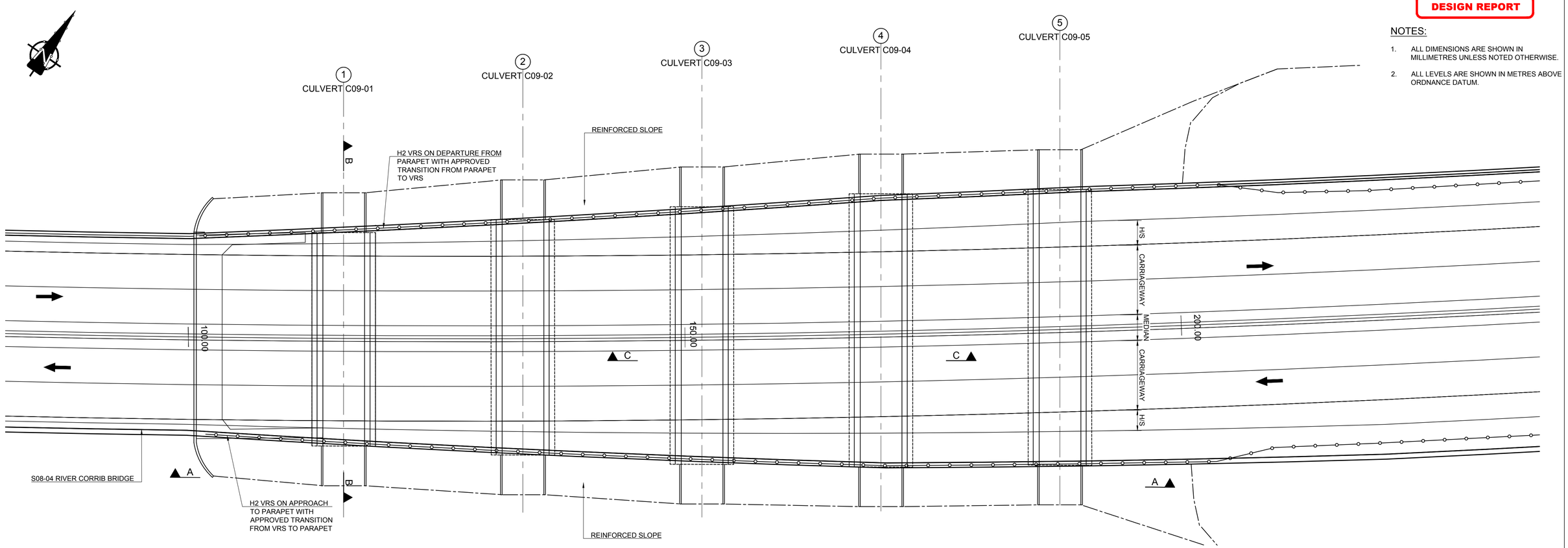

PLAN ON CULVERTS

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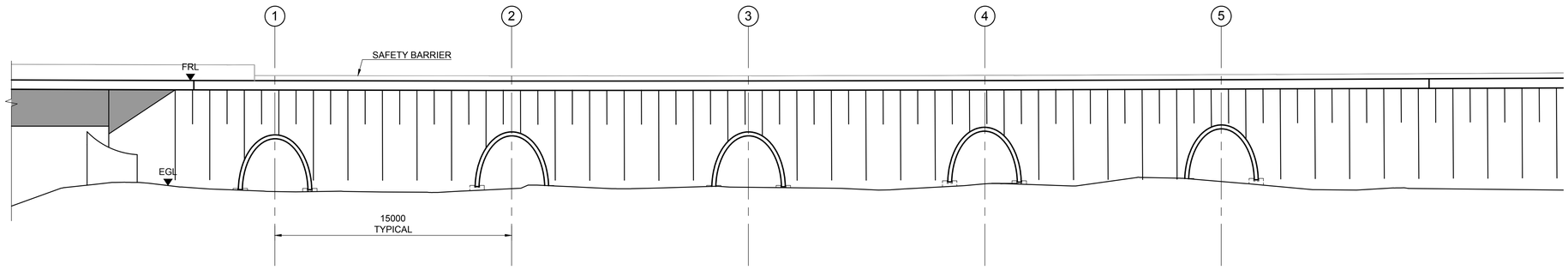

ELEVATION A-A

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Date: June 2017

Issue	Date	By	Chkd	Appd
I2	17/10/2017	LM	PM	MS
I1	1/06/2017	LM	PM	MS

Drawing Title: Culverts and Underpasses Structure C09-01 to 05 Sheet 1

Drawing Status: **For Information**

Job No	Drawing No	Issue
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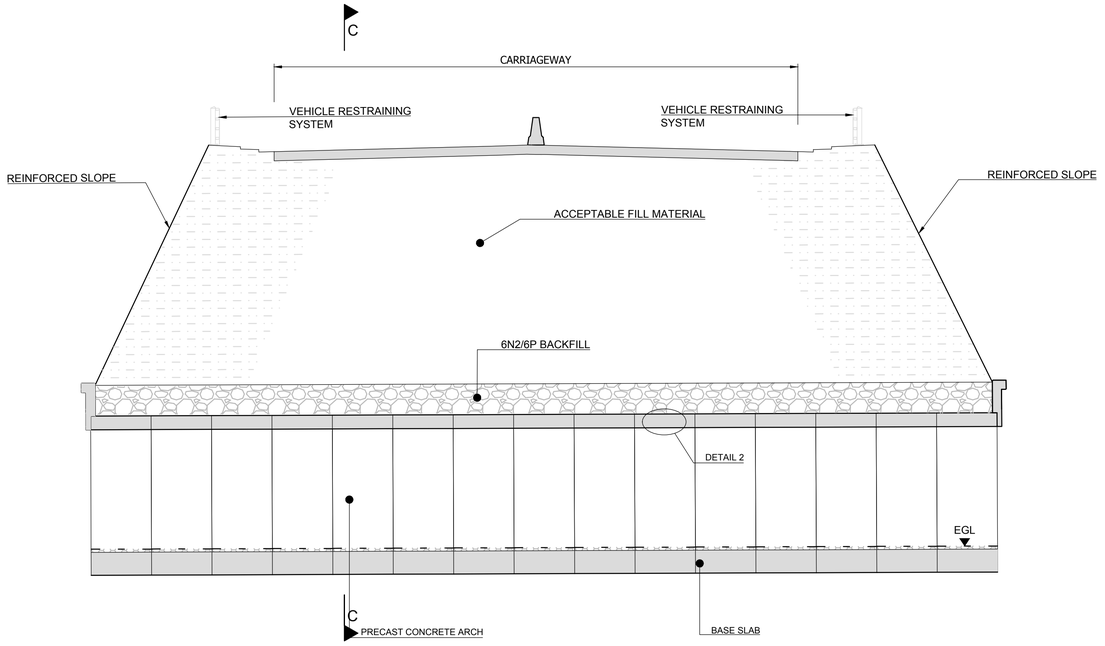

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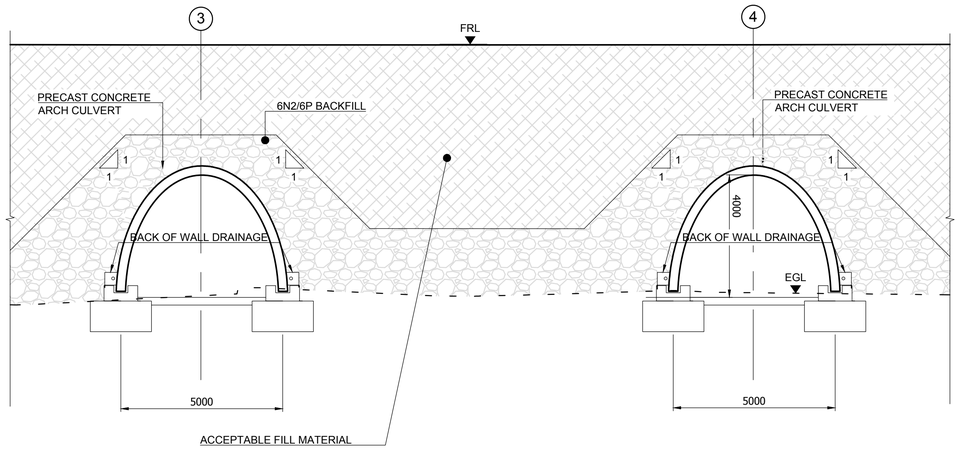

TYPICAL SECTION C-C
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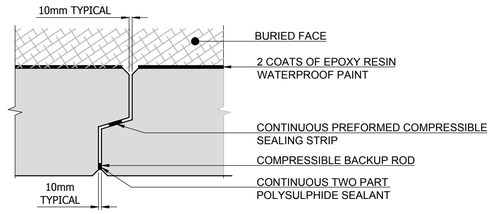

DETAIL 2
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Clients
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Issue	Date	By	Chkd	Appd
I2	17/10/2017	LM	PM	MS
I1	01/06/2017	LM	PM	MS

Drawing Title
Culverts and Underpasses
Structure C09-01 to 05
Sheet 2

Drawing Status
For Information

Job No	Drawing No	Issue
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DESIGN REPORT

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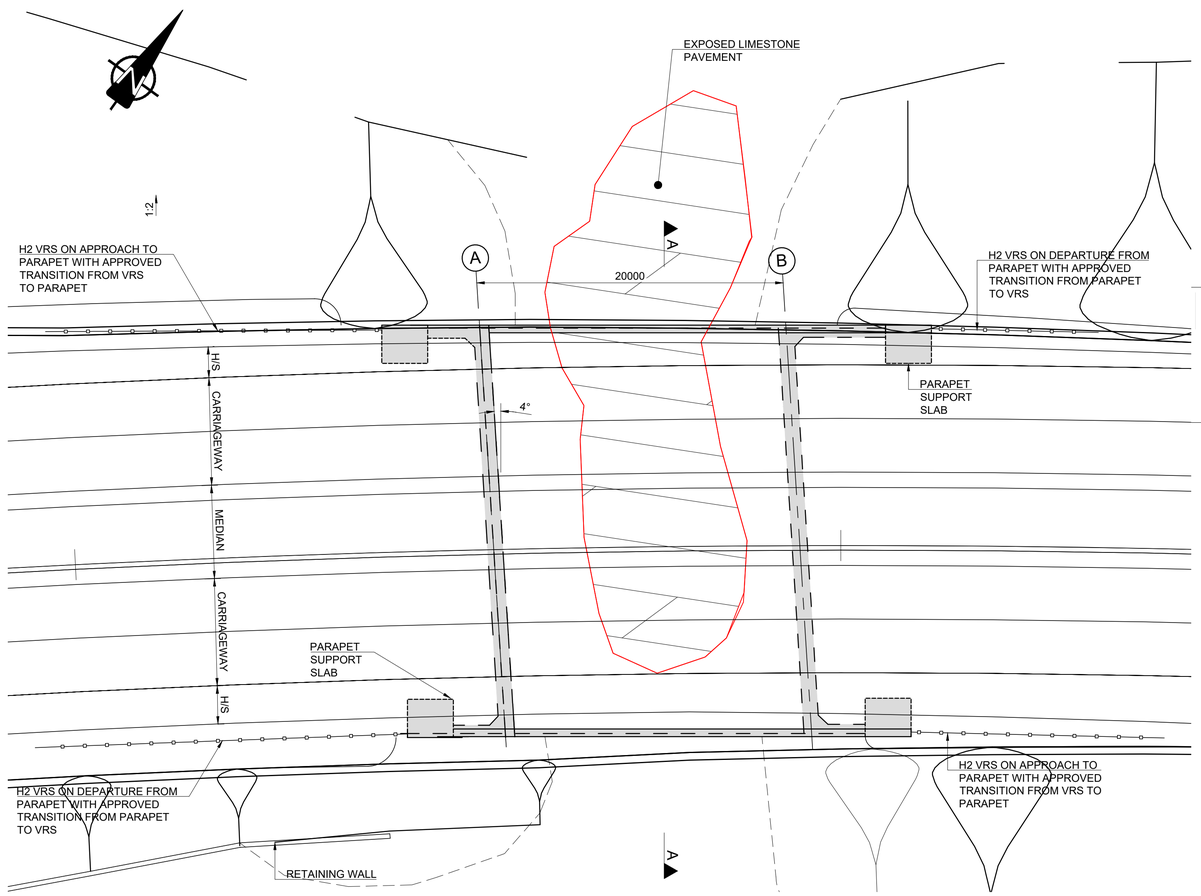

PLAN ON BRIDGE

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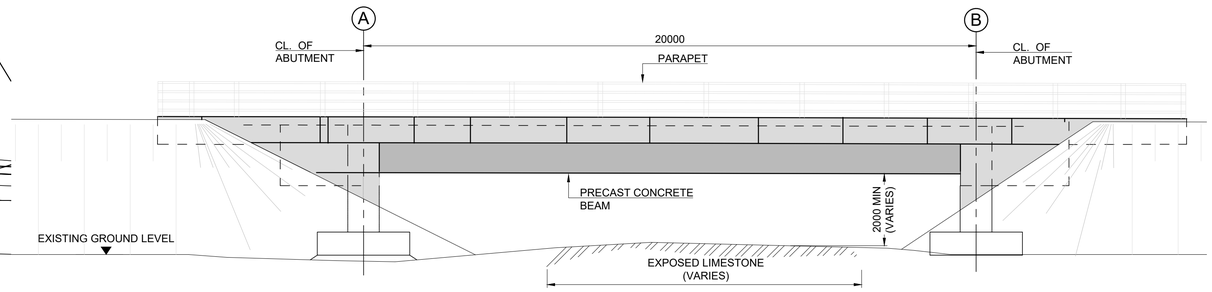

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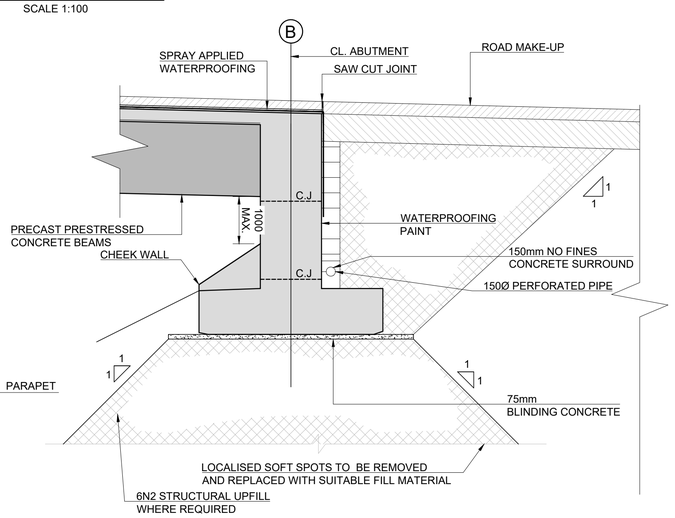

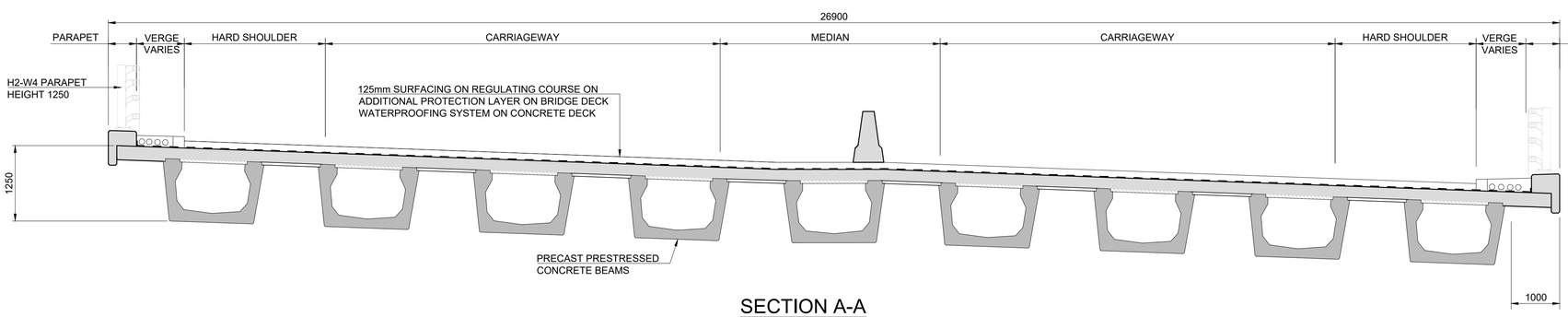

SECTION A-A

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TYPICAL WEST ABUMENT CROSS SECTION

SCALE 1:50

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Issue	Date	By	Chkd	Appd
I2	30/06/2017	LM	PM	EMC
I1	11/07/2016	PD	PM	EMC

Drawing Title: Culverts and Underpasses: Structure C10/01

Drawing Status: **For Information**

Job No	Drawing No	Issue
233985	GCOB-1700-D-C10-01-001	I2

Do not scale

Appendix B

Extract from ground investigation data

GEOTECHNICAL BORING RECORD

REPORT NUMBER 18963

CONTRACT N6 Galway City Transport Project - Phase 3

BOREHOLE NO. BH3/23
SHEET Sheet 1 of 1

CO-ORDINATES 527,770.91 E, 727,345.14 N
GROUND LEVEL (m AOD) 26.78
RIG TYPE Dando 3000
BOREHOLE DIAMETER (mm)
BOREHOLE DEPTH (m) 3.70
DATE COMMENCED 05/02/2016
DATE COMPLETED 05/02/2016

CLIENT Galway County Council
ENGINEER ARUP
SPT HAMMER REF. NO.
ENERGY RATIO (%)
BORED BY WC
PROCESSED BY JL

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples: Ref. Number	Samples: Sample Type	Samples: Depth (m)	Samples: Recovery	Field Test Results	Standpipe Details
0	Firm dark brown sandy gravelly CLAY with a low to medium cobble and boulder content									
1					AA32640	B	1.00-1.45		N = 15 (2, 3, 3, 3, 4, 5)	
2			24.48	2.30	AA32641	B	2.00-2.45		N = 15 (3, 3, 2, 3, 4, 6)	
	Medium dense light brown slightly clayey gravelly SAND with a low to medium cobble and boulder content									
3					AA32643	B	3.00-3.45		N = 16 (3, 4, 3, 4, 4, 5)	
			23.08	3.70						
4	End of Borehole at 3.70 m									
5										
6										
7										
8										
9										

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
3.6	3.7	0.75	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
3.70	3.70	No	3.20	20	Slow

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GROUNDWATER PROGRESS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

REMARKS 0.5hr moving boulders obstructing access to plot. 0.5hr moving rig and tracked dumper from borehole including replacement of boulders to block entrance.

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
UT - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

IGSL BH LOG 18963.GPJ IGSL.GDT 12/5/16

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 18963

CONTRACT	N6 Galway City Transport Project - Phase 3	**DRILLHOLE NO**	**BH3/23R**
		SHEET	Sheet 1 of 2
CO-ORDINATES	527,773.63 E 727,346.05 N	**DATE DRILLED**	24/02/2016
GROUND LEVEL (mOD)	26.93	**DATE LOGGED**	24/02/2016
CLIENT	Galway County Council	**DRILLED BY**	IGSL
ENGINEER	ARUP	**LOGGED BY**	D. O'Shea
RIG TYPE	Casagrande		
FLUSH	Air/Mist		
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	80		

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm) 0 250 500	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	SPT (N Value)
0								SYMMETRIX DRILLING: No recovery, observed by driller as clayey gravelly cobbles				
1												
2									2.80	24.13		
3								SYMMETRIX DRILLING: No recovery, observed by driller as sandy gravelly clay with occasional cobbles	3.70	23.23		
4	4.20							SYMMETRIX DRILLING: No recovery, observed by driller as greenish grey weathered rock	4.20	22.73		
5		100	31	14				Very strong to strong, thickly to thinly banded, light green/grey/white mottled, porphyritic, medium to coarse-grained, GRANITE, fresh to locally moderately weathered. Dips are 20° to locally 80°. Discontinuities are widely to medium spaced, rough to locally smooth, planar. Apertures are tight to partly open, very thin brown clay smearing. 4.20-5.30m - Moderately weathered, slight weakening.				
6	5.70	100	95	91								
7	7.20				660							
8		100	100	93								
9	8.70				650							
		100	100	100	1100							

REMARKS

Hole cased 0.00-4.20m.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
24-02-16	5.50	3.50	5.70	50mm SP

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

IGSL RC FI 10M 18963.GPJ IGSL.GDT 24/6/16

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 18963

CONTRACT	N6 Galway City Transport Project - Phase 3	**DRILLHOLE NO**	**BH3/23R**
		SHEET	Sheet 2 of 2
CO-ORDINATES	527,773.63 E 727,346.05 N	**DATE DRILLED**	24/02/2016
GROUND LEVEL (mOD)	26.93	**DATE LOGGED**	24/02/2016
CLIENT	Galway County Council	**DRILLED BY**	IGSL
ENGINEER	ARUP	**LOGGED BY**	D. O'Shea
RIG TYPE	Casagrande		
FLUSH	Air/Mist		
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	80		

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm) 0 250 500	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	SPT (N Value)
10	10.20							End of Borehole at 10.20 m	10.20	16.73		
11												
12												
13												
14												
15												
16												
17												
18												
19												

REMARKS

Hole cased 0.00-4.20m.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
24-02-16	5.50	3.50	5.70	50mm SP

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

IGSL RC FI 10M 18963.GPJ IGSL.GDT 24/6/16

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 18963

CONTRACT	N6 Galway City Transport Project - Phase 3	**DRILLHOLE NO**	**BH3/25R**
		SHEET	Sheet 1 of 2
CO-ORDINATES	528,734.81 E 727,833.14 N	**DATE DRILLED**	26/02/2016
GROUND LEVEL (mOD)	12.85	**DATE LOGGED**	29/02/2016
CLIENT	Galway County Council	**DRILLED BY**	IGSL
ENGINEER	ARUP	**LOGGED BY**	D. O'Shea
RIG TYPE	Comacchio		
FLUSH	Air/Mist		
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	80		

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm) 0 250 500	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	SPT (N Value)
0								SYMMETRIX DRILLING: No recovery, observed by driller as made ground consisting of Shell & Auger material				
1												
2												
3									3.80	9.05		
4	4.10							SYMMETRIX DRILLING: No recovery, observed by driller as weathered rock	4.10	8.75		
		100	100	100		940		Very strong, thick to thinly bedded, blueish dark grey, fine grained, LIMESTONE (locally fossiliferous, localized chert and stylolites), fresh to slightly weathered.				
5	5.10							Dips are 20° to locally 40°. Discontinuities are widely to medium spaced, rough to locally smooth, planar. Apertures are tight to partly open, very thin brown clay smearing.				
		100	93	73		810						
6	6.70											
		100	100	100		1000						
7						510.0000000000001						
8	8.30											
		100	100	100		629.9999999999999						
9						680.0000000000001						
	9.90											

REMARKS

Hole cased 0.00-4.10m.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 18963

CONTRACT	N6 Galway City Transport Project - Phase 3	**DRILLHOLE NO**	**BH3/25R**
		SHEET	Sheet 2 of 2
CO-ORDINATES	528,734.81 E 727,833.14 N	**DATE DRILLED**	26/02/2016
GROUND LEVEL (mOD)	12.85	**DATE LOGGED**	29/02/2016
CLIENT	Galway County Council	**DRILLED BY**	IGSL
ENGINEER	ARUP	**LOGGED BY**	D. O'Shea
RIG TYPE	Comacchio		
FLUSH	Air/Mist		
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	80		

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm) 0 250 500	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	SPT (N Value)
10	10.30	100	100	100				End of Borehole at 10.30 m	10.30	2.55		
11												
12												
13												
14												
15												
16												
17												
18												
19												

REMARKS

Hole cased 0.00-4.10m.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments
29-02-16	10.30	4.10	9.60	Water level measured 10 mins after end of drilling

IGSL RC FI 10M 18963.GPJ IGSL.GDT 24/6/16

GEOTECHNICAL BORING RECORD

REPORT NUMBER 18963

CONTRACT N6 Galway City Transport Project - Phase 3

BOREHOLE NO. **BH3/54**
SHEET Sheet 1 of 1

CO-ORDINATES 528,601.86 E, 727,756.28 N
GROUND LEVEL (m AOD) 8.05
RIG TYPE Dando 3000
BOREHOLE DIAMETER (mm)
BOREHOLE DEPTH (m) 3.70
DATE COMMENCED 30/03/2016
DATE COMPLETED 31/03/2016

CLIENT Galway County Council
ENGINEER ARUP
SPT HAMMER REF. NO.
ENERGY RATIO (%)
BORED BY WC
PROCESSED BY JL

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples: Ref. Number	Samples: Sample Type	Samples: Depth (m)	Samples: Recovery	Field Test Results	Standpipe Details
0	TOPSOIL with BOULDERS (Possible MADE GROUND)		7.35	0.70	AA9	B	0.50			
1	Stiff dark and light brown sandy gravelly CLAY with a medium cobble and boulder content				AA10	B	1.00-1.45		N = 40 (6, 9, 12, 14, 8, 6)	
2					AA11	B	2.00-2.45		N = 49 (5, 7, 8, 11, 14, 16)	
3					AA12	B	3.00-3.45		N = 50/200 mm (3, 4, 6, 17, 27)	
			4.35	3.70						
4	End of Borehole at 3.70 m									
5										
6										
7										
8										
9										

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
3.7	3.7	0.75	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

GROUNDWATER PROGRESS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

REMARKS 1.0hr getting plant and equipment to borehole location

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
UT - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

IGSL BH LOG 18963.GPJ IGSL.GDT 12/5/16

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 18963

CONTRACT	N6 Galway City Transport Project - Phase 3	**DRILLHOLE NO**	**BH3/54R**
		SHEET	Sheet 1 of 2
CO-ORDINATES	528,601.20 E 727,757.95 N	**DATE DRILLED**	31/03/2016
GROUND LEVEL (mOD)	8.29	**DATE LOGGED**	01/04/2016
CLIENT	Galway County Council	**DRILLED BY**	IGSL
ENGINEER	ARUP	**LOGGED BY**	D. O'Shea
RIG TYPE	Casagrande		
FLUSH	Air/Mist		
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	80		

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm) 0 250 500	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	SPT (N Value)
0								SYMMETRIX DRILLING: No recovery, observed by driller as gravelly clay				
1									1.20	7.09		
								SYMMETRIX DRILLING: No recovery, observed by driller as sandy gravelly clay with occasional cobbles				
2												
3									3.20	5.09		
								SYMMETRIX DRILLING: No recovery, observed by driller as weathered rock				
4	4.20								4.20	4.09		
		100	94	94				Medium strong to very strong, thick to thinly bedded, blueish dark grey, fine grained, LIMESTONE (locally fossiliferous, localized chert and stylolites), slightly weathered. Dips are 20° to locally 40° & 80°. Discontinuities are widely to medium spaced, rough to locally smooth, planar. Apertures are tight to partly open, very thin brown clay smearing. 6.11-6.35m - Clay-filled fracture				
5												
	5.70											
6		100	97	97		810						
7	7.20					660						
		100	99	99		940						
8	8.70											
9		100	99	99		770.0000000000001						

REMARKS

Hole cased 0.00-4.20m.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

IGSL RC FI 10M 18963.GPJ IGSL.GDT 24/6/16

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 18963

CONTRACT	N6 Galway City Transport Project - Phase 3	**DRILLHOLE NO**	**BH3/54R**
		SHEET	Sheet 2 of 2
CO-ORDINATES	528,601.20 E 727,757.95 N	**DATE DRILLED**	31/03/2016
GROUND LEVEL (mOD)	8.29	**DATE LOGGED**	01/04/2016
CLIENT	Galway County Council	**DRILLED BY**	IGSL
ENGINEER	ARUP	**LOGGED BY**	D. O'Shea
RIG TYPE	Casagrande		
FLUSH	Air/Mist		
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	80		

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm) 0 250 500	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	SPT (N Value)
10	10.20					600		Medium strong to very strong, thick to thinly bedded, blueish dark grey, fine grained, LIMESTONE (locally fossiliferous, localized chert and stylolites), slightly weathered. Dips are 20° to locally 40° & 80°. Discontinuities are widely to medium spaced, rough to locally smooth, planar. Apertures are tight to partly open, very thin brown clay smearing. *(continued)* 11.25-11.40m - Clay-filled fracture				
11		100	92	92		650						
	11.70					639.9999999999999						
12		100	94	94		699.9999999999999						
13	13.20	100	100	100								
14	14.20					2430						
		100	100	100								
15	15.20							End of Borehole at 15.20 m	15.20	-6.91		
16												
17												
18												
19												

REMARKS

Hole cased 0.00-4.20m.

WATER STRIKE DETAILS

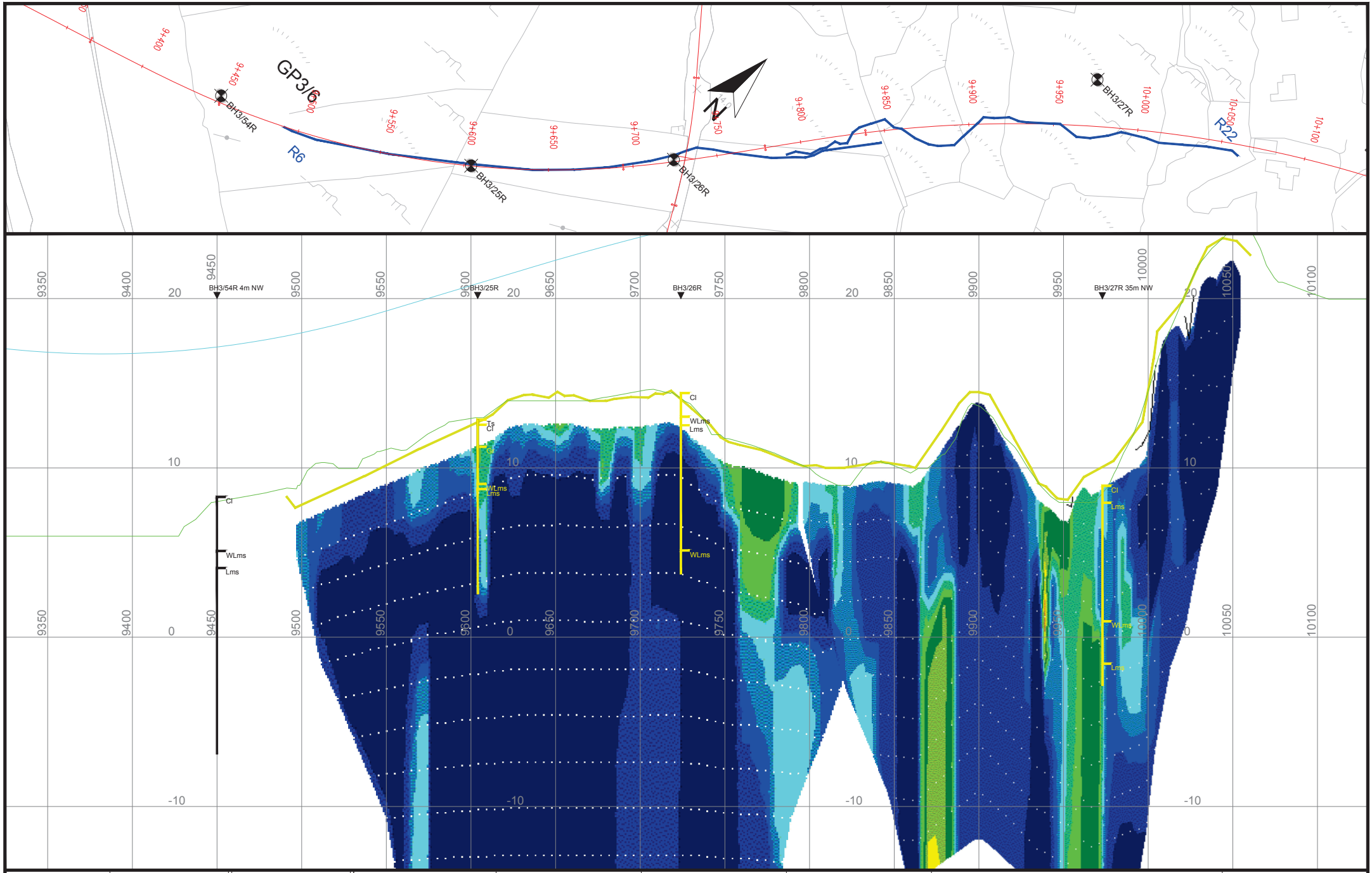
Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type



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CLIENT: IGSL
ARUP

PROJECT: N6 GCTP Phase 3
Geophysical Survey

TITLE: Plan 1e: Survey Locations and Models for GP3/06

SCALE: Hor 1:1000 @ A1, Ver 1:100 @ A1, VE x 10
PROJECT: 6031
DRAWN: RJ
DATE: 18/02/2016
MGX FILE: 6031d_Plans.dwg
STATUS: Draft

LEGEND:

Geophysical Survey Locations:
R2 2D-Resistivity Profile
S1 Seismic Refraction Profile

Chainage based on Alignment received 12.02.2016
Locations are in Irish Transverse Mercator, Elevations are in mOD (Malin Head)

Geophysical Survey Locations:
Ground Surface along Survey Profile
Existing Ground Level along Centre Line
Proposed Vertical Alignment Centre Line

2D Resistivity and Seismic Refraction results are projected onto the Centre Line

2D-Resistivity Model Values:

Resistivities (Ohmm) for 2D-Resistivity Model

A draft interpretation is indicated by yellow/magenta text. At this stage of the project this is intended to give guidance for targeted boreholes and coreholes.

Abbreviated GI Logs:
BH3/18R Borehole Name and Location

Pt	Peat	Si	Silt
Cl	Clay	Lms	Limestone
Ts	Topsoil	WLms	Weathered Limestone
Mg	Made Ground	Gn	Granite
Gr	Gravel	WGn	Weathered Granite
Sd	Sand		

GEOTECHNICAL BORING RECORD

REPORT NUMBER 18963

CONTRACT N6 Galway City Transport Project - Phase 3

BOREHOLE NO. **BH3/25**
SHEET Sheet 1 of 1

CO-ORDINATES 528,732.55 E, 727,834.69 N
GROUND LEVEL (m AOD) 12.60
RIG TYPE Dando 3000
BOREHOLE DIAMETER (mm)
BOREHOLE DEPTH (m) 3.80
DATE COMMENCED 01/02/2016
DATE COMPLETED 01/02/2016

CLIENT Galway County Council
ENGINEER ARUP
SPT HAMMER REF. NO.
ENERGY RATIO (%)
BORED BY WC
PROCESSED BY JL

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples: Ref. Number	Sample Type	Depth (m)	Recovery	Field Test Results	Standpipe Details
0	Gravelly TOPSOIL		12.30	0.30						
	Firm light grey brown sandy gravelly CLAY				AA43893	B	0.50-1.00			
1					AA43894	B	1.00-1.45		N = 16 (3, 3, 4, 3, 4, 5)	
			11.00	1.60						
2	Firm becoming firm to stiff light brown sandy gravelly silty CLAY. Gravel is angular.				AA43895	B	2.00-2.45		N = 18 (4, 4, 3, 4, 5, 6)	
3					AA43896	B	3.00-3.45		N = 20 (3, 3, 4, 4, 4, 8)	
			8.80	3.80						
4	Obstruction End of Borehole at 3.80 m									
5										
6										
7										
8										
9										

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
3.7	3.8	0.75	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

GROUNDWATER PROGRESS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

REMARKS Borehole backfilled upon completion. Borehole scheduled for rotary follow-on coring.

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
UT - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

IGSL BH LOG 18963.GPJ IGSL.GDT 12/5/16

GEOTECHNICAL BORING RECORD

REPORT NUMBER 18963

CONTRACT	N6 Galway City Transport Project - Phase 3	**BOREHOLE NO.**	**BH3/27**
		SHEET	Sheet 1 of 1
CO-ORDINATES	528,960.51 E 728,130.68 N	**RIG TYPE**	Dando 3000
		BOREHOLE DIAMETER (mm)	
GROUND LEVEL (m AOD)	8.94	**BOREHOLE DEPTH (m)**	1.40
		DATE COMMENCED	17/02/2016
		DATE COMPLETED	18/02/2016
CLIENT	Galway County Council	**SPT HAMMER REF. NO.**	
ENGINEER	ARUP	**ENERGY RATIO (%)**	
		BORED BY	WC
		PROCESSED BY	JL

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples: Ref. Number	Samples: Sample Type	Samples: Depth (m)	Samples: Recovery	Field Test Results	Standpipe Details
0	Soft dark brown sandy gravelly CLAY		8.54	0.40						
1	Firm light brown sandy gravelly CLAY with a medium cobble and boulder content				AA48872	B	0.50			
					AA48873	B	1.00-1.45		N = 50/180 mm (2, 2, 4, 8, 38)	
			7.54	1.40						
2	Obstruction End of Borehole at 1.40 m									
3										
4										
5										
6										
7										
8										
9										

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
1.4	1.4	0.5	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

GROUNDWATER PROGRESS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

REMARKS 2.5hr getting rig on to position from BH3/21. Tracked excavator used to assist rig access / egress from field. 3hr removing rig and track machine from field.

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
UT - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

IGSL BH LOG 18963.GPJ IGSL.GDT 12/5/16

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 18963

CONTRACT	N6 Galway City Transport Project - Phase 3	**DRILLHOLE NO**	**BH3/27R**
		SHEET	Sheet 1 of 2
CO-ORDINATES	528,960.43 E 728,133.26 N	**DATE DRILLED**	12/04/2016
GROUND LEVEL (mOD)	9.10	**DATE LOGGED**	13/04/2016
CLIENT	Galway County Council	**DRILLED BY**	IGSL
ENGINEER	ARUP	**LOGGED BY**	D. O'Shea
RIG TYPE	Casagrande		
FLUSH	Air/Mist		
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	80		

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm) 0 250 500	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	SPT (N Value)
0								SYMMETRIX DRILLING: No recovery, observed by driller as clay	0.80	8.30		
1	1.00							SYMMETRIX DRILLING: No recovery, observed by driller as weathered rock	1.00	8.10		
		93	93	93	1350			Medium strong to very strong, thick to thinly bedded, blueish dark grey, fine grained, LIMESTONE (locally fossiliferous, localized chert and stylolites), slightly weathered.				
2	2.50							Dips are 20° to locally 40° & 80°. Discontinuities are widely to medium spaced, rough to locally smooth, planar. Apertures are tight to partly open, very thin brown clay smearing.				
		100	87	87	930			2.90-3.00m - Clay-filled fracture				
3	4.00											
		100	84	64				4.31-4.53m - Clay-filled fracture				
4	5.00											
		100	85	76	720			5.72-5.86m - Clay-filled fracture				
5	6.00											
		100	91	82				6.36-6.51m - Clay-filled fracture				
6	7.00							6.97-7.32m - Clay-filled fracture				
		90	75	70	1080							
7	8.00											
		100	80	30				8.59-8.71m - Clay-filled fracture				
8	9.00											
		20	20	20				9.24-11.05m - Clay-filled fracture				
9												

REMARKS

Hole cased 0.00-1.00m.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

IGSL RC FI 10M 18963.GPJ IGSL.GDT 24/6/16

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 18963

CONTRACT	N6 Galway City Transport Project - Phase 3	**DRILLHOLE NO**	**BH3/27R**
		SHEET	Sheet 2 of 2
CO-ORDINATES	528,960.43 E 728,133.26 N	**DATE DRILLED**	12/04/2016
GROUND LEVEL (mOD)	9.10	**DATE LOGGED**	13/04/2016
CLIENT	Galway County Council	**DRILLED BY**	IGSL
ENGINEER	ARUP	**LOGGED BY**	D. O'Shea
RIG TYPE	Casagrande		
FLUSH	Air/Mist		
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	80		

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm) 0 250 500	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	SPT (N Value)
10	10.50											
11	11.80	92	58	58		750		End of Borehole at 11.80 m	11.80	-2.70		
12												
13												
14												
15												
16												
17												
18												
19												

REMARKS

Hole cased 0.00-1.00m.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

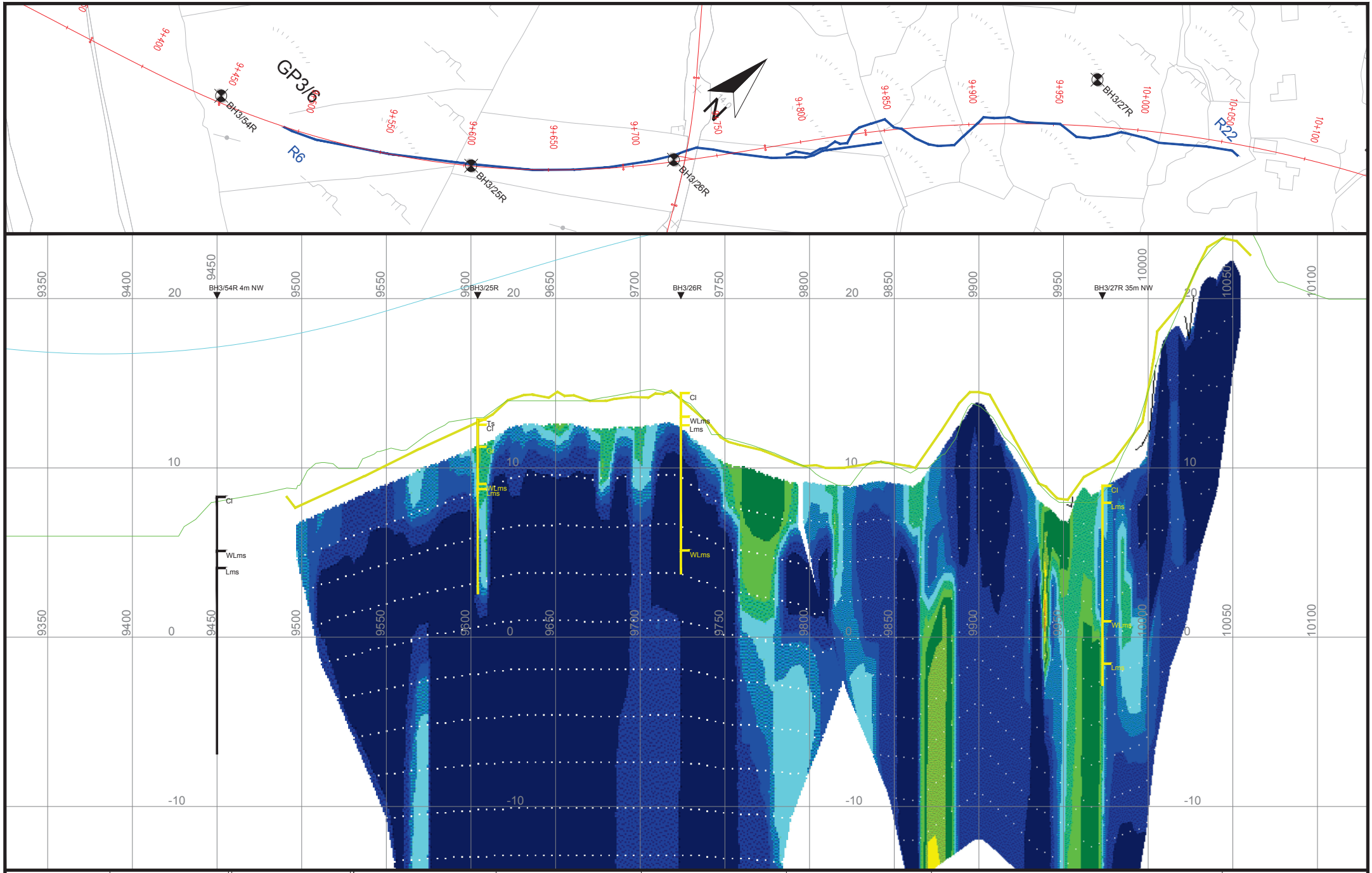
INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

IGSL RC FI 10M 18963.GPJ IGSL.GDT 24/6/16



Minerex Geophysics Limited
Unit F4, Maynooth Business Campus
Maynooth, Co. Kildare
Tel. (01) 6510030
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Web: www.mgx.ie

CLIENT: IGSL
ARUP

PROJECT: N6 GCTP Phase 3
Geophysical Survey

TITLE: Plan 1e: Survey Locations and Models for GP3/06

SCALE: Hor 1:1000 @ A1, Ver 1:100 @ A1, VE x 10
PROJECT: 6031
DRAWN: RJ
DATE: 18/02/2016
MGX FILE: 6031d_Plans.dwg
STATUS: Draft

LEGEND:

Geophysical Survey Locations:
R2 2D-Resistivity Profile
S1 Seismic Refraction Profile

Chainage based on Alignment received 12.02.2016
Locations are in Irish Transverse Mercator, Elevations are in mOD (Malin Head)

Geophysical Survey Locations:
Ground Surface along Survey Profile
Existing Ground Level along Centre Line
Proposed Vertical Alignment Centre Line

2D Resistivity and Seismic Refraction results are projected onto the Centre Line

2D-Resistivity Model Values:

Resistivities (Ohmm) for 2D-Resistivity Model

A draft interpretation is indicated by yellow/magenta text. At this stage of the project this is intended to give guidance for targeted boreholes and coreholes.

Abbreviated GI Logs:
BH3/18R Borehole Name and Location

Pt	Peat	Si	Silt
Cl	Clay	Lms	Limestone
Ts	Topsoil	WLms	Weathered Limestone
Mg	Made Ground	Gn	Granite
Gr	Gravel	WGn	Weathered Granite
Sd	Sand		

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DRILLHOLE LOG

Project				DRILLHOLE No
N6 Galway City Outer Bypass				RC 959 A
Job No	Date 21-11-06 21-11-06	Ground Level (m) 6.67	Co-Ordinates () E 129,030.8 N 228,002.9	
Contractor IDL				Sheet 1 of 1

RUN DETAILS					STRATA				
Depth / Date	TCR (SCR) RQD	(SPT) Fracture Spacing	Red'cd Level	Legend / Depth (Thick-ness)	DESCRIPTION: Discontinuities	Detail	Main	Geology	Instrument/ Backfill
0.00	43 (-) -		5.17	(1.50) 1.50	0.00 - 5.30		Subrounded limestone GRAVEL & COBBLES.		
			4.97	1.70			Dark grey angular to subangular limestone coarse grained GRAVEL.		
2.00	25 (-) -	NA		(3.60)			Subrounded limestone GRAVEL & COBBLES.		
3.50	93 (-) -								
5.00	100 (39) 0		1.37	5.30	5.30 - 8.00 Possible weathered rock or boulders.		Weathered LIMESTONE. Recovered as very strong slightly weathered grey limestone gravel cobbles and boulders.		
6.50	100 (66) 44	NI		(2.70)					
8.00			-1.33	8.00			BH terminated at 8.0m bgl on RE's Instruction.		

Drilling Progress and Water Observations								Rotary Flush				GENERAL REMARKS
Date	Time	Depth	Casing Depth	Casing Dia	Core Dia mm	Water Strike	Water Standing	From	To	Type	Returns	Borehole backfilled with cement bentonite grout.

All dimensions in metres Scale 1:62.5	Client Galway County Council	Method/ Plant Used County Tractor	Bit Design HQ	Logged By EAT

IDL AGS3 UK DH N6GCOB_ROTARY2006.GPJ IDL TP TEMPLATE.GDT 12/02/07

Trial Pit Log

Logged by DJB Checked by ROR	Start 15/10/2003 End 15/10/2003	Equipment, Methods and Remarks Excavated using a JCB	Dimensions and Orientation Width 0.80 m Length 2.50 m 110 (Deg)	Ground Level +7.22 mOD Coordinates E 129009.49 National Grid N 228047.30

Samples and Tests

Depth	Type & No.	Date Records
0.10	D 1	
0.50	D 2	
0.50-0.80	B 3	
0.50-0.80	B 4	

Strata

Description	Depth, Level (Thickness)	Legend	Backfill/ Instrument
1 MADE GROUND: Firm brown slightly sandy slightly gravelly fibrous CLAY with rare brick fragments. 2 Gravel is subangular to rounded fine to coarse.	0.10 +7.12		
Very stiff grey slightly sandy slightly gravelly CLAY with many cobbles. Gravel is subangular to angular fine to coarse. Cobbles are subangular of limestone.	(0.70)		
EXPLORATORY HOLE ENDS AT 0.80 m	0.80 +6.42		

Depth	Type & No.	Records Date

Groundwater Entries

No. Struck	Post Strike (m)	Behaviour
None observed (see Key Sheet)		

Depth Related Remarks

From	to (m)	
0.80		Trail pit terminated due to obstruction - presumed bedrock.

Stability Good

Shoring None

Weather

Notes: For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.

Scale 1:25

AGS

Project N6 Galway City Outer Bypass Contract 2 Ground Investigation Gortatleva to Menlough

Project No. KC3210

Carried out for Galway County Council

Trial Pit

TP127A

Sheet 1 of 1

Trial Pit Log

Logged by DB Checked by ROR	Start 07/11/2003 End 07/11/2003	Equipment, Methods and Remarks Excavated using a JCB	Dimensions and Orientation Width 0.90 m Length 3.20 m A B C D 272 (Deg)	Ground Level +8.28 mOD Coordinates E 129058.83 National Grid N 227961.17

Samples and Tests

Depth	Type & No.	Date Records
0.10	D 1	
0.50	D 2	
0.50-1.00	B 3	
0.50-1.00	B 4	

Strata

Description	Depth, Level (Thickness)	Legend	Backfill/ Instrument
1 TOPSOIL: Brown slightly gravelly CLAY with many roots. Gravel is subangular to subrounded fine to coarse.	0.10 +8.18		
2 Stiff brown slightly sandy gravelly CLAY with many cobbles and boulders. Gravel is subangular to subrounded fine to coarse. Cobbles and boulders are subangular to subrounded of limestone. Boulders are up to 1100mm in length.	(1.10)		
3 Weathered LIMESTONE: Recovered as grey GRAVEL with many cobbles. Gravel is angular to subangular fine to coarse. Cobbles are angular to subangular of limestone.	1.20 +7.08		
	(0.30)		
EXPLORATORY HOLE ENDS AT 1.50 m	1.50 +6.78		

Depth	Type & No.	Records Date

Groundwater Entries

No.	Struck (m)	Post Strike (m)	Behaviour
None observed (see Key Sheet)			

Depth Related Remarks

From (m)	to (m)	
1.50		Trial pit terminated due to obstruction - presumed bedrock.

Stability Good

Shoring None

Weather

Notes: For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.

Scale 1:25

Project	N6 Galway City Outer Bypass Contract 2 Ground Investigation Gortatleva to Menlough
Project No.	KC3210
Carried out for	Galway County Council

Trial Pit

TP127B

Sheet 1 of 1

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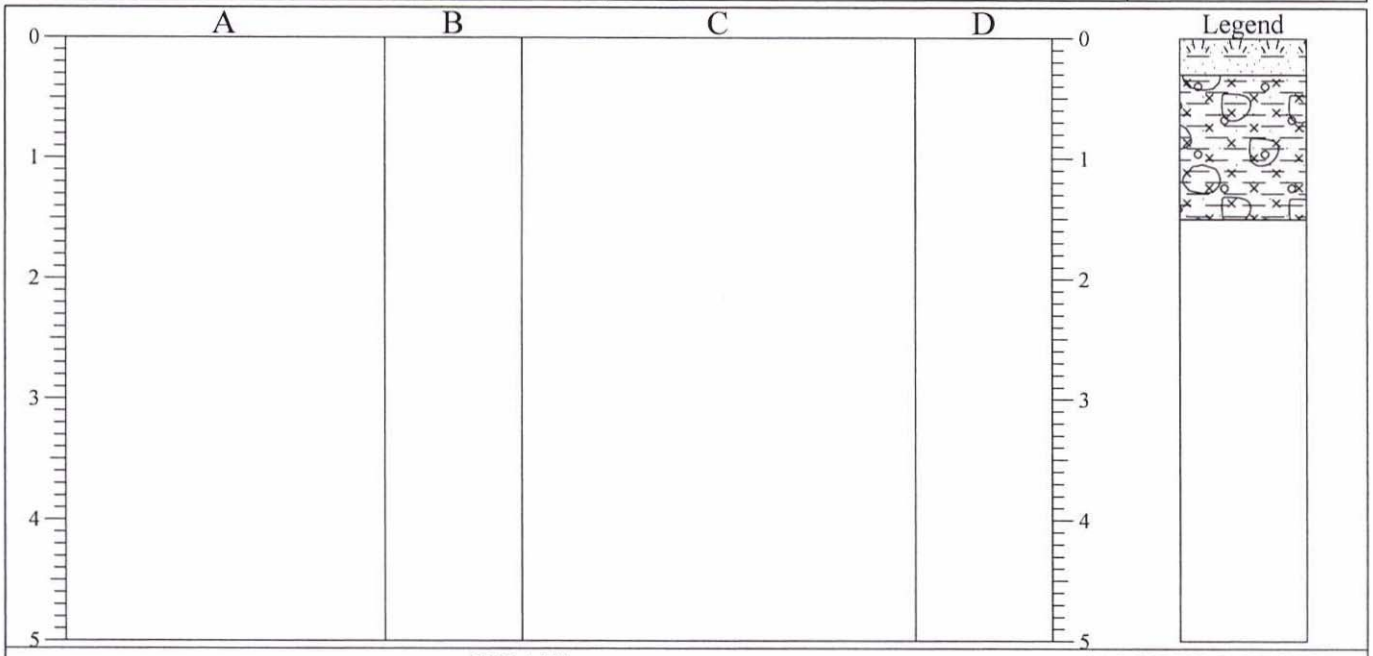
TRIAL PIT LOG

Project				TRIAL PIT No
N6 Galway City Outer Bypass				TP 958
Job No	Date 14-11-06 14-11-06	Ground Level (m) 6.53	Co-Ordinates () E 129,019.6 N 228,018.3	
Contractor IDL	GROUNDWATER STRIKES	Water strikes: 1st: 1.50m 2nd: 3rd:	Rose to (@ 20 min.): Sealed at:	Sheet 1 of 1

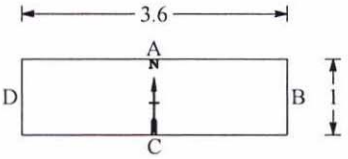


STRATA

SAMPLES & TESTS

Depth	No	DESCRIPTION	In Situ Tests	Water	Depth (m)	No	Remarks/Tests
0.00-0.30		TOPSOIL - soft dark brown peaty clay.					
0.30-1.50		Firm to stiff grey brown slightly sandy gravelly SILT/CLAY with some subangular to subrounded cobbles and subangular to tabular boulders of limestone.Boulders up to 1000mm long.Gravel is coarse.			0.50	B	
1.50		Refusal - possible rock or boulders.		▼	1.50	J	

Shoring/Support:
Stability:



GENERAL REMARKS

Pit stable during excavation.Slight inflow at 1.50m depth.

All dimensions in metres Scale 1:62.5	Client Galway County Council	Method/ Plant Used Hitachi ex120	Bit Design	Logged By DK

IDL AGS3 UK TP GALWAYBYPASSN6TPSLAB1.GPJ AGS 3_1.GDT 30/01/07

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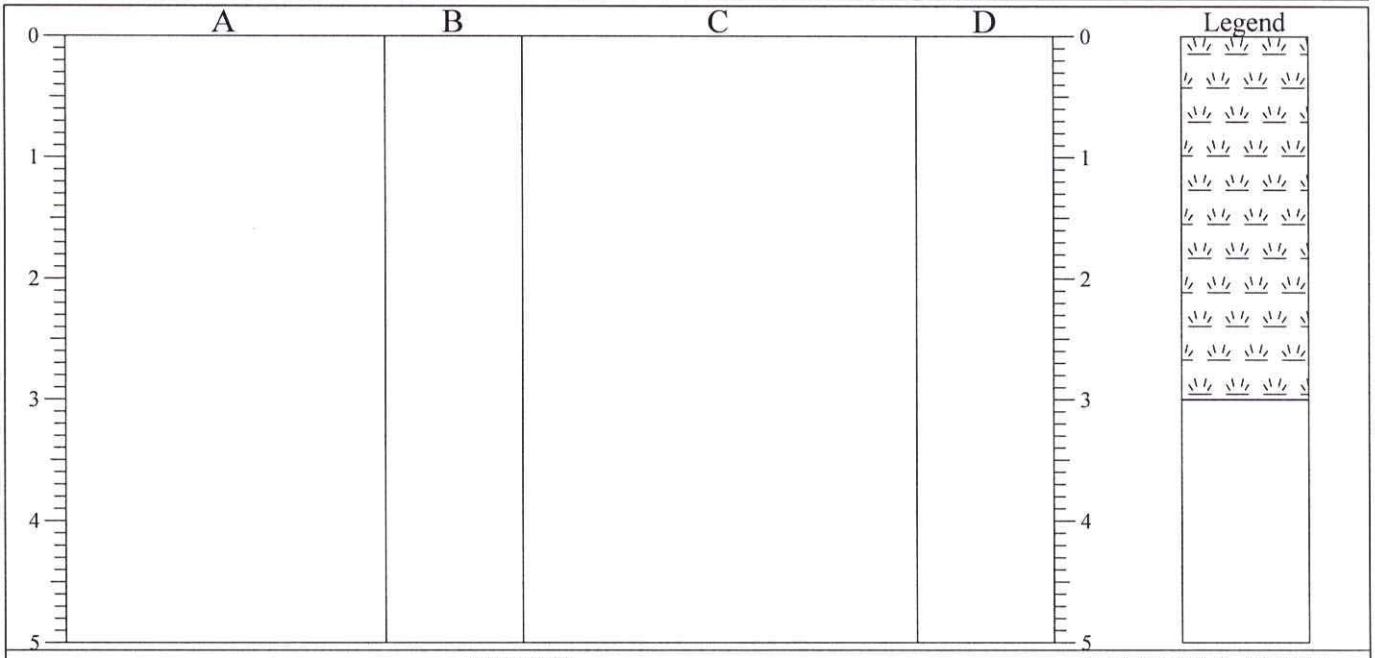
TRIAL PIT LOG

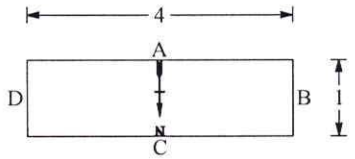
Project				TRIAL PIT No
N6 Galway City Outer Bypass				TP 1435
Job No	Date 14-11-06 14-11-06	Ground Level (m) 6.24	Co-Ordinates () E 129,001.7 N 227,958.5	
Contractor IDL	GROUNDWATER STRIKES	Water strikes: 1st: 2.50m 2nd: 3rd:	Rose to (@ 20 min.):	Sealed at: Sheet 1 of 1



STRATA / SAMPLES & TESTS

Depth	No	DESCRIPTION	In Situ Tests	Water	Depth (m)	No	Remarks/Tests
0.00-3.00		Soft light brown fibrous PEAT with many rootlets.			1.00	B	
					1.00	J	
					2.00	B	
				▼1	2.00	J	
3.00		Pit abandoned - constant collapse of pit sides.					

Shoring/Support:
Stability:



GENERAL REMARKS

Pit unstable during excavation.Collapsing of sides.Water seepage at 2.50m.

All dimensions in metres Scale 1:62.5	Client Galway County Council	Method/ Plant Used Hitachi ex120	Bit Design	Logged By DK

IDL AGS3 UK TP GALWAYBYPASSN6TPSLAB2.GPJ AGS 3_1.GDT 30/01/07

WINDOW SAMPLE RECORD

REPORT NUMBER 18963

CONTRACT	N6 Galway City Transport Project - Phase 3	**PROBE NO.**	**WS3/03**
		SHEET	Sheet 1 of 1
CO-ORDINATES	528,959.08 E 728,090.10 N	**DATE DRILLED**	08/04/2016
GROUND LEVEL (mOD)	7.63	**DATE LOGGED**	08/04/2016
CLIENT	Galway County Council	**SAMPLED BY**	CK
ENGINEER	ARUP	**LOGGED BY**	JL

Depth (m)	Geotechnical Description	Legend	Depth (m)	Elevation	Water Strike	Depth of Sample Run (m)	Recovery (%)	Blowcount	Vane Test (KPa)	Hand Penetrometer (KPa)
0.0	Soft brown sandy slightly gravelly CLAY with occasional rootlets. Sand is fine to medium. Gravel is subangular to subrounded fine to coarse of limestone.		0.25	7.38						
	Firm yellow brown sandy gravelly CLAY. Sand is fine to medium. Gravel is subangular to subrounded fine to coarse of limestone.		0.65	6.98						
	Angular COBBLE and BOULDER-sized fragments of strong grey fine grained limestone					0.00-1.00	80			
1.0	Final Depth 1.00m		1.00	6.63						
2.0										
3.0										
4.0										
5.0										

General Remarks

Installations

IGSL WS LOG 18963.GPJ IGSL.GDT 12/5/16

Appendix C

Hydrology Assessment for OPW Section 50 Approval

N6 Galway City Transport Project

Hydrology Assessment
For OPW Section 50 Approval
Of proposed watercourse culverts

Report No. HEL209001_v1.1

Galway County Council NRDO

July 2017

Hydro Environmental Ltd

No. 4 Caiseal Riada,
Clarinbridge,
Galway,
Ireland.

Tel/Fax: 091 796734

N6 Galway City Transport Project

Hydrology Assessment
For OPW Section 50 Approval
Of proposed watercourse culverts

on behalf of

Galway Co. Council NRDO

Job No.:	209001
Report No.:	HEL209001
Prepared by:	Anthony Cawley BE, M.EngSc, CEng MIEI
Approved by:	Anthony Cawley BE, M.EngSc, CEng MIEI
Date:	07th July 2017

Contents

1. INTRODUCTION

The proposed N6 Galway City Ring Road (GCRR) runs from the existing M6 at Coolagh on the east side of the city, passing to the north of the city and eventually joining with the R336 Coast Road, west of Bearna Village. The proposed route lies within hydrometric Areas 30 and 31. The proposed road intercepts a number of watercourses to the west of the River Corrib which will require culverting. To the east of the River Corrib due to the highly karst nature of the terrain there is a very sparse network of surface drainage channels and streams with rainwater generally infiltrating to ground through the porous karstified limestone bedrock rather than running off. As a consequence only one dry ditch was noted as being intercepted near the Coolagh lakes complex to the east of the River Corrib. Whereas, to the west of the River Corrib the bedrock and quaternary changes to a more impervious type resulting in a much higher density of surface water features with little ability for rainwater to infiltrate to groundwater. This gives rise to wetter conditions with peatlands and marshy areas common.

2. CULVERTS

Excluding the River Corrib there are a total of 16 stream culvert sites proposed, 15 culverts in the western section and 1 in the eastern section. The catchment areas of these watercourses is generally very small ranging from a number of hectares to the largest crossing of the Bearna River with a catchment area of 5.5 km^2. The majority of these watercourses flow in a general southerly direction discharging to Galway Bay with watercourses from the Bearna Stream east discharging to the Galway Bay SAC and watercourses west of the Bearna Stream to Galway Bay outside of the SAC.

The general guidelines provided by the OPW in respect to culverts and sizing of such have been applied to this study and generally as per the guidance whether required or not the minimum size exceeds 900 mm diameter pipe equivalent. This sizing avoids maintenance issues for small streams and drainage channel crossings and the obstruction of such by debris or silt build-up.

The catchment sizes involved are considered to represent very small catchments in terms of flood estimation and appropriate estimation methods for such small catchments have been used which include the IH 124 method and the recent OPW FSU method. As part of the ground survey for this road project a topographical survey of the drainage channels was carried out and this data is used in selection of the appropriate inverts both upstream and downstream and in assessing the capacity and hydraulic profile of the culvert under design flood conditions. Figure 1 presents a general location map of the proposed culverts labelled 1 to 17 (note reference 11 represents a channel long diversion of the Tonabrocky Stream). Figure 2 presents the estimated catchment areas for these culverts. It can be seen from Figure 2 that these catchments are generally to the north of the urban area and generally represent rural catchments.

Table 1 Proposed Culvert Details

Ref	N6 GCRR Ref	X	Y	Cat Area km^2	Qdesign cumec	Culvert type	Length m
1	**C00/01**	521324.58	723181.58	0.47	1.26	box 2.5m by 1.35	94.4
2	**C00/02**	521521.68	723446.01	0.324	0.89	1.2m diameter	46.1
3	**C01/01**	521983.64	723778.87	0.06	0.09	1.2m diameter	27.6
4	**C02/01a**	523086.54	724283.58	1.192	1.63	box 2.1m by 1.8m	36.66
5	**C02/01b**	523179.61	724198.04	1.192	1.63	box 2.5m by 2.5m	68.2
6	**C03/01**	523354.16	724244.47	0.08	0.12	box 2.5m by 1.2m	47.7
7	**C03/02**	523615.65	724390.32	0.15	0.23	0.9m diameter	15
8	**C03/03** **C03/04**	524066.24 & 524079.03	724705.91 & 724722.20	0.692	1.09	box 2.5m by 2.5m box 2.5m by 2.5m	53.4 51.7
9	**C04/01**	524201.84	724845.74	5.485	7.58	box 5m by 2.5	34.9
10	**C04/02**	524895.00	725274.42	1.652	2.13	box 3.1m by 2.5	80.4
11	**Channel Diversion**	524918.98 525096.21	725303.36 725475.14	1.517	1.97	1.5m base width, 1:2 side slopes and 1.5m depth	250m
12	**C06/01**	526420.87	726389.37	0.138	0.20	box 2.5m by 2.5m	64.8
13	**C07/02B**	526710.48	726684.02	0.209	0.30	1.2m diameter	14
14	**C07/02A**	526698.49	726637.16	0.209	0.30	box 2.5m by 2.5m	82.1
15	**C08/01**	527663.93	727211.93	0.159	0.23	1.2m diameter	82.5
16	**C10/02**	529687.79	728412.26	0.629	0.19	1.2m diameter	41.8
17	**C07/01a**	527147.52	726262.40	0.38	0.55	1.2m diameter	37.2

Table 2 Invert Levels for Proposed Culverts

Ref	N6 GCRR Ref	Buried m	eff ht m	u/s invert mOD	d/s invert mOD	u/s soffit mOD	d/s soffit mOD
1	**C00/01**	0.30	1.05	32.99	30.9	34.34	32.25
2	**C00/02**	0.15	1.05	39.62	37.94	40.82	39.14
3	**C01/01**	0.15	1.05	48	46.82	49.20	48.02
4	**C02/01a**	0.30	1.5	39.73	39.04	41.53	40.84
5	**C02/01b**	0.30	2.2	38.48	37.25	40.98	39.75
6	**C03/01**	0.30	0.9	38.63	37.44	39.83	38.64
7	**C03/02**	0.00	0.9	36.83	36.58	37.73	37.48
8	**C03/03**	0.30	2.2	18.93	18.51	21.43	21.01
	C03/04	0.30	2.2	18.92	18.62	21.32	21.12
9	**C04/01**	0.30	2.2	21.17	20.69	23.67	23.19
10	**C04/02**	0.30	2.2	44.56	42.32	47.06	44.82
11	**Diversion**			50.1	45.9		
12	**C06/01**	0.30	2.2	53.6	51.69	56.1	54.19
13	**C07/02B**	0.15	1.05	57.84	57.65	59.04	58.85
14	**C07/02A**	0.30	2.2	56.88	55.79	59.38	58.29
15	**C08/01**	0.00	1.2	32.5	29.035	33.7	30.235
16	**C10/02**	0.15	1.05	11.58	11.3	12.78	12.5
17	**C07/01a**	0.15	1.05	35.89	35.57	37.09	36.77

Figure 1 Location Map of Culverts (note reference 11 represents a channel diversion to the northwest of alignment to achieve a single stream crossing at reference 10)

Figure 2 Contributing catchment area of culverts

3. ROAD DRAINAGE OUTFALLS

The proposed road drainage has been developed generally in accordance with the NRA Design Manual for Roads and Bridges and in particular in accordance with the NRA Addendum to HD33/06 Surface and Sub-Surface Drainage Systems for Highways.

The principal objectives for national road drainage systems include: -

- To ensure the speedy removal of surface water in order to provide safe driving conditions;
- To provide effective sub-surface drainage to maximise longevity of the road pavement and associated earthworks;
- To minimise the impact of the runoff on the receiving environment; and
- To maintain, as far as possible, the road drainage to the outfall separate from other catchment drainage (including land drains) in the interest of pollution control.

The proposed drainage design for the project incorporates Sustainable Drainage Systems (SuDS) which are aimed at the provision of volumetric and quality control of storm water runoff. The proposal includes the provision of a series of constructed linear wetlands and attenuation basins at the outfall locations prior to discharge to the receiving environment. The proposed attenuation for all drainage networks has been designed to achieve estimated Greenfield flood run-off rates up to the 100 year return period event.

The Flood Study Report (NERC 1975) Soil Runoff Classification is type 2 having a Soil Factor of 0.3 or 30% standard percentage runoff rate for the granite areas west of the Corrib and soil type I for the Karst limestone area east of the Corrib. The SAAR (seasonal annual average rainfall) is typically 1200 to 1300 mm increasing westward. This represents an annual average flood run-off rate of 0.8 l/s per ha, 3.6 l/s per ha and 6.7l/s per ha at Soil types 1, 2 and 3 respectively. Attenuation storage is provided to achieve these greenfield runoff rates up to the 100 year return period storm event. These will be maintained systems and therefore are designed not to increase peak flood flow conditions in the receiving rivers and streams.

The proposed road drainage outfalls discharge to watercourses in the vicinity of culvert references 1, 2, 3, 4/5, 8, 9, 10, 12, 13, 14, 15 and 17. A number of these watercourses are very small and of low capacity and therefore stormwater management in terms of attenuation and control of road drainage discharges is critical to protecting downstream reaches from additional flooding. A summary of the relevant road outfalls are presented below in Table 3, all of which will be attenuated to greenfield flood runoff rates.

Table 3 Road Outfall Details for Proposed Road

Drainage Network Outfall Reference	Catchment Area (ha)	Receiving Water and culvert location	Greenfield Discharge Rate, Qbar (m3/s)
S2	0.55	discharges Sruthán na Líbeirtí d/s of culvert 1	0.002
S3	2.31	discharges Sruthán na Líbeirtí d/s of culvert 2 and u/s of culvert 1	0.0083
S4A	0.96	discharges to Trusky trib u/s of culvert 3	0.0035
S5A	2.45	discharges to Trusky stream upstream of culvert ref 4 and 5	0.0088
S7A	0.3	discharges to a minor drain d/s of culvert 6	0.0011
S7B	2.94	Discharges to Bearna Stream tributary d/s of culvert 8	0.0106
S8	0.42	discharges to Bearna Stream tributary downstream of 8	0.0015
S9	1.75	discharges to Bearna Stream upstream of 9	0.0063
S10	2.19	discharges to Tonabrooky Stream downstream of culvert 10	0.0079
S12	3.15	Discharges to drain downstream of 12	0.0113
S13	0.91	Discharges to drain upstream of culvert 13 and 14 culverts	0.0033
S14A	5.66	Discharges to culvert downstream of culvert 15	0.0203
S16A	4.16	Discharges to storm sewer downstream of culvert 17	0.0149

4. DESIGN FLOWS

Description

The Drainage Catchments for the proposed culvert crossings of the N6 Galway City Ring Road are very small at 0.06 to 5.49 km^2 (Berna Stream). Consequently none of these catchments are gauged for the purpose of flood estimation. Of the 17 catchments the following culvert references: 1 and 2 on the Scruthán na Libeirti Stream, 3 and 4 on the Trusky Stream (method includes Lough Inch and catchment within Trusky catchment which is incorrect), 8 and 9 on the Bearna stream, 10 on the Tonabrocky stream and 17 on the Rahoon stream are represented in the new Flood Study update FSU method on the OPW web portal site. The streams and the catchment areas and node estimation points are presented in Figures 4 to 8.

The FSU method uses as an index flood the Qmed (2 year return period flood or the median of the annual maxima series) value calculated by catchment descriptors and adjusted where an appropriate gauged site is available. The QMED estimate is multiplied up by the computed flood growth factor.

The other common method for flood estimation in small on gauged catchments is the use of the IH 124 equation using the SAAR, SOIL and catchment area parameters, obtained from the original FSR report or from more recent sources of meteorological information catchment mapping and site inspections to determine the run-off characteristics.

These methods are presented in the following sub-sections

IH-124 Flood Estimation Method

The mean annual maximum flood flow (Qbar) for each of the watercourse crossings listed have been estimated using The **Institute of Hydrology 3-variable equation** as follows:

$$Q_{BAR} = 0.00108\ AREA^{0.89} SAAR^{1.17} SOIL^{2.17}$$

where

Area	Catchment area in km^2
SOIL	Typical proportion of rain contributing to flood runoff, based on mapped soil types Type 2 (SOIL = 0.3)
SAAR	long term mean annual rainfall amount for the catchment,
Qbar	Calculated mean annual maximum flood in cumec.
Urban Factor (UF)	An index based on the % of the area covered by Urban Development
Standard Factorial Error (FE)	Factorial error from the regression equation: 1.65 for the IH-124 equation
CC	Climate Change Allowance +20%

The above method is combined with the Flood Study National Growth Curve to determine the 100year flood rate and the factorial error is included.

Table 4 Design Flow Estimates using IH124 Equation at Culvert Crossings

Culvert Ref	Area km2	SAAR mm	SOIL	Qbar cumec	Q100 cumec	Q100*FE*CC cumec
1	0.47	1280	0.3	0.17	0.35	0.69
2	0.324	1280	0.3	0.12	0.24	0.48
3	0.06	1280	0.3	0.02	0.04	0.09
4	1.188	1301	0.3	0.41	0.82	1.63
5	1.192	1301	0.3	0.41	0.82	1.63
6	0.08	1300	0.3	0.03	0.06	0.12
7	0.15	1300	0.3	0.06	0.11	0.23
8	0.692	1310	0.3	0.25	0.51	1.01
9	5.485	1310	0.3	1.60	3.23	6.40
10	1.652	1253	0.3	0.52	1.05	2.09
11	1.517	1253	0.3	0.48	0.98	1.93
12	0.138	1251	0.3	0.05	0.10	0.20
13	0.209	1249	0.3	0.07	0.15	0.30
14	0.209	1249	0.3	0.07	0.15	0.30
15	0.159	1249	0.3	0.06	0.12	0.23
16	0.629	1235	0.15	0.05	0.10	0.19
17	0.380	1249	0.3	0.14	0.28	0.55

CC = 1.2 and FE = 1.65 and Growth factor X100 = Q100/QBAR = 2.04

The FSR national Growth factor for the 100year flood event is 1.96 and the FSU pooling group using the most hydrologically similar catchments producing 500station years gives a growth factor of 2.04. The higher growth factor is used in the 100year flood flow estimation.

Flood Study Update (FSU) Method

The new (2015) OPW Flood Study Update method uses physical catchment descriptors (PCD's) and pivotal site adjustment to determine the ungauged index flood magnitude (Qmed (Q2)) at nearest nodal point to the culvert location. The principal physical descriptors are AREA, BFISOIL, SAAR, FARL, DRAIND, S1085, ARTDRAIN2, URBEXT. The pivotal site is the FSU gauged flow station that is most relevant to the particular estimation location. For this particular application given the relatively small catchment areas involved the most hydrologically similar gauged catchment was a 10km2 catchment to the north of Dundalk. Given its remoteness to the subject area it was rejects and the FSU Qmed estimates were used without adjustment.

The FSU method used to determine the index flood (Qmed – median flood flow) is based on detailed catchment descriptors accessed via a GIS system on the FSU Web Portal Site and provides an option to use a gauged site as a donor / pivotable site to adjust the Qmed estimate as presented in the equations below.

$$Qmed\ (rural) = 1.237 \times 10^{-5} AREA^{0.937} BFIsoils^{-0.922} SAAR^{1.306} FARL^{2.217} DRAIND^{0.341} S1085^{-0.185} (1 + ARTDRAIN2)^{0.408}$$

The urban Adjustment to the rural Qmed is defined as follows:

$$UAF = (1 + URBEXT)^{1.482}$$

$$Qmed\ (urban) = Qmed\ (rural) \times UAF$$

Adjusted QMED estimate using Donor/Analogue Catchment

$$Qmed^s = Qmed^d \left(\frac{Qmed^s (model\ rural\ )}{Qmed^d (model\ rural\ )} \right)$$

The FSU method determines the Flood growth curve through a pooled analysis of hydrologically similar catchments (Eulidean distance using the above PCD's and distance between catchment centroids). Multiplying the QMed estimate by the flood growth curve produced the return period peak flood flow magnitudes. The FSU Flood Hydrograph width method was also used to generate the return period design flood hydrographs at the various nodal points along the study reach. Figures 4 to 8 shows the FSU catchment characteristics and the unadjusted Q_{med} values at different nodal locations within the respective catchments.

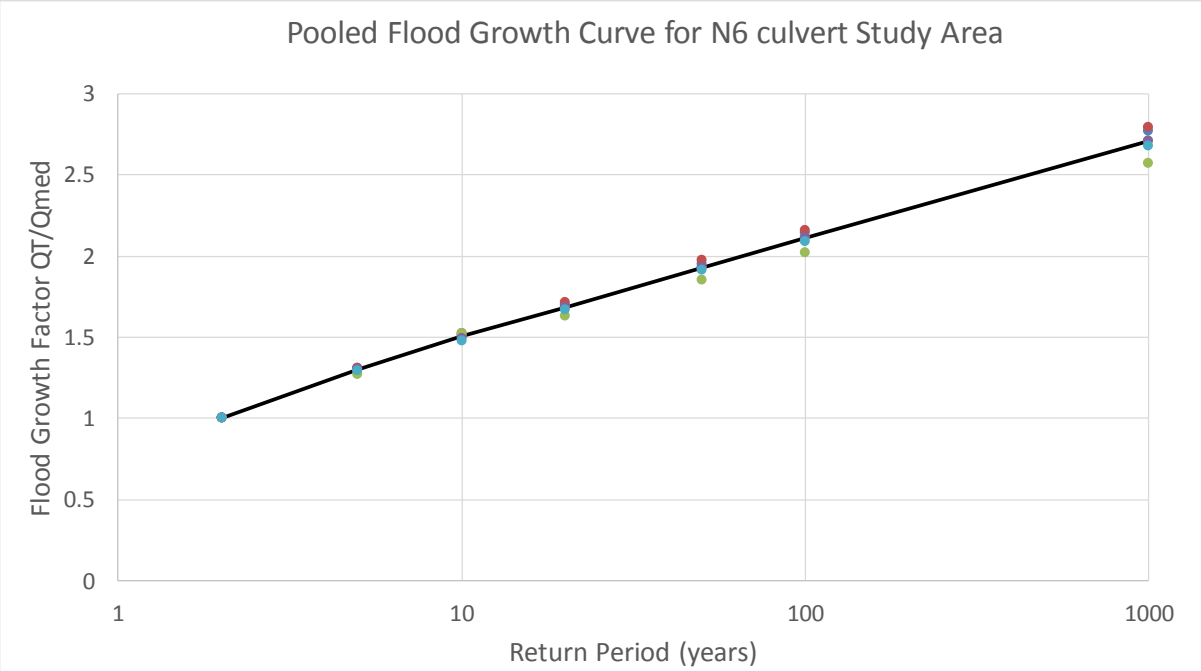


Figure 3 Pooled flood Growth curves derived for the various estimation points with the average for the study area shown as a solid line.

The FSU hydrological estimation nodal points are not available for every stream and particularly for small drain like sub-catchments. Also given the relatively small scale of the

catchments the available estimation point did not coincide with the required location (refer to Figure 4 to 8) and extrapolation was necessary to provide an estimate at the required culvert location.

Table 5 Design Flow Estimates using FSU Method at Culvert Crossings

Culvert Ref	Area km2	Qmed cumec	Q100 cumec	Q100*FE*CC cumec
1	0.47	0.36	0.76	1.26
2	0.324	0.26	0.54	0.89
3	0.06			
4	1.188	0.36	0.77	1.27
5	1.192	0.36	0.77	1.27
6	0.08			
7	0.15			
8	0.692	0.31	0.66	1.09
9	5.485	2.17	4.58	7.58
10	1.652	0.61	1.29	2.13
11	1.517	0.56	1.19	1.97
12	0.138			
13	0.209			
14	0.209			
15	0.159			
16	0.629			
17	0.38	0.11	0.23	0.39

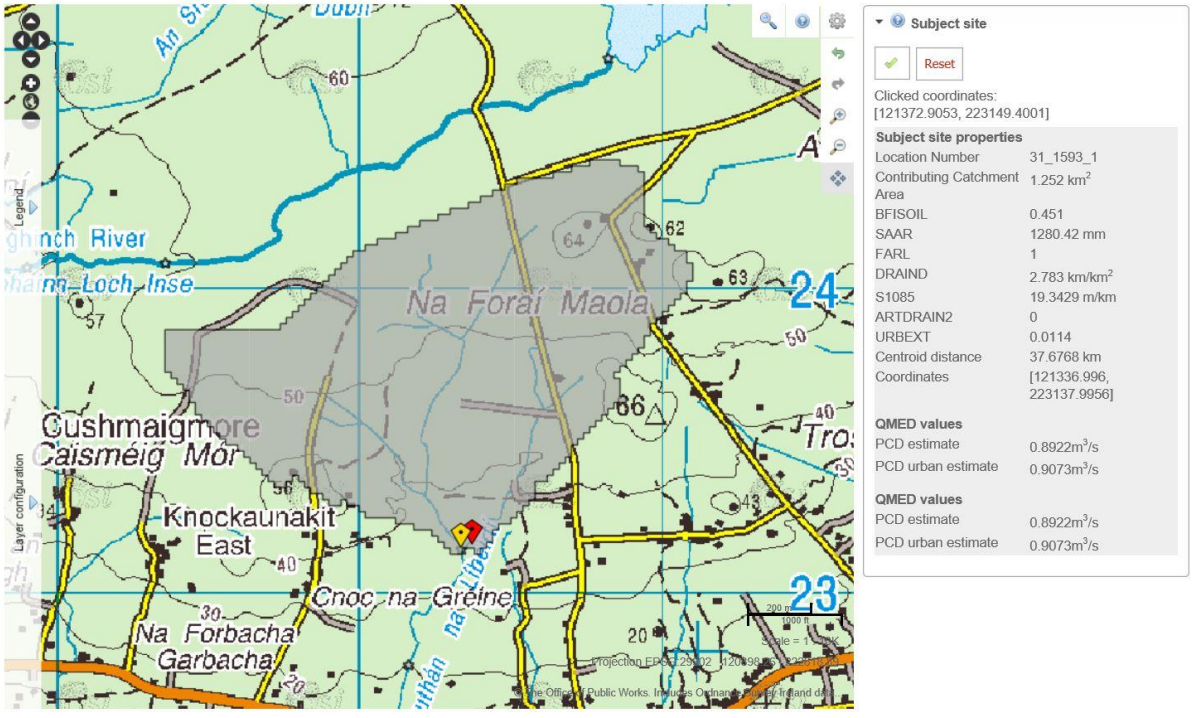


Figure 4 Estimation point on Sruthán na Líbeirtí nearest to culvert crossings

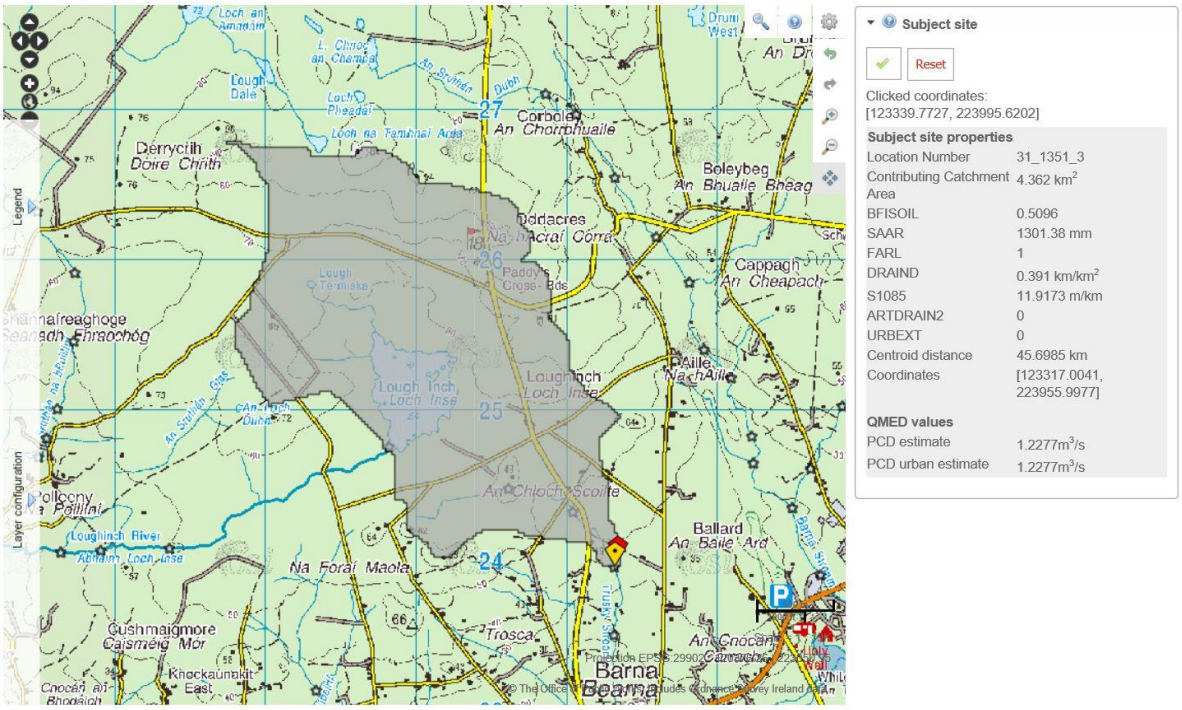


Figure 5 Estimation point on Trusky Stream nearest to culvert crossings (note error in catchment extent which includes the Lough Inch drainage area

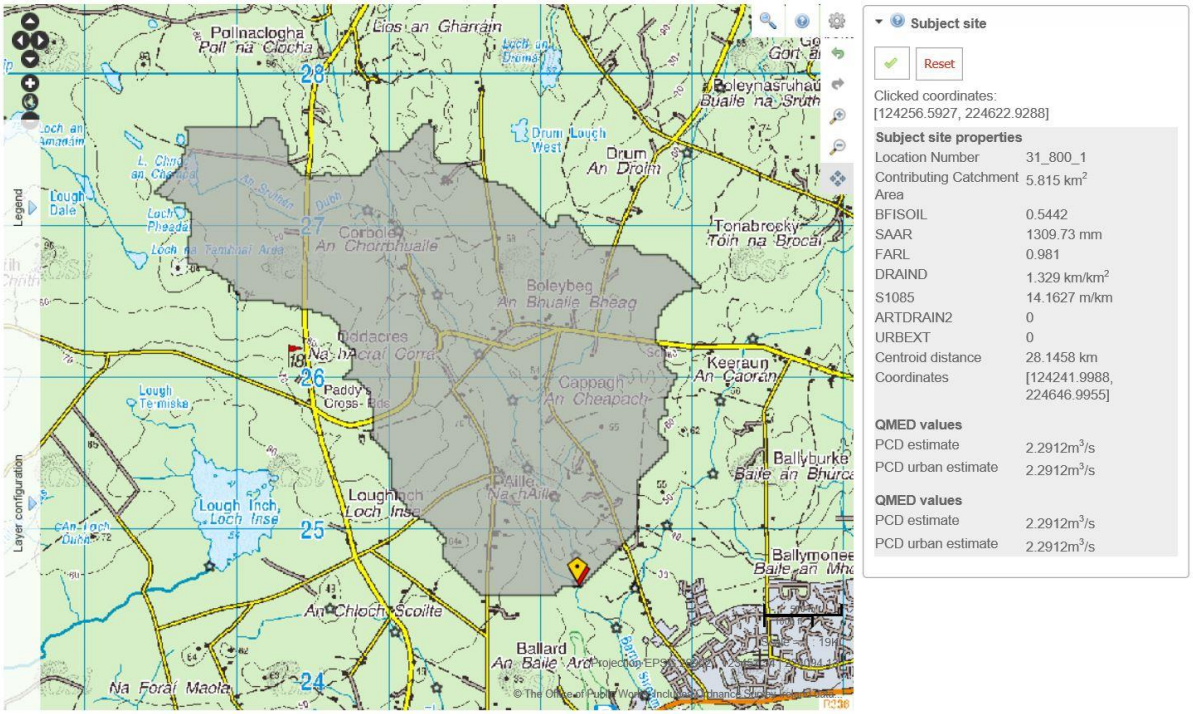


Figure 6 Estimation point on the Bearna Stream nearest to culvert crossings

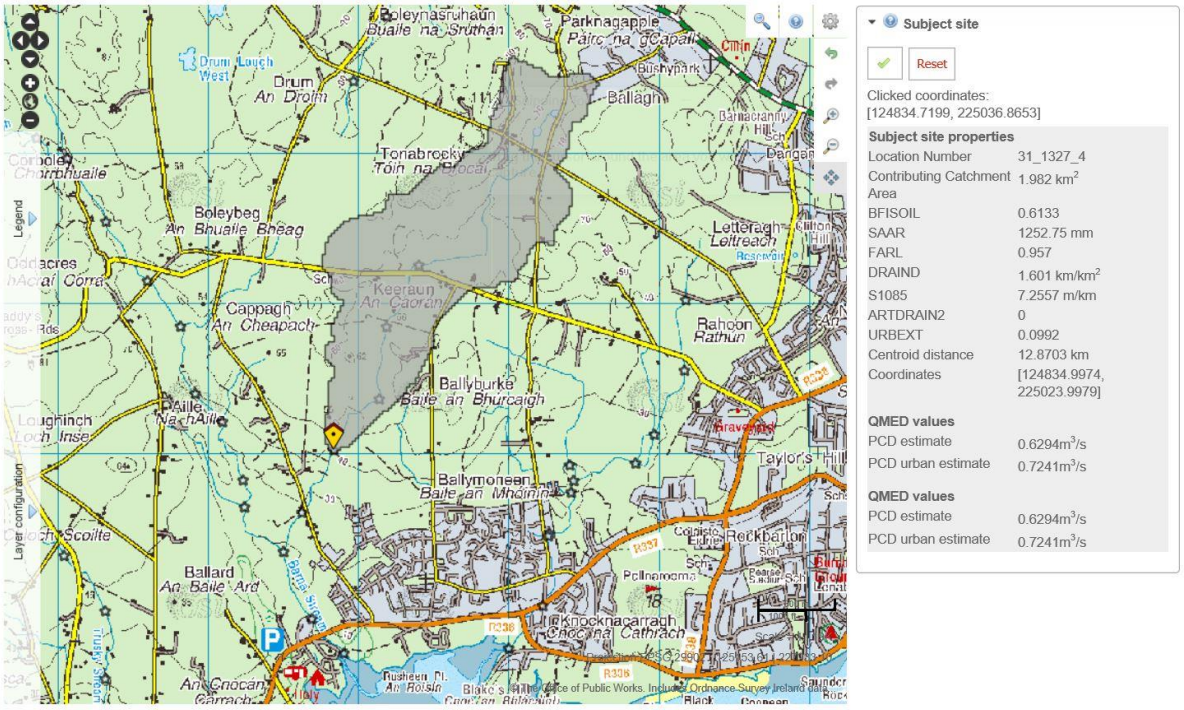


Figure 7 Estimation point on the Tonabrocky Stream nearest to culvert crossings

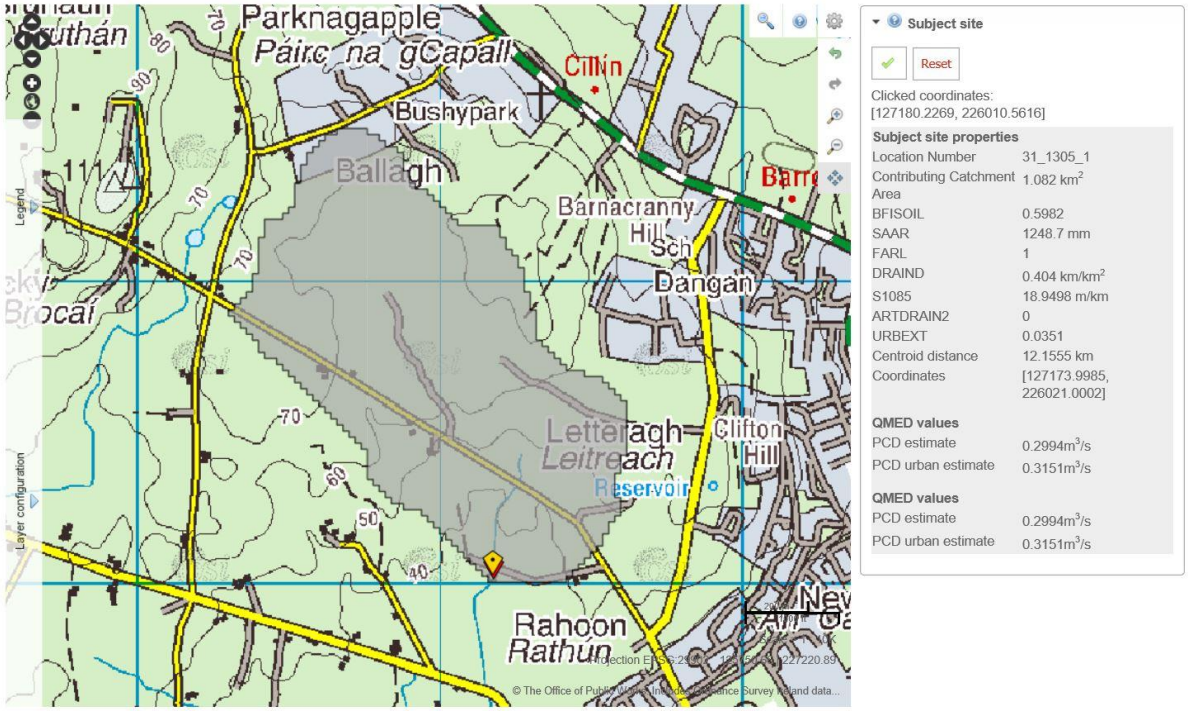


Figure 8 Estimation point on the Rahoon/Knocknacarra Stream nearest to culvert crossings

Recommended Design Flow

The maximum estimated flow magnitude from the various methods was selected as the design flow for sizing the proposed culvert and determining the flood levels at the culvert site and the resultant flood risk. The design flow includes the factorial error of the method and the climate change allowance and is presented below in Table 6

Table 6 Recommended Design Flow Magnitude for Proposed culverts

		IH 124 Equation		FSU CD Method		
Culvert Ref	**Area km2**	**Q100 cumec**	**Q100*FE*CC cumec**	**Q100 cumec**	**Q100*FE*CC cumec**	**Design Q100 cumec**
1	0.47	0.35	0.69	0.76	1.26	1.26
2	0.324	0.24	0.48	0.54	0.89	0.89
3	0.06	0.04	0.09			0.09
4	1.188	0.82	1.63	0.77	1.27	1.63
5	1.192	0.82	1.63	0.77	1.27	1.63
6	0.08	0.06	0.12			0.12
7	0.15	0.11	0.23			0.23
8	0.692	0.51	1.01	0.66	1.09	1.09
9	5.485	3.23	6.40	4.58	7.58	7.58
10	1.652	1.05	2.09	1.29	2.13	2.13
11	1.517	0.98	1.93	1.19	1.97	1.97
12	0.138	0.10	0.20			0.20
13	0.209	0.15	0.30			0.30
14	0.209	0.15	0.30			0.30
15	0.159	0.12	0.23			0.23
16	0.629	0.10	0.19			0.19
17	0.380	0.28	0.55	0.23	0.39	0.55

5. HYDRAULIC MODEL ANALYSIS

The proposed culverts were hydraulically assessed in terms of flow capacity and resultant upstream and downstream flood levels for the design flow condition using the 1-D river network hydraulic model HEC-RAS. Specific topographical channel surveys were conducted to provide the geometry information for the modelling exercise. Other sources of topographical information including lidar was also used in defining the geometry of the channel and floodplain area.

All of the proposed stream crossings are considered to have small contributing catchment areas and therefore involve relatively small flood flows. None of these streams were assessed by the OPW as part of the Galway CFRAM study.

The design flood flow considered for each of the culverts is the estimated 100year return period flood flow multiplied by the factorial error of the estimation method and further multiplied by a climate change allowance factor of 1.2.

The channel roughness of the existing channels was specified as 0.1 Manning's n representing high roughness as they are generally unmaintained. The roughness of the proposed culverts as modelled using a roughness of 0.025 for the near bed section and 0.015 for the upper top section of the culvert.

A summary of the results for each of the culvert references is presented below in Table 7 and presents the computed upstream and downstream flood level relative to Malin Head datum.

Table 7 Estimated head and tailwater design flood levels for proposed N6 culverts

Culvert	N6 GCRR Ref	Design Q100	u/s invert	d/s invert	u/s Flood Level	d/s Flood Level	u/s soffit	d/s soffit
Ref		cumec	mOD	mOD	mOD	mOD	mOD	mOD
1	C00/01	1.26	32.99	30.9	33.68	32.10	34.34	32.25
2	C00/02	0.89	39.62	37.94	40.20	39.09	40.82	39.14
3	C01/01	0.09	48	46.82	48.34	47.78	49.20	48.02
4	C02/01a	1.63	39.73	39.04	40.88	40.08	41.53	40.84
5	C02/01b	1.63	38.48	37.25	39.3	38.18	40.98	39.75
6	C03/01	0.12	38.63	37.44	39.01	37.94	39.83	38.64
7	C03/02	0.23	36.83	36.58	37.26	37.29	37.73	37.48
8	C03/03	1.09	18.93	18.51	19.65	19.65	21.43	21.01
	C03/04	1.09	18.82	18.62	19.67	19.67	21.32	21.12
9	C04/01	7.58	21.17	20.69	22.51	22.16	23.67	23.19
10	C04/02	2.13	44.56	42.32	45.33	43.0	47.06	44.82
11*	Diversion	1.97	50.1	45.9	51.00	46.72		
12	C06/01	0.20	53.6	51.69	54.04	52.16	56.1	54.19
13	C07/02B	0.30	57.84	57.65	58.71	58.71	59.04	58.85
14	C07/02A	0.30	56.88	55.79	57.84	57.65	59.38	58.29
15	C08/01	0.23	32.5	29.035	33.74	29.435	33.7	30.235
16	C10/02	0.19	11.58	11.3	11.95	11.62	12.78	12.5
17	C07/01a	0.55	35.89	35.57	38.58	38.56	37.09	36.77

11* is a 250m channel realignment / diversion

Culvert 1 crosses the Sruthán na Líbeirtí stream in the townland of Cnoc na Gréine 2km west of Bearna Village. This section of stream channel is moderately steep and the design flow through the culvert will be supercritical. For fishery friendly design some baffles and a low flow channel may be required within the culvert.

Culvert 2 crosses the Sruthán na Líbeirtí stream upstream of Culvert 1 in the townland of Cnoc na Gréine 2km west of Bearna Village. This section of stream channel is moderately steep and the design flow through the culvert will be supercritical. For fishery friendly design some baffles and a low flow channel within the culvert may be required.

Culvert 3 is a very minor drain of 6ha catchment area and at 1200mm diameter culvert there is ample capacity available for this drain.

Culvert 4 and 5 cross the Trusky Stream in the townland of An Chloch Scoilte towards the upstream end of the catchment draining peaty lands to the east and south-east of Lough Inch. These culverts are aligned in series with culvert 5 located downstream of culvert 4. Two large box culverts are proposed, 2.1 m x 1.8 m and 2.5 m x 2.5 m respectively. The large culvert sizes is to facilitate Bat passage as opposed to flow conveyance or fishery requirements.

Culverts 6 and 7 in the townland of An Chloch Scoilte are located on minor drains with small contributing catchment and the proposed culvert sizes of 1200mm and 900mm diameter are generous and will not impede drainage or impact flooding.

Culvert 8 crosses the tributary branch of the Bearna Stream in the townland of Aille. At this location there are 2 branches both of which are to be culverted with a box section 2.5 m x 2.5 m and buried 0.3 m. This proposed sizing is very generous and will not impede drainage or impact locally on flooding.

Culvert 9 crosses the mainline channel of the Bearna Stream in the townland of Cappagh. This stream along its downstream reach has been identified as a fishery stream. A generous culvert size is proposed for this stream which is 5 m wide by 2.5 m in height. Mammal passage ledges are proposed on both sides of this culvert which effectively reduces the open width to 4m. The survey indicates a moderately steep channel and the hydraulic analysis shows supercritical flow through the culvert barrel. This culvert represents the biggest stream crossing the road scheme aside from the River Corrib bridge crossing. Given the fishery interest for this stream a low flow channel maybe provided within the culvert so as to avoid shallow depths and steep gradient which represents a barrier to fish passage.

Culvert 10 crosses the Tonabrocky Stream in the townland of Ballyburke. The survey shows this to be a narrow steep channel often cascading and jumping between critical and supercritical flow. A box culvert 3.1 m wide by 2.5 m high with mammal ledges along both sides of the culvert reducing the open width to 2.1 m. The hydraulic analysis shows flow to be at critical and supercritical resulting in shallow depths and high velocities. Through the culvert the flow goes supercritical due to the steep gradient.

Upstream a proposed diversion channel connects to this culvert. Culvert reference 11 is a diversion channel of the Tonabrocky Stream along the north edge of the road, which avoids the requirement of a second culvert crossing and facilitates the proposed road alignment which is on top of this stream channel for much of its length along this section. The new channel will have a trapezoidal shape of 1.5m base width, 1.5m deep and side slopes of 1 in 2. The longitudinal gradient for this diverted section of channel will complement the existing channel at a fall of 1 in 60. The hydraulic analysis shows that at the design flow moderately shallow depths and high velocities occur in this channel. To protect the channel a number of stone

weirs in a cascade like fashion should be constructed at various intervals along the channel so as to produce pools and shoals.

Culvert 12 conveys a moderately small drainage catchment, the provision of a 2.5 m x 2.5m box culvert is generously sized for this purpose and will not impede flow or impact on flooding as a result.

It should be noted that culvert Reference 17 discharges to a 450mm storm pipe at the edge of the existing Rahoon Road which connects to the local authority 600mm diameter storm sewer that runs southeast along the Rahoon Road. At the estimated design flow of 0.55cumec this 450mm culvert acts as a serious constriction causing the proposed 1200mm culvert under the proposed link Road to be fully submerged.

Culvert Reference 13 and 14 represent two culverts in series and a small channel diversion. The diversion including channel and culverts is almost 270m long and connects to the drain that discharges to culvert 17. The proposed channel is trapezoidal of 1m base width and side slopes of 1 in 2.

Culvert reference 15 is the culverting of a small minor stream/drain under the proposed road alignment at Barnacranny Hill, Bushypark. This stream / drain is very minor and is already culverted under the Ard an Locha estate road and under the N59 Moycullen Road in a 600mm diameter pipe culvert. The proposal is to increase the size of the culvert beneath the road structure from the existing 600mm storm line to a 1200mm. There is no capacity issue with the existing 600mm diameter culvert as the design flow is relatively small and the vailable hydraulic gradient large at a fall of 1 in 31 through the housing estate and across the N59.

Culvert 16 is located to the east of the River Corrib and represents the culverting of a generally dry ditch. The contributing catchment area is off the steep limestone slopes to the north-east of Coolagh. The run-off coefficient for this area is characterised as very low and therefore the design flow to be catered for is small. A 1200 mm diameter culvert is proposed which will not impede flows or impact on flooding.

6. CONCLUSIONS

The proposed culvert sizes are very generous in respect to the provision of effective open area and flow conveyance and do not for any of the 16 sites represent a constriction to flow. In a lot of cases they have been upsized further to cater for mammal passage with ledges and for bat passage. Where ledges have been included the width of the ledge included is 0.5m on both internal box culvert faces and were modelled hydraulically as being 1m narrower than the width specified (i.e. culvert ref 9 (Bearna Stream crossing) was modelled as 4m wide as opposed to 5m wide). Generally the minimum size provided for this scheme is a 1200mm diameter pipe which is buried by 150mm (except for culvert reference 7 which has a 900mm diameter). All of the structures have inlet and outlet wing and head wall structures. Potential for debris blockage is small given the nature of catchments involved and generous dimensions provided.

The hillside nature of the drainage catchments involved will in flood conditions result in supercritical flow occurring in a lot of cases and therefore where the stream bed is not sitting onto bedrock some armouring / channel protection may be required. Therefore all diversion channels and transitions to and from culverts will be designed and armoured so as to protect against scouring.

Appendix 1 OPW Section 50 Culvert applications

Appendix 2 Section 50 Supporting Drawings of Culverts