Appendix A.10.5

Aquifer Tests Report

A.10.5 Aquifer Tests Report

Galway County Council

N6 Galway City Ring Road

Aquifer Test Reports

EIAR Appendix A.10.5.docx

Issue 2 | 28 March 2025

Job number 233985-00

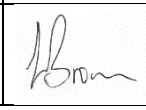
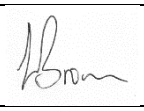
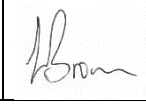
Ove Arup & Partners Ireland Ltd

Arup
Corporate House
City East Business Park
Ballybrit
Galway
H91 K5YD
Ireland
www.arup.com

ARUP

Document Verification

ARUP

Job title		N6 Galway City Ring Road			**Job number** 233985-00
Document title		Aquifer Test Reports			**File reference** GCOB-4.04.03_30.9.10_A.10.5
Document ref		EIAR Appendix A.10.5.docx			
Revision	**Date**	**Filename**	GCOB-04.04-019_A.10.5, Appendix A.10.5_I1.docx		
Issue 1	26 Jul 2018	**Description**	Issue 1 Issue for 2018 EIAR		
			Prepared by	Checked by	Approved by
		Name	Alison Orr	Les Brown	Les Brown
		Signature			
Issue 2	28 Mar 2025	**Filename**	Appendix A.10.5_I2.docx		
		Description	Issue 2 Updated for the 2025 RFI Response		
			Prepared by	Checked by	Approved by
		Name	Alison Orr	Les Brown	Gerry Baker
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
				Issue Document Verification with Document	✓

Contents

Appendices

1 Aquifer Testing

This report is an updated version of the Appendix A.10.5 produced in 2018 to inform the hydrogeology assessment as part of the response to the request by ABP for further information in December 2023 where they requested Galway County Council to *"Update the Environmental Impact Assessment Report"* (EIAR) submitted to An Bord Pleanála in October 2018 as part of the application for approval of the proposed N6 GCRR pursuant to Section 51 of the Roads Act 1993 (as amended). This Appendix has been updated to incorporate additional data that has been collected during the intervening period since the 2020 Oral Hearing.

Aquifer testing undertaken as part of the N6 GCRR ground investigations comprises of:

- Two pumping tests (PW01 and TW101 (Galway Racecourse))
- 15 (No.) variable head tests
- Eight packer tests (BH04 and BH05)

1.1 Pumping tests

1.1.1 PW01 (Undertaken in 2016)

A pumping test was undertaken in March 2016 on PW01, which lies immediately east of the existing N6 junction with the Monivea Road. The design of the pumping test comprised of a step test followed by a constant head test. During the step test the recharge rate to the well proved to be too low to complete either the step test or the constant rate test.

The recovery of the groundwater level in PW01 was recorded for two weeks following the aborted test. Analysis of the residual drawdown data by this recovery method estimates a permeability value of $2x10^{-8}$m/s. Further details of this pumping test is contained in **Appendix A.10.5.1**.

1.1.2 TW101 (Undertaken in 2024)

A trial well was drilled at the Galway Racecourse to identify a suitable replacement well for the irrigation water supply well that is due to be decommissioned because of the development of the Racecourse tunnel. The borehole was drilled to a total depth of 220m encountering a 5m deep cavity at the base of the hole which yielded significant volumes of water. All ground investigation data from the Galway Racecourse is presented in EIAR Appendix 9.1d.

A step test and constant rate test were performed in August 2024. The trial well liner limited the pump size to 100mm diameter and this, in combination with the deep static water level (44mbgl) meant the maximum pumping rate achievable was $18m^3$/hr.

The constant rate test was completed at 18m^3/hr with a maximum drawdown of only 38cm recorded at the conclusion of the test as the maximum pumping rate. **Figure 1** presents the manually recorded data for water level drawdown and pumping rate for the constant rates test in TW101. The generator powering the pump malfunctioned during the first night of the test, as shown in Figure 1. The total test duration was extended to account for this. The water level in the well recovered early in the morning of 15/08/2024 following heavy rainfall. The logger data during the recovery period shows a faint tidal signal and a background trend of reducing groundwater level.

This indicates a massive fracture transmissivity for the main conduit, however the bulk permeability taking the entire saturated thickness into account (176m) is estimated as 6.9x10^{-5}m/s.

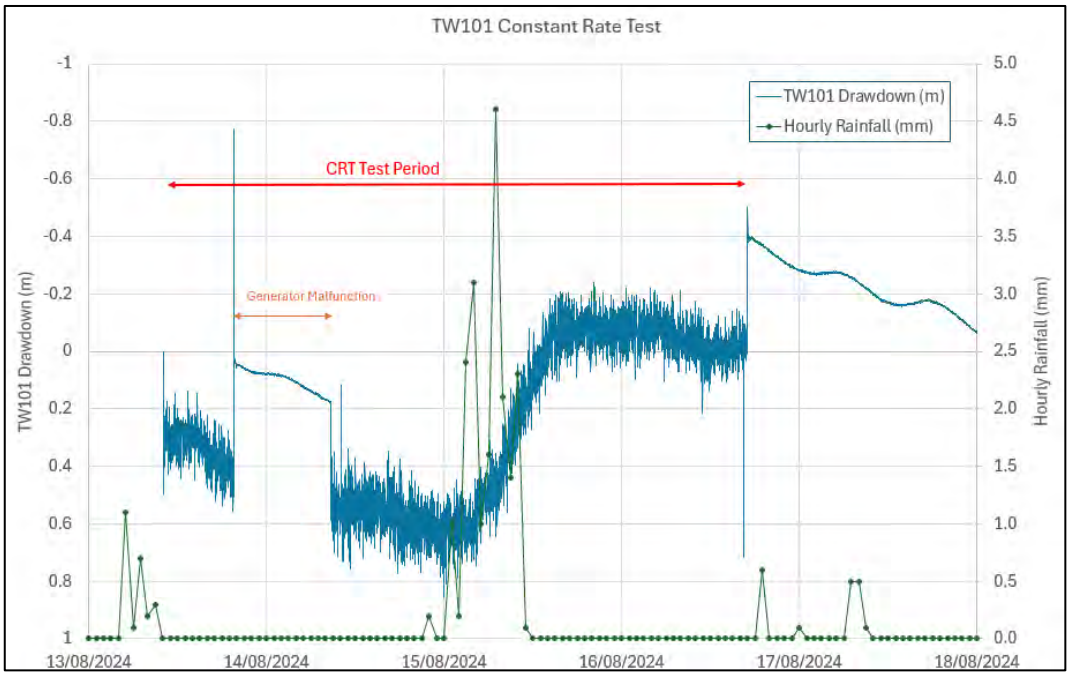


Figure 1: TW101 Constant Rate Test (manual readings)

1.2 Variable Head Tests

Variable head tests were undertaken as part of the N6 Galway City Transport Project Phase III Ground Investigation Contract 2 works and were supplemented with additional data from rising head tests undertaken where groundwater sampling was performed to inform the 2018 EIAR. This data is summarised below in **Table 1** and comprises of five variable head tests undertaken in granite and ten variable head data undertaken in limestone. Refer to **Appendix A.10.3** for the location of the monitoring well locations.

Table 1: Summary of variable head tests

Borehole	Geology	Variable Head test Horslev Method K m/s
BH3/04	Granite	4.60E-06
BH3/06	Granite	1.59E-06
BH3/17	Granite	9.65E-07
BH3/18	Granite	2.38E-06
BH3/20	Granite	2.29E-06
BH3/35	Limestone	2.64E-06
BH3/38	Limestone	3.45E-06
BH3/40	Limestone	5.80E-07
BH3/41	Limestone	2.59E-06
BH3/42	Limestone	2.93E-07
BH3/46	Limestone	1.46E-06
BH3/47	Limestone	3.70E-07
BH3/48	Limestone	4.39E-05
LQMW3	Limestone	4.96E-09
BH05	Limestone	5.26E-04

1.3 Packer Test Data

A total of eight packer tests were undertaken under N6 Galway City Transport Project Phase III Ground Investigation Contract 2 of the ground investigation. All packer tests were completed in limestone. These tests comprised of four tests undertaken in BH04 and four tests undertaken in BH05. The focus of these tests was to target fractures and voids in the bedrock to determine the potential higher permeabilities in the formation. The data from the packer tests (**Table 2**) indicates permeabilities that range from $1.5x10^{-5}$m/s to $5.8x10^{-6}$m/s. A number of these Lugeon tests failed to attain the high pressures.

Table 2: Summary of packer tests

Borehole *1	Test Zone	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Interpreted Permeability K*2
	mBGL	m/s	m/s	m/s	m/s	m/s	m/s
BH04	18-20	5.9E-06	6.3E-06	4.5E-06	6.5E-06	5.9E-06	5.8E-06
BH04	21-23	1.5E-05	1.1E-05				1.3E-05
BH04	24-26	3.8E-06	4.4E-06	4.9E-06	6.4E-06	7.1E-06	5.3E-06
BH04	28-30	1.1E-05					1.1E-05
BH05	20-23	1.7E-05	1.4E-05	1.2E-05	1.3E-05	1.8E-05	1.5E-05
BH05	27-29	1.7E-05	1.4E-05	1.2E-05	1.3E-05	1.8E-05	1.5E-05
BH05	30-32	1.8E-05	1.4E-05	1.2E-05	1.5E-05	2.0E-05	1.5E-05
BH05	36-38	2.0E-05	1.5E-05	1.2E-05	1.5E-05	2.0E-05	1.5E-05

*1- BH04 and BH05 are completed in limestone

*2- Interpretation as per Quiñones-Rozo, Camilo (2010):Lugeon test interpretation, revisited. In: Collaborative Management of Integrated Watersheds, US Society of Dams, 30th Annual Conference, S. 405–414.

2 Conclusions

Based on the data a range of permeability is present for both the granite and limestone areas that the proposed Project traverses.

The permeability data for granite provides a range of k values from 9.7 $x10^{-7}$ to 4.6 x 10^{-6}m/s, which is considered to be appropriate for the Galway Granite Batholith. It is however recognised that locally if faulting is present that the permeability can be locally higher, although for very limited distances. On this basis of the testing undertaken, a permeability k value of 4.6$x10^{-6}$m/s is considered to be a conservative estimation of groundwater flow in the Galway Granite Batholith.

The permeability data measured for the limestone has a range k values from 5.0$x10^{-9}$m/s to 5.3$x10^{-4}$m/s. The lower permeability data is from a borehole in Lackagh Quarry, where the borehole intersected few fractures, whilst the highest permeability was recorded less than 1km away in BH05, which includes karst. The new trial well at the Galway Racecourse confirms the presence of deep karst conduits with significant water yields. These results are typical of the range of permeability for karst and the types of flow paths that can develop.

Based on the permeability data recorded an estimate k value of 1.5$x10^{-4}$m/s is taken as a conservative value for the Visean Undifferentiated Limestone. This estimate is based upon one order of magnitude greater than the highest permeability calculated from the packer tests in BH05, where the test was focused on measuring high flows but not as high as the permeability k value of 5.3$x10^{-4}$ m/s which was recorded in karst.

Appendix A.10.5.1

Pumping Test PW01 Report

ARUP

Galway County Council

N6 Galway City Ring Road

Pumping Test PW01

Reference: Appendix A.10.5.1

Issue 1 | 1 June 2017

Job number 233985-00

Ove Arup & Partners Ireland Limited
Arup Corporate House
City East Business Park Ballybrit
Galway
Ireland
arup.com

ARUP

Document Verification

Project title	N6 Galway City Ring Road
Document title	Pumping Test PW01
Job number	233985-00
Document ref	Appendix A.10.5.1
File reference	Appendix A.10.5.1 Pumping test report

Revision	**Date**	**Filename**	Appendix A.10.5.1 Pumping Test Report		
Issue 1	1 Jun 2017	**Description**	Issue 1 Issue for 2018 EIAR		
			Prepared by	**Checked by**	**Approved by**
		Name	Alison Orr	Christopher Newton	Les Brown
		Signature			
		Filename			
		Description			
			Prepared by	**Checked by**	**Approved by**
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	**Checked by**	**Approved by**
		Name			
		Signature			

Issue Document Verification with Document ✓

Contents

Appendices

1. Introduction

A pumping test was carried out in the area between the Monivea Road and the existing N6.

The pumping test site lies immediately east of the existing N6 junction with the Monivea Road, adjacent to the Galway Technology Park and Galway Racecourse. The location forms part of the high ground east of Galway City and has a gentle topography that lies between 40-50m OD (EPA topography, GSI Data Viewer). The site in which the pumping tests were carried out is currently agricultural land.

1.1 Objective

The objective of this factual report is to present a summary of the results of a pumping test carried out at the site to inform the design of any proposed dewatering.

1.2 Outline of the pumping test

The pumping test was carried out as part of N6 Galway City Transport Project Phase III Ground Investigation Contract 3 in accordance with BS ISO 14686:2003. The pumping well was drilled by Dempsey Drilling (Sub-contracted by Priority Drilling) on 30 November 2016. The pumping test was carried out by Priority Drilling between 24 and 25 January 2017.

The test comprised:

- Drilling of the pumping well
- A step testing
- Recovery

A summary of the pump test is presented in Section 3.

2. Background

2.1 Site investigations

Site investigations, including trial pits and boreholes, were carried out in February to March 2016 as part of N6 Galway City Transport Project Phase III Ground Investigation Contract 1. The results of this investigation are presented in the IGSL report dated January 2017, included in Appendix A.9.1.

The ground investigations as part of Phase III Contract 1 include:

- Five boreholes; BH3/40, BH3/41, BH3/42, BH3/43 and BH3/48. The boreholes were drilled by cable percussion with rotary follow on and standpipes were installed
- Two trial pits; TP3/30 and TP3/32

An additional two monitoring boreholes, RC03-63 and RC03-64 and one pumping well, PW01, were drilled as part of N6 Galway City Transport Project Phase III Ground Investigation Contract 3. The monitoring boreholes were completed with 50mm diameter standpipes to allow for groundwater monitoring.

2.2 Geology

A summary of the geology proven is presented in Table 1.

Table 1 Geological description

Stratum	Depth to top of strata (mBGL)	Thickness (m)
Topsoil	0	0 to 0.3
Sandy gravelly CLAY	0 to 0.15	0.35 to 0.4
Sandy gravelly SILT	0.1 to 0.5	0 to 0.45
Weathered rock	0.4 to 5.0	0.6 to 4.8
Limestone described as fresh to slightly weathered with occasional clay filled fractures.	1.2 to 5.0	>19

The site investigation has shown that competent bedrock lies 1.2 to 5.0m below ground level in the area of the pumping test. Above the competent rock the borehole log records no recovery, observed by the driller as weathered rock or as cobbles and boulders.

3. Pumping test

A pumping test was carried out in pumping well PW/01. A log of PW/01 and the details of the construction is presented in Annex 1 of this report.

3.1 Monitoring

Groundwater levels were continually monitored in PW01 and observation wells, RC03-63 and RC03-64 prior to, during and after the pumping test. The results of the water level monitoring are presented in a hydrograph in Figure 1.

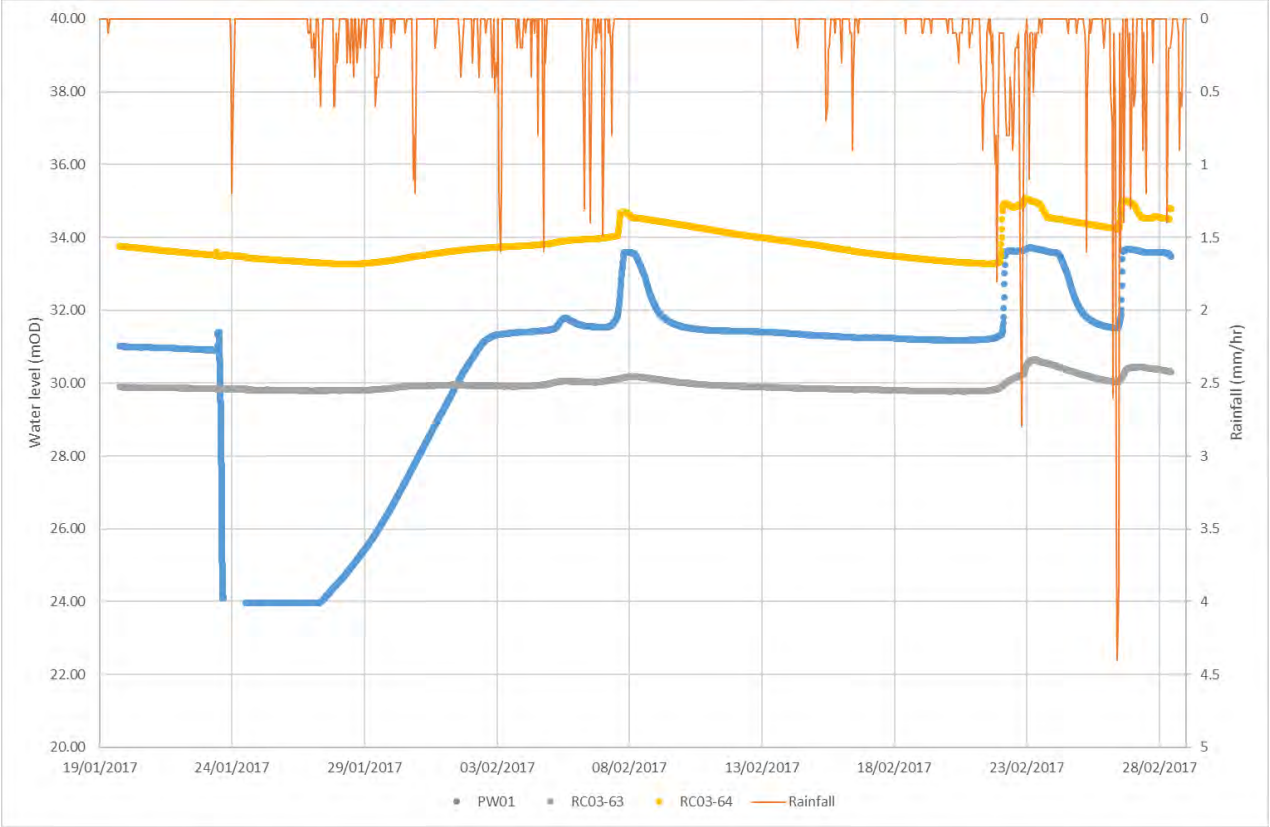


Figure 1 Hydrograph of water levels in pumping well PW01 and monitoring wells RC03-63 and RC03-64

The methodology for the pumping test was to carry out a step test with a pumping rate of 0.5l/s, followed by sequential increases to 1.0l/s, 2.0l/s and 3.0l/s. A constant rate test would have followed recovery of the well at a rate indicated from the step test data. However, during the first step test that water level was drawn down very rapidly at a constant rate without stabilisation. On the basis of the result the initial step the pumping rate was continued for 3hours to see if the water level stabilised. However, the rate of drawdown remained constant and after 3 hours the water level dropped to the level of the pump intake and the test was stopped. The drawdown achieved during the step test was 7.8m.

A response to the pumping test in PW01 showed no initial drawdown in either monitoring wells BH03-63 and BH03-63, refer Figure 1.

Recovery of the borehole occurred 7 days following the pumping test following significant rainfall. Responses in the groundwater level were observed following rainfall events on the 8/02/2017 and 22/02/2017, refer Figure 1.

4. Conclusion

The step test in PW01 was unable to be completed due to the groundwater level lowering below the level of the pump intake during the first step pumping rate (0.5l/s). Recovery of groundwater level to the initial level took seven days following the step test. The data from the step test was used to determine permeability based on the residual drawdown data using this recovery method, which indicates a permeability of 2 x 10^{-8}m/s.

Annex 1

PW01 Borehole log

A.1 Annex 1 – PW0

ARUP

Borehole Log

Job No.	Hole ref	Page
233985-00	**PW01**	1 of 2

Contractor: Dempsey Drilling

Galway City Transport Project

NG co-ordinates	Ground Level (mOD)	Date
		30/11/2016

Samples & tests			Water	Strata log				Geology	Instrument/ Backfill
Depth	Sample Type Ref	Test Result		Red. Level	Legend	Depth (Thick-ness)	Description		
						(3,00)	Dark grey or black WEATHERED LIMESTONE. Recovered as limestone chippings. (BURREN FORMATION)		
						3,00			
						(12,00)	Dark grey or black LIMESTONE. Recovered as limestone chippings. Driller noted that the limestone was harder (BURREN FORMATION)		

Open hole between 3 and 15 mBGL

Client

Logged by: Laura McGrath

Database check:

ARUP	Borehole Log	Job No. 233985-00	Hole ref **PW01**	Page 2 of 2
		Contractor Dempsey Drilling		
Galway City Transport Project		NG co-ordinates	Ground Level (mOD)	Date 30/11/2016

Samples & tests			Water	Strata log				Geology	Instrument/ Backfill
Depth	Sample Type Ref	Test Result		Red. Level	Legend	Depth (Thick-ness)	Description		
							Dark grey or black LIMESTONE. Recovered as limestone chippings. Driller noted that the limestone was harder (BURREN FORMATION) *(continued)*		
							.... 11,00 - 15,00 Limestone is dark grey		
						15,00			
							Borehole completed at 15m depth		

Open hole between 3 and 15 mBGL

Client	Logged by: Laura McGrath	Database check: