Welsh Water

Wrexham – Wynnstay Avenue

Hydrogeological Impact Assessment

4391_S_240-ARP-01-BG-RP-GE-10003

Issue Rev 0 | 10 September 2019

Job number 241513

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ARUP

Document Verification

ARUP

Job title		Wrexham – Wynnstay Avenue		**Job number** 241513
Document title		Hydrogeological Impact Assessment		**File reference**
Document ref		4391_S_240-ARP-01-BG-RP-GE-10003		
Revision	**Date**	**Filename**		
Rev 0	10 Sep 2019	**Description**		
			Prepared by	Checked by	Approved by
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		Signature			
		Filename		
		Description		
			Prepared by	Checked by	Approved by
		Name			
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		Filename		
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			Prepared by	Checked by	Approved by
		Name			
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		Name			
		Signature			
				Issue Document Verification with Document	✓

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1 Introduction

1.1 Purpose of this Report

This report presents a Hydrogeological Impact Assessment (HIA) of temporary construction dewatering activities required for the Wrexham – Wynnstay Avenue storage tank, this is furthermore known in this report as "The Site".

'Water Abstraction and Impounding (Exemptions) Regulations 2017' requires that certain temporary construction dewatering activities in England and Wales require an abstraction licence. This report presents hydrogeological context of the Site to assess whether an abstraction license is required.

This report outlines a conceptual hydrogeological model of the construction site, summarises the findings of additional ground investigation, considers the potential connection and risk of impact on nearby sensitive environmental receptors. The conceptual model has then been used to inform a Tier-1 HIA following NRW guidelines[1].

1.2 Legislative Background

The introduction of the 'Water Abstraction and Impounding (Exemptions) Regulations 2017' in England and Wales has introduced the need to licence temporary construction dewatering activities in certain situations.

All large-scale groundwater abstractions required for construction dewatering, as of January 2018, require a licence to carry out these operations. These regulations have been brought into motion to help create a fairer system for all abstractors as well as enable the Regulator to manage water resources more effectively.

The new regulations are cited as the 'Water Abstraction and Impounding (Exemptions) Regulations 2017'[2]. Under Part 2, Section 5 (entitled 'Small scale dewatering in the course of building or engineering works') of these Regulations, the following exemptions to groundwater abstraction licencing are identified:

"Small scale dewatering in the course of building or engineering works"

5.(1) The restriction on abstraction does not apply to an abstraction or series of abstractions of water carried out in the course of building or engineering works for the purpose of dewatering from a sump or excavation if:

> *(a) the abstraction or series of abstractions are temporary and, in any event, carried out over a period of less than six consecutive months beginning with commencement of the first abstraction;*
>
> *(b) each abstraction does not cause or is not likely to cause damage to a conservation site or specific features in such a site;*
>
> *(c) each abstraction does not cause or is not likely to cause damage to protected species; and,*
>
> *(d) either:*

(i) the water abstracted is immediately discharged to a soakaway;

or,

(ii) the volume of water abstracted is less than 100 cubic metres of water per day and there is no intervening use of that water before discharge.

5.(2) Where the abstraction is undertaken within 500 metres of a conservation site or within 250 metres of a spring, well or borehole used to supply water for any lawful use, paragraph (1)(d)(ii) applies in respect of that abstraction as if the reference to 100 cubic metres of water per day were a reference to 50 cubic metres of water per day."

All of these provisions listed above must be satisfied to qualify for an abstraction licence exemption. All abstractions less than 20 m^3/d, for whatever use, will still (as of April 2005) not need to undergo an application for an abstraction licence.

1.3 Description of Proposed Construction Activities

The proposed works at Wrexham includes a 1500 m^3 underground storage tank and gravity fed sewerage lines that will connect into the existing sewage network. It is anticipated that the excavation for the storage tank will intercept the superficial deposits aquifer and require dewatering during construction. The approximate storage tank excavation dimensions are 50 m (long) x 40 m (wide) x 4.8 m (depth below ground level).

The proposed dewatering activities, including construction phases of excavation and installation will be temporary. The dewatering design and programme is currently in development by the Contractor.

1.4 Need for an Abstraction Licence

It is anticipated that an abstraction licence will be required to permit dewatering at the Site. The estimated daily abstraction rate is approximately 107 m^3/d (1.2 l/s), which marginally exceeds the 100 m^3/d threshold as cited in the regulations. However, during wetter periods the abstraction rate could be up to 128 m m^3/d (1.5 l/s), so an abstraction licence is recommended.

NRW have stated that an application for an abstraction licence must be accompanied by a HIA. The HIA methodology is described in 'Hydrogeological Impact Appraisal for dewatering abstractions'[1]. The HIA methodology is composed of a series of 14 steps as follows:

1. Establish the regional water resource – see Section 2;
2. Develop a conceptual model for the dewatering operation and the surrounding area – see Section 3;
3. Identify all potential water features which are susceptible to flow impacts – see Section 4.1;
4. Apportion the likely flow impacts to the water features – see section 4.2;

5. Mitigate the flow impacts – see Section 4.3;
6. Assess the significance of the net flow impacts – see Section 4.4;
7. Define the search area for drawdown impacts – see Section 5.1;
8. Identify all potential water features which could be impacted by drawdown – see Section 5.2;
9. Predict the likely drawdown impacts – see Section 5.3;
10. Mitigate the drawdown impacts – see Section 5.4;
11. Assess the significance of net drawdown impacts – see Section 5.5;
12. Assess the water quality impacts – see Section 6;
13. Redesign the mitigation measures to minimise flow and drawdown impacts – see Section 7;
14. Develop a monitoring strategy – see Section 8.

2 Regional Water Resource Status

The Site is located within the River Dee surface water catchment. No further surface water resources in the catchment are available for abstraction within the catchment[3]. Groundwater resources in the site area have not been assessed for availability according to the 'Dee Catchment Abstraction Management Strategy 2015'[3].

3 Development of the Conceptual Model

3.1 Site Location and Topography

The Site is located approximately 1 km northeast from the centre of Wrexham (approximate grid reference SJ346506) within North Wales. The proposed dewatering activities will take place at the storage tank location, as shown in the site plan in **Figure 1**.

The site is located in a shallow valley feature that gently slopes towards the River Gwenfro to the south. The ground level elevation at the storage tank location is approximately 72 mAOD.

3.2 Published Geology

3.2.1 Geology

The mapped geological conditions[4][5] for the site are presented in **Table 1**.

Table 1: Mapped geological conditions

Geological Formation	Period	Aquifer Designation[6][7]	Material Description
Superficial Geology			
Made ground (fine grained)	Recent	N/A	Made ground is anticipated to be encountered due to the construction of the residential properties and infrastructure[9].
Alluvium	Quaternary	Secondary A	Comprises clay, silt sand and gravel.
Glaciofluvial deposits	Quaternary	Secondary A	Comprises sand and gravel.
Bedrock Geology			
Salop Formation (Warwickshire Group)	Carboniferous	Secondary A	Includes mudstone, sandstone containing beds of pebbly sandstone and conglomerate containing limestone and chert clasts and thin *Spirobis* limestone beds and caliche in the lower part of the unit[4].

3.2.2 Structural geology

The structural features mapped[8] in the vicinity of the site include inferred faults striking north-south and spaced at approximately 1200 m. One inferred fault is approximately 400 m north of the storage tank.

Previous mine workings in the area include two sand pits approximately 265 m northwest and 475 m west of the storage tank.

3.3 Ground Investigation

3.3.1 Completed investigations

One phase of ground investigation has been undertaken between 8 January 2019 and 10 January 2019 to inform the design of the Wrexham – Wynnestay Avenue storage tanks. A total of two cable percussion boreholes were excavated. BH1 and BH2 are located approximately 30 m and 260 m north of the proposed storage tank location. These boreholes were located at tank locations proposed during earlier stages of the project.

Table 2 below summarises the borehole depths and the methods used, and **Figure 1** below shows the location of these ground investigation boreholes.

Table 2: Ground investigation schedule in vicinity of the Site

Location	GI Phase	Grid Reference	Ground level (mAOD)	Overall depth (m)	Excavation method
BH1	1	Not provided	Not provided	10.20	0 – 1.2m hand dug 1.2 – 10.2m cable percussion
BH2	1	Not provided	Not provided	10.15	0 – 1.2m hand dug 1.2 – 10.15m cable percussion

The encountered ground conditions in the vicinity of the Site are provided below in **Table 3**. The made ground comprised slightly gravelly sandy CLAY and both the alluvium and glaciofluvial deposits comprised slightly gravelly, slightly silty fine to coarse SAND.

Table 3: Summary of encountered ground conditions in vicinity of the Site

Location	Made ground base (m)	Alluvium base (m)	Glaciofluvial deposits base (m)	Groundwater strikes during investigation
BH1	2.9	> 10.2	-	2.7m and rose to 2.4m
BH2	2.9	-	> 10.15	3.0m and rose to 1.0m

Due to the similar particle size distribution of the alluvium and glaciofluvial deposits in BH1 and BH2, it is expected that the hydraulic response of these units will also be similar. For this assessment the alluvium and glaciofluvial deposits will be combined and referred to as the superficial deposits.

3.4 Groundwater

Groundwater strikes during borehole drilling were encountered at 2.7m and 3.0 m depth. The groundwater strikes were around the interface of cohesive made ground over granular superficial deposits. It is anticipated that the superficial deposits are the main water bearing unit that the excavation is likely to interact with. The results of the groundwater monitoring are presented in **Table 4**.

Table 4: Summary groundwater monitoring

Location	Installed response zone (m)	Geological unit monitored	16/01/2019	31/01/2019	26/02/2019
BH1	3.0 – 6.5	Superficial deposits (alluvium)	1.55 mbgl	1.53 mbgl	1.51 mbgl

Location	Installed response zone (m)	Geological unit monitored	16/01/2019	31/01/2019	26/02/2019
BH2	3.0 – 6.5	Superficial deposits (glaciofluvial deposits)	1.41 mbgl	1.33 mbgl	1.37 mbgl

In-situ variable head testing and analysis was completed by the ground investigation contractor, SOCOTEC. Falling head tests were conducted in BH1 and BH2 during drilling, however these tests failed to show a response. Variable head testing was completed in the piezometers on the 14th February 2019. The tests achieved full head recovery within 6 minutes or less. These hydraulic responses are considered to be representative of the superficial deposits encountered in the boreholes. The results of SOCOTEC's variable head testing analysis are presented in Appendix B. Note, SOCOTEC's analysis does not consider the hydraulic gradient to 37% head recovery as per BS22282-2: 2012. SOCOTEC's analysis considers the hydraulic gradient to 100% head recovery.

The hydraulic conductivity has been calculated using the results of the final rising head test completed in the second round of testing by SOCOTEC and applying the hydraulic gradient up to 37% head recovery. For this assessment, a hydraulic conductivity of $5.7x10^{-6}$ m/s has been adopted for the superficial deposits.

3.5 Conceptual Model

The superficial deposits are anticipated to be the main water-bearing aquifer. Recharge of the superficial aquifer is assumed to be from direct rainfall recharge or via infiltration through made ground particularly adjacent to the site and to the north and east where grassed areas are used for agriculture and parks/playing fields.

The River Gwenfro, approximately 680 m south of the site, is expected to be in hydraulic connection with groundwater in the superficial deposits and groundwater flow paths in the local area are generally towards the river.

The connection between the superficial deposits with the Salop Formation is unknown, though the bedrock is expected to have some connection to permeable superficial deposits in the region.

A figurative conceptual model is shown in **Figure 2**.

3.6 Short-term Construction Activities Associated with Removal of Groundwater

The proposed construction programme at the Site includes phases of underground works. Dewatering will be required for the construction of the new storage tank. The dewatering programme will be temporary, with a scheduled duration yet to be determined as the dewatering design is currently being developed. The location of the proposed works is provided in more detail on **Figure 1**.

4 Flow Impacts

4.1 Water Features Susceptible to Flow Impacts

The following features have been considered as part of a desk study to determine all water-dependent receptors that have potential to be affected by flow impacts:

- **Conservation sites:**

  There are no known conservation sites within 500 m of the excavation[11].

- **Surface watercourses:**

  There are no known surface watercourses within 500 m of the excavation[11].

- **Local springs:** A desk-based assessment of water features indicates that there are no known springs within 500m of the excavation[11].

- **Local licensed and unlicensed abstractions:** There are no known groundwater abstractions within 500 m of the excavation[10].

4.2 Apportioning of the Flow Impacts

It is not considered necessary to apportion possible flow impacts because no receptors are deemed to be impacted.

4.3 Mitigation of Flow Impacts

No mitigation is deemed necessary.

4.4 Significance of Net Flow Impacts

No significant flow impacts anticipated.

5 Drawdown Impacts

5.1 Search Area for Drawdown Impacts

The radius of influence was calculated using the analytical equation proposed by Marinelli and Niccoli[12]. The drawdown impacts and resultant abstraction rates have been assessed for estimated average summer and winter recharge conditions. The results are presented in **Table 5** and provided in **Appendix B**.

Table 5: Range of radius of influences calculated

Scenario	Recharge rate, P (m/day)	Hydraulic Conductivity, K (m/s)	Radius of Influence, Ro (m)	Abstraction rate, Q (m^3/day)
Summer	0.0014	$5.7x10^{-6}$	85	107
Winter	0.0027	$5.7x10^{-6}$	69	128

5.2 Water Features Susceptible to Drawdown Impacts

The following features have been considered as part of a desk study to determine all water-dependent receptors that have potential to be affected by drawdown impacts:

- **Conservation sites:** There are no known conservation sites within the radius of influence of the dewatering works[11].
- **Surface watercourses:** There are no known rivers or surface water features within the radius of influence of the dewatering works[11].
- **Local springs:** A desk-based assessment of water features indicates that there are no known springs within the radius of influence[11].
- **Local licensed and unlicensed abstractions:** There are no known groundwater abstractions within the radius of influence of the dewatering works[4].

5.3 Prediction of Maximum Drawdown Impacts

The maximum radius of influence from the excavation is anticipated to be 85 m, as estimated from Marinelli and Niccoli[12] using variable head testing results. There are no known receptors within 500 m of the dewatering works.

5.4 Mitigation of Drawdown Impacts

No mitigation is deemed necessary.

5.5 Significance of Drawdown Impacts

No significant drawdown impacts anticipated.

6 Water Quality Impacts

The contractor will adhere to the conditions of the Environmental Permit (temporary discharge consent) to ensure that the rate and quality of any discharge

does not cause adverse effects to the wider environment. The method of treatment will be explained in detail in the Construction Environmental Management plan (CEMP) to be produced prior to any activities on site. Contamination of water bodies should be prevented by best practice (following Guidance for Pollution Prevention[12]).

The dewatering design and discharge solution is currently under development, however it is anticipated that a well point system may be used. Should the contractor use a well-point system, the following is recommended:

- A settlement tank should be used to allow settling in the abstracted water and reduce levels of silt that might be released to the environment.
- Use of a 2mm-5mm silica filter pack within each wellpoint, to act as an additional treatment barrier, filtering the groundwater prior to it reaching the surface.

7 Redesign Mitigation Methods

Currently the dewatering design and discharge solution is being developed and it is understood a well point solution is likely. The design is being developed by the Contractor in consultation with Arup.

A second phase of ground investigations is being planned to commence in September 2019. The purpose of this second phase of investigation is to supplement the previous investigation by providing more detailed ground conditions along the proposed sewer alignment and the proposed storage tank location. The results of this investigation will be reviewed in conjunction with this HIA to inform the dewatering design.

8 Monitoring and Reporting Plan

Regular monitoring of abstraction volumes should be undertaken throughout the duration of the dewatering works. The discharge quality should also be monitored visually to check that quality and turbidity is suitable for discharge.

9 Conclusions

This report presents an HIA that follows the methodology outlined in NRW guidelines. The assessment concludes that a temporary abstraction licence will be required for the proposed construction dewatering activities at Wrexham – Wynnstay Avenue. This is because the estimated abstraction volume is marginal relative to the 100 m^3/d criteria and is likely to exceed this if dewatering activities occur during wetter periods of the year. The 100 m^3/d criteria is the maximum permitted abstraction volume when water is not discharged to soakaway.

The assessment has reviewed all possible impacts to any local water features and concluded there are none.

In addition, no changes to the existing hydrological regime are anticipated post-construction as a result of the construction works.

Further ground investigation works are proposed, and the results will be reviewed in conjunction with this HIA for dewatering design.

10 References

[1] Environment Agency, 2007. Hydrogeological impact appraisal for dewatering abstractions. Science Report - SC040020/SR1

[2] The Water Abstraction and Impounding (Exemptions) Regulations 2017. 2017 No. 1044, PART 2, Regulation 5. https://www.legislation.gov.uk/uksi/2017/1044/regulation/5/made Accessed 29/20/2018

[3] Dee Catchment Abstraction Management Strategy. 2015. https://cdn.naturalresources.wales/media/674759/dee_cams_2015_english.pdf?mode=pad&rnd=131596369480000000. Accessed 29/03/2019

[4] British Geological Survey, Bedrock Geology 1:50,000 scale map, http://mapapps2.bgs.ac.uk/geoindex/home.html. Accessed 20/3/19

[5] British Geological Survey, Superficial Deposits Geology 1:50,000 scale map, http://mapapps2.bgs.ac.uk/geoindex/home.html. Accessed 20/3/19

[6] British Geological Survey, Aquifer Designation Wales: Bedrock Geology 1:50,000 scale map, http://mapapps2.bgs.ac.uk/geoindex/home.html. Accessed 20/3/19

[7] British Geological Survey, Aquifer Designation Wales: Superficial Deposits 1:50,000 scale map, http://mapapps2.bgs.ac.uk/geoindex/home.html. Accessed 20/3/19

[8] British Geological Survey, Linear Features 1:50,000 scale map, http://mapapps2.bgs.ac.uk/geoindex/home.html. Accessed 20/3/19

[9] Arup, July 2018, Part 1: Preliminary Review of Features / Constraints, Doc. No. 4391_S_240-ARP-XX-BG-RP-GE-10001-S2-P1

[10] British Geological Survey https://www.bgs.ac.uk/research/groundwater/datainfo/hydromaps/hydro_maps_scanviewer.html. Accessed 12/11/2018

[11] Magicmap. http://magic.defra.gov.uk/MagicMap.aspx. Accessed 02/04/2019

[12] Marinelli, F. and Niccoli, W.L., 2000, *Simple Analytical Equations for Estimating Ground Water Infow to a Mine Pit*, Ground Water, Vol. 38, No. 2.

[13] Guidance for Pollution Prevention http://www.netregs.org.uk/environmental-topics/pollution-prevention-guidelines-ppgs-and-replacement-series/guidance-for-pollution-prevention-gpps-full-list/. Accessed 30/05/2018

Figures

A3

334000 334500 335000

351000 350500 350000

SPRING LODGE SAND PIT- on historical map 1892-1914. Next available map 1944 in which the old sand pit is no longer shown and area has been developed on. No record of what the sand pit has been backfilled with.

BEACONSFIELD SAND PIT- on historical map 1892-1914. Next available map 1944 in which the old sand pit is no longer shown and area has been developed on. No record of what the sand pit has been backfilled with.

BH2

BH1

Storage tank

HISTORIC LANDFILL- THE DUNKS
In use 1960-1980
Combination of inert, industrial, commercial, household and special waste

The Dunks

The Dunks No.2

River Gwenfro

Bala Road

SJ35SW762

SJ35SW761 SJ35SW760 SJ35SW759 SJ35SW758 SJ35SW757 SJ35SW756 SJ35SW755 SJ35SW754 SJ35SW753

SJ35SW862

SJ35SW854 SJ35SW855 SJ35SW853 SJ35SW859 SJ35SW856 SJ35SW861 SJ35SW858 SJ35SW857 SJ35SW860

BGS Borehole scan SJ35SW762 (Approximately 450m southeast of site)
0-0.5m: sandy, clayey topsoil
0.5-1.9m: made ground with medium sand and fine gravel
1.9-2.3m: made ground with fine to medium sand
2.3-3.3m: soft, clayey sandy silt
3.3-4.5m: fine sand with gravel of up to 50mm
4.5-6m: very silty fine sand

BGS Borehole scan SJ35SW862 (Approximately 600m southwest of site)
0-3.5m: brick, soil and ash filling 3.5-4m: peat
4-9.6m: sand and gravel

LEGEND

- PROPOSED TANK OPTION
- HISTORICAL LANDFILL
- HISTORICAL BGS BOREHOLE SCAN
- HISTORICAL SAND PIT
- DCWW SEWER NETWORK
- INDICATIVE GI LOCATION

BGS Superficial Geology

- Alluvium consisting of clay, silt, sand and gravel
- Glaciofluvial sheet deposits comprised of sand and gravel

Issue	Date	By	Chkd	Appd
P0	06/09/19	TR	LB	AP

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Client
DCWW

Dŵr Cymru Welsh Water

Job Title

Wrexham (Wynnstay Avenue) Site plan

Scale at A3
1:5,000

Job No	Drawing Status
241513	**Preliminary**

Drawing No	Issue
Figure 1	**P0**

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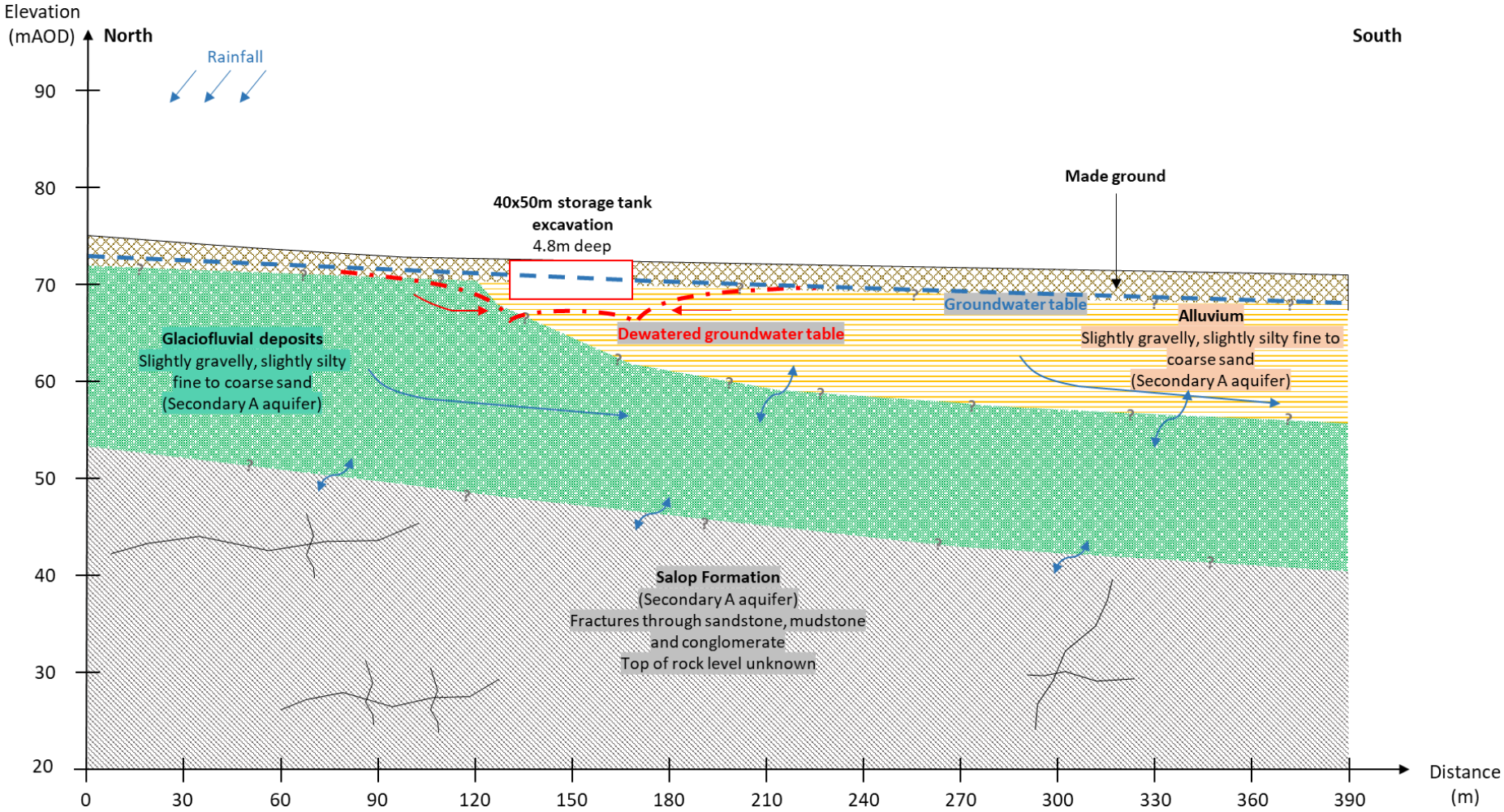
Template A3: Version 2

Figure 2: Conceptual site model of the proposed dewatering works



Appendices

Appendix A

Ground Investigation Data

Borehole Log

SOCOTEC

Drilled	DD	**Start**	**Equipment, Methods and Remarks**	**Depth from (m)**	**to (m)**	**Diameter (mm)**	**Casing Depth (m)**	**Ground Level**	70.59 mOD
Logged	JP	09/01/2019	Dando 3000	0.00	2.70	200	2.70	**Coordinates (m)**	E 334692.47
Checked	RF	**End**	Hand dug inspection pit to 1.20m. Cable percussion boring to 10.20m.	2.70	10.20	150	9.70	**National Grid**	N 350675.91
Approved	RF	10/01/2019							

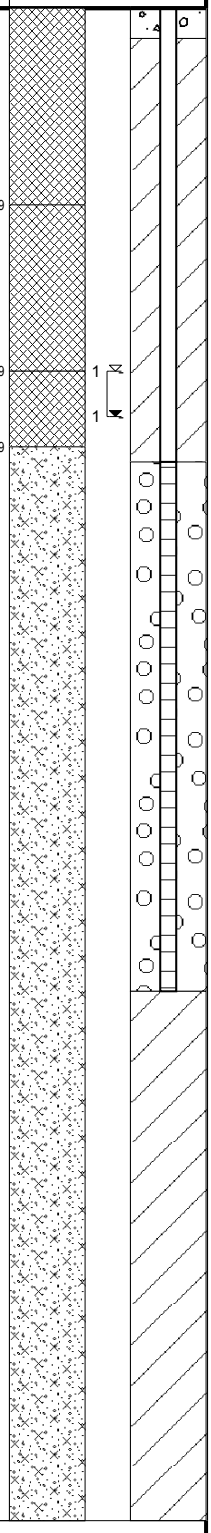
Samples and Tests

Depth	Type & No.	Records	Date / Casing	Time / Water
0.10	D 1			
0.20	ES 2			
0.50	ES 3			
0.50 - 1.00	B 4			
1.00	ES 5			
1.00	D 6			
1.20 - 1.65	SPTS	N=2 (1,0/1,0,1,0)	1.20	Dry
1.20	D 7			
1.20 - 1.70	B 8			
2.00	ES 10			
2.00	D 9			
2.20 - 2.65	SPTS	N=11 (1,2/3,3,3,2)	2.20	Dry
2.20	D 11			
2.20 - 2.70	B 12			
			09/01/19	1800
			2.70	2.40
			10/01/19	0645
			2.70	1.10
3.00	ES 14			
3.00	D 13			
3.20 - 3.65	SPTS	N=8 (2,2/3,2,2,1)	3.20	2.10
3.20	D 0			
3.20 - 3.70	B 15			
4.00	ES 17			
4.00	D 16			
4.20 - 4.65	SPTS	N=6 (3,2/2,2,1,1)	4.20	2.70
4.20	D 18			
4.20 - 4.70	B 19			
5.00	KFH	k=2.4E-7 m/s		
5.00	D 20			
5.20 - 5.65	SPTS	N=5 (2,1/1,2,1,1)	5.20	3.30
5.20	D 21			
5.20 - 5.70	B 22			
6.00	D 23			
6.70 - 7.15	SPTS	N=5 (1,1/1,1,2,1)	6.70	4.40
6.70	D 24			
6.70 - 7.20	B 25			
7.50	D 26			
8.20 - 8.65	SPTS	N=5 (1,1/1,1,2,1)	8.20	5.30
8.20	D 27			
8.20 - 8.70	B 28			
9.00	D 29			
9.70 - 10.15	SPTS	N=4 (2,2/1,1,1,1)	9.70	6.10
9.70	D 30			
			10/01/19	1800
			0.00	Dry

Strata Description

Main	Detail	Depth, Level (Thickness)
MADE GROUND: Dark brown slightly gravelly sandy CLAY. Gravel is subangular to subrounded fine to coarse of various lithologies including brick, concrete, plastic and sandstone.		(1.30)
MADE GROUND: Soft dark brown slightly gravelly sandy CLAY.		1.30 +69.29 (1.10)
Grey sandy gravelly CLAY. Gravel is subangular to subrounded fine to coarse of various lithologies including sandstone and quartzite. (Possible MADE GROUND)		2.40 +68.19 (0.50)
Loose brown slightly gravelly slightly silty SAND. (ALLUVIUM)	9.00-10.20 Becomes silty.	2.90 +67.69 (7.30)

Legend / Backfill



Groundwater Entries

No.	Depth Strike (m)	Remarks	Depth Sealed (m)
1	2.70	Rose to 2.40 m after 20 minutes. Slow inflow	2.70

Depth Related Remarks

Depths (m)	Remarks
1.20 - 10.20	SPT Hammer ID: TH50 ER= 61%

Hard Boring

Depths (m)	Duration (mins)	Tools used

Notes: For explanation of symbols and abbreviations see Key to Exploratory Hole Records. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.

Scale 1:50

08/03/2019 14:24:20

Project WYNNSTAY AVENUE, WREXHAM

Project No. F8054-18

Carried out for Morgan Sindall

Borehole BH1

Borehole Log

SOCOTEC

Drilled	DD	**Start**	**Equipment, Methods and Remarks**	**Depth from (m)**	**to (m)**	**Diameter (mm)**	**Casing Depth (m)**	**Ground Level**	70.59 mOD
Logged	JP	09/01/2019	Dando 3000	0.00	2.70	200	2.70	**Coordinates (m)**	E 334692.47
Checked	RF	**End**	Hand dug inspection pit to 1.20m. Cable percussion boring to 10.20m.	2.70	10.20	150	9.70	**National Grid**	N 350675.91
Approved	RF	10/01/2019							

Samples and Tests

Strata Description

Depth	Type & No.	Records	Date Casing	Time Water	Main	Detail	Depth, Level (Thickness)	Legend	Backfill
					Loose brown slightly gravelly slightly silty SAND. (ALLUVIUM)		10.20 +60.39		
					END OF EXPLORATORY HOLE				

Groundwater Entries

No.	Depth Strike (m)	Remarks	Depth Sealed (m)

Depth Related Remarks

Depths (m)	Remarks

Hard Boring

Depths (m)	Duration (mins)	Tools used

Notes: For explanation of symbols and abbreviations see Key to Exploratory Hole Records. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.

Scale 1:50

08/03/2019 14:24:20

Project WYNNSTAY AVENUE, WREXHAM

Project No. F8054-18

Carried out for Morgan Sindall

Borehole BH1

Borehole Log

SOCOTEC

Drilled	DD	**Start**	**Equipment, Methods and Remarks**	**Depth from (m)**	**to (m)**	**Diameter (mm)**	**Casing Depth (m)**	**Ground Level**	73.46 mOD
Logged	JP	08/01/2019	Dando 3000	0.00	2.00	200	2.00	**Coordinates (m)**	E 334736.72
Checked	RF	**End**	Hand dug inspection pit to 1.20m. Cable percussion boring to 10.15m.	2.00	10.15	150	9.70	**National Grid**	N 350973.57
Approved	RF	09/01/2019							

Samples and Tests

Strata Description

Depth	Type & No.	Records	Date / Casing	Time / Water	Main	Detail	Depth, Level (Thickness)	Legend	Backfill
0.10	D 1				MADE GROUND: Brown slightly sandy slightly gravelly CLAY. Gravel is subangular to subrounded fine and medium of various lithologies including sandstone.		(0.40)		
0.20	ES 2						0.40 +73.06		
0.40	D 3				MADE GROUND: Dark brown slightly sandy slightly gravelly CLAY. Gravel is subangular to subrounded fine and medium of various lithologies including sandstone.		(0.80)		
0.50	ES 4								
0.50 - 1.00	B 5								
1.00	ES 6								
1.20 - 1.65	UT 7	31 blows 100% rec	1.20	Dry	Soft grey mottled brown slightly gravelly sandy CLAY with a slight black staining. Gravel is subangular to subrounded fine to coarse of various lithologies including sandstone and mudstone. (Possible MADE GROUND)		1.20 +72.26		
1.70	D 8						(1.70)		
2.00	ES 9								
2.20 - 2.65	SPTS	N=8 (1,1/2,2,2,2)	2.20	Dry					
2.20 - 2.65	D 10								
2.20 - 2.70	B 11								
2.90	D 12				Medium dense grey mottled brown gravelly clayey fine to coarse SAND. Gravel is subangular to subrounded fine to coarse of various lithologies including sandstone, mudstone and quartzite. (GLACIOFLUVIAL SHEET DEPOSITS)		2.90 +70.56		
3.00	ES 13								
3.20 - 3.65	SPTS	N=10 (1,2/2,2,3,3)	3.20	Damp					
3.20 - 3.65	D 14								
3.20 - 3.70	B 15						(1.10)		
4.00	KFH	k=7.2E-7 m/s							
4.00	D 16						4.00 +69.46		
4.20 - 4.65	SPTS	N=2 (1,0/1,1,0,0)	4.20	0.50	Very loose and loose grey mottled brown slightly gravelly slightly silty fine to coarse SAND. Gravel is subangular to subrounded fine to coarse of various lithologies including sandstone, mudstone and quartzite. (GLACIOFLUVIAL SHEET DEPOSITS)				
4.20 - 4.65	D 17								
4.20 - 4.70	B 18								
			08/01/19	1800					
			5.00	3.30					
5.00	D 19								
			09/01/19	0650					
5.20 - 5.65	SPTS	N=5 (1,1/1,1,1,2)	5.00	1.60					
5.20 - 5.70	B 20		5.20	1.80					
6.00	D 21						(4.40)		
6.70 - 7.15	SPTS	N=2 (1,1/1,0,1,0)	6.70	2.90					
6.70 - 7.20	B 22								
7.50	D 23								
8.20 - 8.65	SPTS	N=5 (1,1/1,1,1,2)	8.20	4.70					
8.20 - 8.65	D 24								
8.20 - 8.70	B 25				Loose grey mottled brown slightly gravelly silty fine to coarse SAND. Gravel is subangular to subrounded fine to coarse of various lithologies including sandstone, mudstone and quartzite. (GLACIOFLUVIAL SHEET DEPOSITS)		8.40 +65.06		
9.00	D 26						(1.75)		
9.70 - 10.15	SPTS	N=8 (2,2/2,2,2,2)	9.70	5.30					
9.70 - 10.15	D 27								
			09/01/19	1230					
			9.70						

Groundwater Entries

No.	Depth Strike (m)	Remarks	Depth Sealed (m)
1	3.00	Rose to 1.00 m after 20 minutes. Medium inflow	3.00

Depth Related Remarks

Depths (m)	Remarks
1.20 - 10.15	SPT Hammer ID: TH50 ER= 61%

Hard Boring

Depths (m)	Duration (mins)	Tools used

Notes: For explanation of symbols and abbreviations see Key to Exploratory Hole Records. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.

Scale 1:50

08/03/2019 14:24:21

Project WYNNSTAY AVENUE, WREXHAM

Project No. F8054-18

Carried out for Morgan Sindall

Borehole BH2

Borehole Log

SOCOTEC

Drilled	DD	**Start**	**Equipment, Methods and Remarks**	**Depth from (m)**	**to (m)**	**Diameter (mm)**	**Casing Depth (m)**	**Ground Level**	73.46 mOD
Logged	JP	08/01/2019	Dando 3000	0.00	2.00	200	2.00	**Coordinates (m)**	E 334736.72
Checked	RF	**End**	Hand dug inspection pit to 1.20m. Cable percussion boring to 10.15m.	2.00	10.15	150	9.70	**National Grid**	N 350973.57
Approved	RF	09/01/2019							

Samples and Tests

Strata Description

Depth	Type & No.	Records	Date Casing	Time Water	Main	Detail	Depth, Level (Thickness)	Legend	Backfill
					Loose grey mottled brown slightly gravelly silty fine to coarse SAND. Gravel is subangular to subrounded fine to coarse of various lithologies including sandstone, mudstone and quartzite. (GLACIOFLUVIAL SHEET DEPOSITS)		10.15 +63.31		
					END OF EXPLORATORY HOLE				

Groundwater Entries

No.	Depth Strike (m)	Remarks	Depth Sealed (m)

Depth Related Remarks

Depths (m)	Remarks

Hard Boring

Depths (m)	Duration (mins)	Tools used

Notes: For explanation of symbols and abbreviations see Key to Exploratory Hole Records. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.

AGS

Scale 1:50

08/03/2019 14:24:21

Project WYNNSTAY AVENUE, WREXHAM

Project No. F8054-18

Carried out for Morgan Sindall

Borehole

BH2

Groundwater Monitoring

Instrument Reference	Instrument Type	Instrument Base, mbgl	Date Time dd/mm/yyyy hh:mm:ss	Groundwater depth, mbgl	Comments
BH1 (1)	SP	6.50	16/01/2019 11:00:00	1.55	
BH1 (1)	SP	6.50	31/01/2019 10:50:00	1.53	
BH1 (1)	SP	6.50	26/02/2019 12:22:00	1.51	
BH2 (1)	SP	6.50	16/01/2019 10:50:00	1.41	
BH2 (1)	SP	6.50	31/01/2019 11:20:00	1.33	
BH2 (1)	SP	6.50	26/02/2019 12:45:00	1.37	

Notes: Type: SP - Standpipe

Project	WYNNSTAY AVENUE, WREXHAM
Project No.	F8054-18
Carried out for	Morgan Sindall

Table

FINAL

Appendix B

Aquifer Testing Raw Data and Hydrogeological Impact Assessment

Variable Head Permeability Test

SOCOTEC

TYPE OF TEST	Borehole
	Falling Head

DETAILS OF INSTALLATION:

Depth of borehole	5.00	m BGL
Depth of casing	5.00	m BGL
Groundwater level for analysis	2.40	m BGL
Height of casing above ground level (datum)	0.00	m

Elapsed time, t (minutes)	Depth to water from datum (m)	Head, H_t (m)	Head Ratio H_t/H_0
0	0.00	2.40	1.00
0.5	0.01	2.39	1.00
1	0.01	2.39	1.00
1.5	0.01	2.39	1.00
2	0.01	2.39	1.00
2.5	0.01	2.39	1.00
3	0.01	2.39	1.00
3.5	0.01	2.39	1.00
4	0.01	2.39	1.00
4.5	0.01	2.39	1.00
5	0.02	2.38	0.99
6	0.02	2.38	0.99
7	0.02	2.38	0.99
8	0.02	2.38	0.99
9	0.02	2.38	0.99
10	0.02	2.38	0.99
15	0.02	2.38	0.99
20	0.03	2.37	0.99
25	0.03	2.37	0.99
30	0.03	2.37	0.99
35	0.04	2.36	0.98
40	0.04	2.36	0.98
45	0.04	2.36	0.98
50	0.05	2.35	0.98
55	0.05	2.35	0.98
60	0.05	2.35	0.98

BOREHOLE No.	BH1
TEST NUMBER	1
DATE OF TEST	09 Jan 2019

CONDITIONS OF TEST ZONE

Ref BS 5930:1999+A2 (2010) Figure 6

Soil flush with bottom in uniform soil (b)

Diameter of borehole (D)	150	mm
Length of response zone (L)	0	mm
Intake Factor (F)	0.41	m

REMARKS

Depth to groundwater prior to test	2.40	m BGL

Depth to water measured from top of casing

Permeability calculated using BS 5930:1999 (Section 25.4.6) (General Approach)

Permeability calculated from minimal change in head ratio, result should be treated with caution.

CALCULATED VALUES

Differential head at start of test, H_0	2.40	m
Differential head at end of test, H_f	2.35	m
Time Elapsed at end of test	60	mins

General Approach

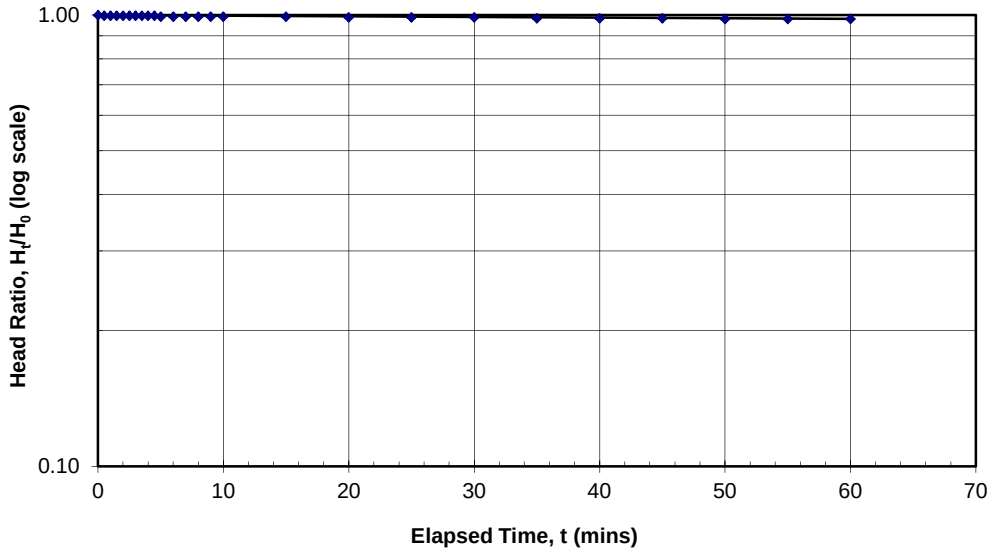
Coordinates of best fit line to data:

t_1 = 0.0 mins H_1/H_0 = 1.000

t_2 = 60.0 mins H_2/H_0 = 0.980

Permeability (k) 2.4E-07 m/sec

Head Ratio against Time



Notes:

Project	WYNNSTAY AVENUE, WREXHAM
Project No.	F8054-18
Carried out for	Morgan Sindall

Test **BH1T1**

Variable Head Permeability Test

LOCATION TYPE	Standpipe
TEST TYPE	Falling Head

DETAILS OF TEST ZONE:

Top of response zone	3.00	m BGL
Base of response zone	6.50	m BGL
Diameter of borehole (D)	150	mm
Height of tubing above ground level (datum)	0.00	m
Diameter of standpipe tubing	50	mm

BOREHOLE No.	BH1
TEST NUMBER	1
DATE OF TEST	14-Feb-19

TEST ZONE CONDITIONS

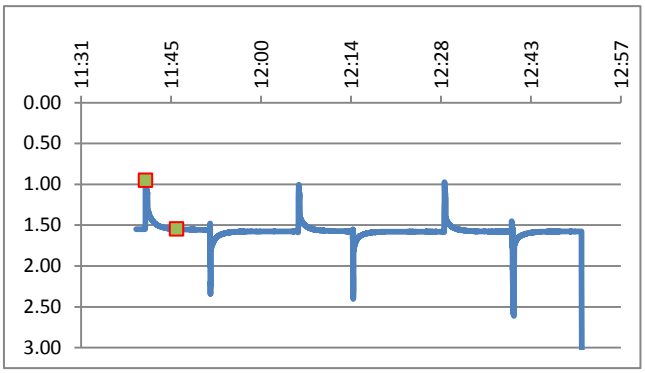
Diameter of response zone (D)	150	mm
Length of response zone (L)	3500	mm
Standpipe piezometer		
Shape factor (F) after Hvorslev (1951)	6.52	m

GROUNDWATER CONDITIONS

Depth to groundwater prior to test	1.65	m BGL
Groundwater level for analysis (Based on end of test water depth)	1.56	m BGL

TEST DATA

Elapsed time, t (minutes)	Depth to water below datum (m)	Head, H_t (m)	Head Ratio H_t/H_0
0	0.95	0.61	1.00
0.5	1.35	0.21	0.34
1	1.42	0.14	0.23
1.5	1.47	0.09	0.15
2	1.51	0.05	0.08
2.5	1.52	0.04	0.07
3	1.53	0.03	0.05
3.5	1.54	0.02	0.03
4	1.55	0.01	0.02
4.5	1.56	0.00	0.00
5	1.56	0.00	0.00
6	1.56	0.00	0.00
7	1.56	0.00	0.00
8	1.56	0.00	0.00
9	1.56	0.00	0.00
10	1.56	0.00	0.00



CALCULATED VALUES

Permeability calculation based on BS EN ISO 22282-2 : 2012 Section B.4.2 (Hvorslev method - general approach)

Differential head at start of test, H_0	0.61	m
Differential head at end of test, H_f	0.00	m
Time elapsed at end of test	10	mins
Proportion of test recovery	100	%

Coordinates of best fit line to data:

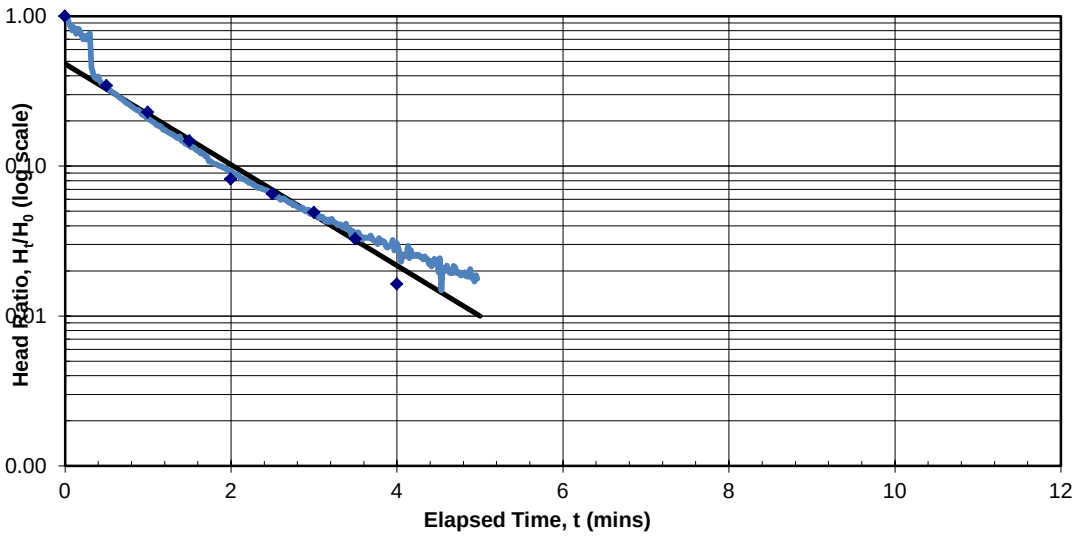
t_1 = 0.0 mins	H_1/H_0 = 0.480
t_2 = 5.0 mins	H_2/H_0= 0.010

Permeability (k) = 3.9E-06 m/sec

REMARKS

Slug testing carried out using dataloggers

Head Ratio against Time



AGS

Testing: JP/AE
Checked: RF
Approved: PH

Notes:

Project: Wynnstay Avenue, Wrexham
Project No.: F8054-18
Carried out for: Morgan Sindall

Test: **BH1T1**

Variable Head Permeability Test

LOCATION TYPE	Standpipe
TEST TYPE	Rising Head

DETAILS OF TEST ZONE:

Top of response zone	3.00	m BGL
Base of response zone	6.50	m BGL
Diameter of borehole (D)	150	mm
Height of tubing above ground level (datum)	0.00	m
Diameter of standpipe tubing	50	mm

BOREHOLE No.	BH1
TEST NUMBER	2
DATE OF TEST	14-Feb-19

TEST ZONE CONDITIONS

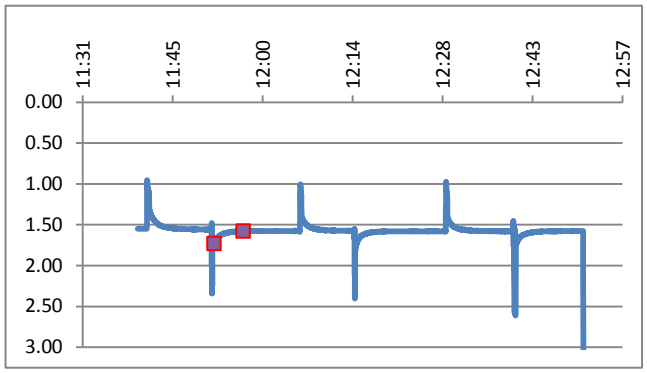
Diameter of response zone (D)	150	mm
Length of response zone (L)	3500	mm
Standpipe piezometer		
Shape factor (F) after Hvorslev (1951)	6.52	m

GROUNDWATER CONDITIONS

Depth to groundwater prior to test	1.55	m BGL
Groundwater level for analysis (Based on end of test water depth)	1.55	m BGL

TEST DATA

Elapsed time, t (minutes)	Depth to water below datum (m)	Head, H_t (m)	Head Ratio H_t/H_0
0	1.73	0.18	1.00
0.5	1.66	0.11	0.61
1	1.63	0.08	0.44
1.5	1.61	0.06	0.33
2	1.59	0.04	0.22
2.5	1.58	0.03	0.17
3	1.57	0.02	0.11
3.5	1.57	0.02	0.11
4	1.56	0.01	0.06
4.5	1.56	0.01	0.06
5	1.56	0.01	0.06
6	1.55	0.00	0.00
7	1.55	0.00	0.00
8	1.55	0.00	0.00
9	1.55	0.00	0.00
10	1.55	0.00	0.00



CALCULATED VALUES

Permeability calculation based on BS EN ISO 22282-2 : 2012 Section B.4.2 (Hvorslev method - general approach)

Differential head at start of test, H_0	0.18	m
Differential head at end of test, H_f	0.00	m
Time elapsed at end of test	10	mins
Proportion of test recovery	100	%

Coordinates of best fit line to data:

t_1 = 0.0 mins H_1/H_0 = 1.000

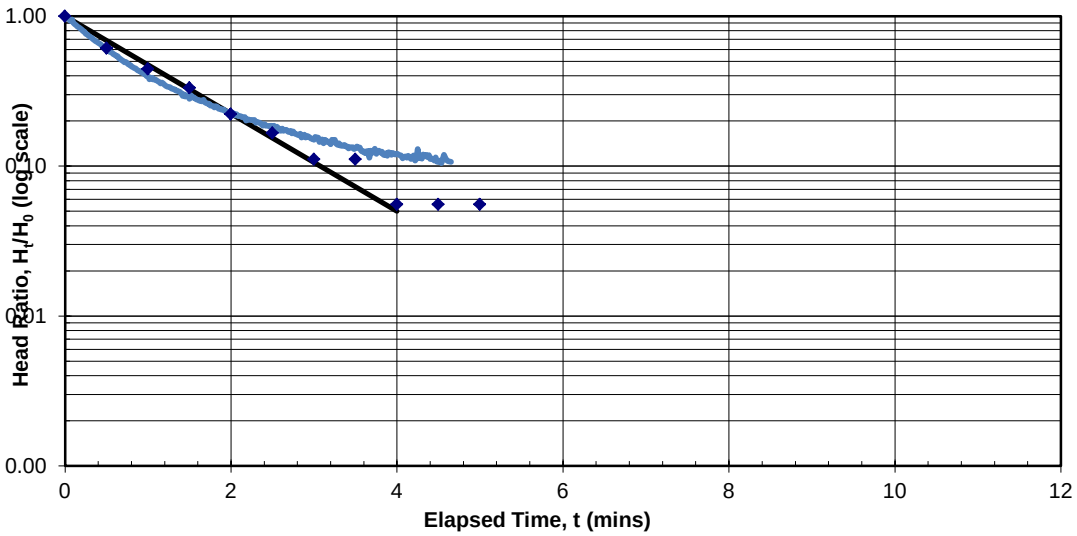
t_2 = 4.0 mins H_2/H_0= 0.050

Permeability (k) = 3.8E-06 m/sec

REMARKS

Slug testing carried out using dataloggers

Head Ratio against Time



AGS

Testing: JP/AE
Checked: RF
Approved: PH

Notes:

Project: Wynnstay Avenue, Wrexham
Project No.: F8054-18
Carried out for: Morgan Sindall

Test: **BH1T1**

Variable Head Permeability Test

LOCATION TYPE	Standpipe
TEST TYPE	Falling Head

DETAILS OF TEST ZONE:

Top of response zone	3.00	m BGL
Base of response zone	6.50	m BGL
Diameter of borehole (D)	150	mm
Height of tubing above ground level (datum)	0.00	m
Diameter of standpipe tubing	50	mm

BOREHOLE No.	BH1
TEST NUMBER	3
DATE OF TEST	14-Feb-19

TEST ZONE CONDITIONS

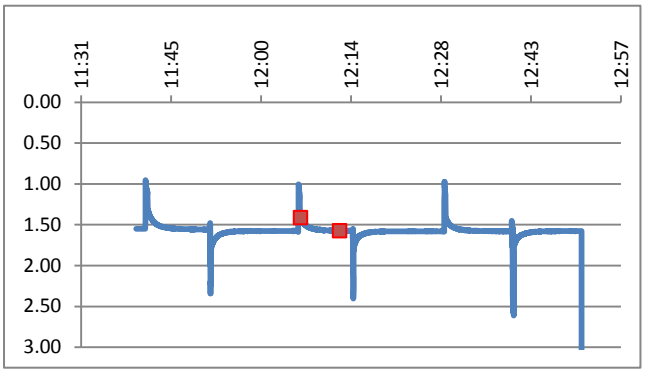
Diameter of response zone (D)	150	mm
Length of response zone (L)	3500	mm
Standpipe piezometer		
Shape factor (F) after Hvorslev (1951)	6.52	m

GROUNDWATER CONDITIONS

Depth to groundwater prior to test	1.55	m BGL
Groundwater level for analysis (Based on end of test water depth)	1.55	m BGL

TEST DATA

Elapsed time, t (minutes)	Depth to water below datum (m)	Head, H_t (m)	Head Ratio H_t/H_0
0	1.42	0.13	1.00
0.5	1.48	0.07	0.54
1	1.51	0.04	0.31
1.5	1.52	0.03	0.23
2	1.53	0.02	0.15
2.5	1.54	0.01	0.08
3	1.55	0.00	0.00
3.5	1.55	0.00	0.00
4	1.55	0.00	0.00
5	1.55	0.00	0.00
6	1.55	0.00	0.00
7	1.55	0.00	0.00
8	1.55	0.00	0.00



CALCULATED VALUES

Permeability calculation based on BS EN ISO 22282-2 : 2012 Section B.4.2 (Hvorslev method - general approach)

Differential head at start of test, H_0	0.13	m
Differential head at end of test, H_f	0.00	m
Time elapsed at end of test	8	mins
Proportion of test recovery	100	%

Coordinates of best fit line to data:

t_1 = 0.0 mins H_1/H_0 = 1.000

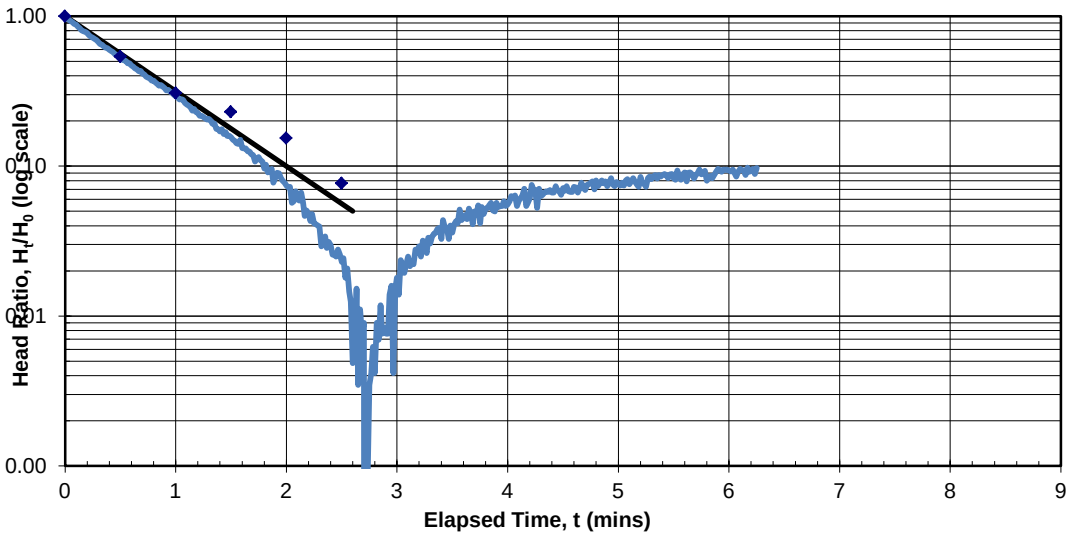
t_2 = 2.6 mins H_2/H_0= 0.050

Permeability (k) = 5.8E-06 m/sec

REMARKS

Slug testing carried out using dataloggers

Head Ratio against Time



AGS

Testing: JP/AE
Checked: RF
Approved: PH

Notes:

Project: Wynnstay Avenue, Wrexham

Project No.: F8054-18

Carried out for: Morgan Sindall

Test: BH1T1

Variable Head Permeability Test

LOCATION TYPE	Standpipe
TEST TYPE	Rising Head

DETAILS OF TEST ZONE:

Top of response zone	3.00	m BGL
Base of response zone	6.50	m BGL
Diameter of borehole (D)	150	mm
Height of tubing above ground level (datum)	0.00	m
Diameter of standpipe tubing	50	mm

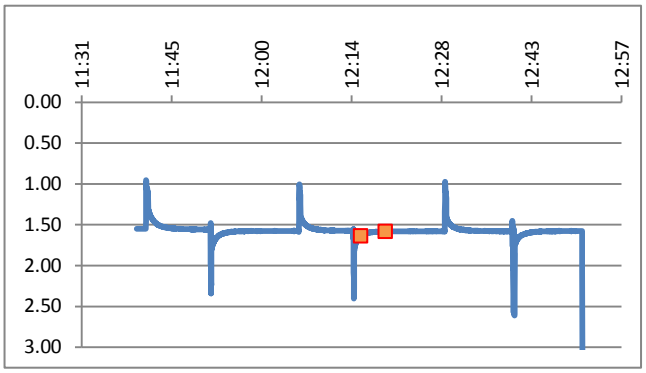
BOREHOLE No.	BH1
TEST NUMBER	4
DATE OF TEST	14-Feb-19

TEST ZONE CONDITIONS

Diameter of response zone (D)	150	mm
Length of response zone (L)	3500	mm
Standpipe piezometer		
Shape factor (F) after Hvorslev (1951)	6.52	m

TEST DATA

Elapsed time, t (minutes)	Depth to water below datum (m)	Head, H_t (m)	Head Ratio H_t/H_0
0	1.63	0.08	1.00
0.5	1.61	0.06	0.75
1	1.59	0.04	0.50
1.5	1.58	0.03	0.38
2	1.57	0.02	0.25
2.5	1.56	0.01	0.13
3	1.56	0.01	0.13
2.5	1.56	0.01	0.13
4	1.56	0.01	0.13
5	1.55	0.00	0.00
6	1.55	0.00	0.00
7	1.55	0.00	0.00
8	1.55	0.00	0.00
9	1.55	0.00	0.00
10	1.55	0.00	0.00



GROUNDWATER CONDITIONS

Depth to groundwater prior to test	1.55	m BGL
Groundwater level for analysis	1.55	m BGL
(Based on end of test water depth)		

CALCULATED VALUES

Permeability calculation based on BS EN ISO 22282-2 : 2012 Section B.4.2 (Hvorslev method - general approach)

Differential head at start of test, H_0	0.08	m
Differential head at end of test, H_f	0.00	m
Time elapsed at end of test	10	mins
Proportion of test recovery	100	%

Coordinates of best fit line to data:

t_1 = 0.0 mins H_1/H_0 = 1.000

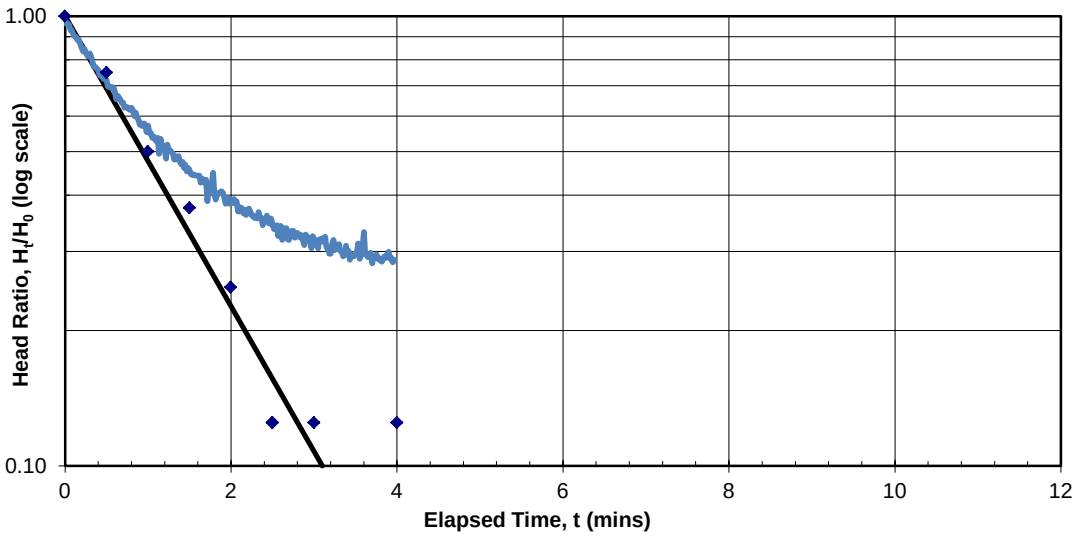
t_2 = 3.1 mins H_2/H_0= 0.100

Permeability (k) = 3.7E-06 m/sec

REMARKS

Slug testing carried out using dataloggers

Head Ratio against Time



AGS

Testing: JP/AE
Checked: RF
Approved: PH

Notes:

Project Wynnstay Avenue, Wrexham

Project No. F8054-18

Carried out for Morgan Sindall

Test BH1T1

Variable Head Permeability Test

LOCATION TYPE	Standpipe
TEST TYPE	Falling Head

DETAILS OF TEST ZONE:

Top of response zone	3.00	m BGL
Base of response zone	6.50	m BGL
Diameter of borehole (D)	150	mm
Height of tubing above ground level (datum)	0.00	m
Diameter of standpipe tubing	50	mm

BOREHOLE No.	BH1
TEST NUMBER	5
DATE OF TEST	14-Feb-19

TEST ZONE CONDITIONS

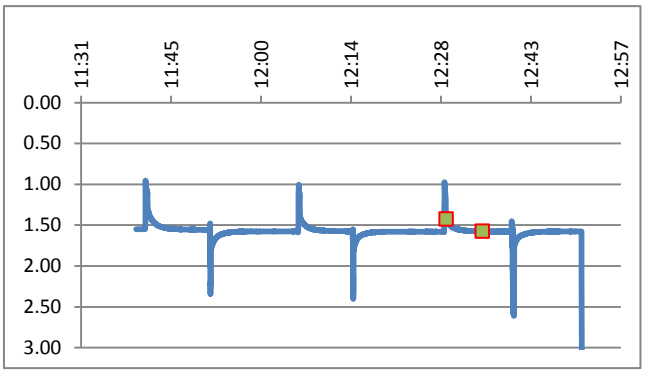
Diameter of response zone (D)	150	mm
Length of response zone (L)	3500	mm
Standpipe piezometer		
Shape factor (F) after Hvorslev (1951)	6.52	m

GROUNDWATER CONDITIONS

Depth to groundwater prior to test	1.55	m BGL
Groundwater level for analysis (Based on end of test water depth)	1.55	m BGL

TEST DATA

Elapsed time, t (minutes)	Depth to water below datum (m)	Head, H_t (m)	Head Ratio H_t/H_0
0	1.43	0.12	1.00
0.5	1.48	0.07	0.58
1	1.51	0.04	0.33
1.5	1.50	0.05	0.42
2	1.53	0.02	0.17
2.5	1.54	0.01	0.08
3	1.54	0.01	0.08
3.5	1.54	0.01	0.08
4	1.54	0.01	0.08
4.5	1.55	0.00	0.00
5	1.55	0.00	0.00
6	1.55	0.00	0.00
7	1.55	0.00	0.00
8	1.55	0.00	0.00
9	1.55	0.00	0.00
10	1.55	0.00	0.00



CALCULATED VALUES

Permeability calculation based on BS EN ISO 22282-2 : 2012 Section B.4.2 (Hvorslev method - general approach)

Differential head at start of test, H_0	0.12	m
Differential head at end of test, H_f	0.00	m
Time elapsed at end of test	10	mins
Proportion of test recovery	100	%

Coordinates of best fit line to data:

t_1 = 0.0 mins H_1/H_0 = 1.000

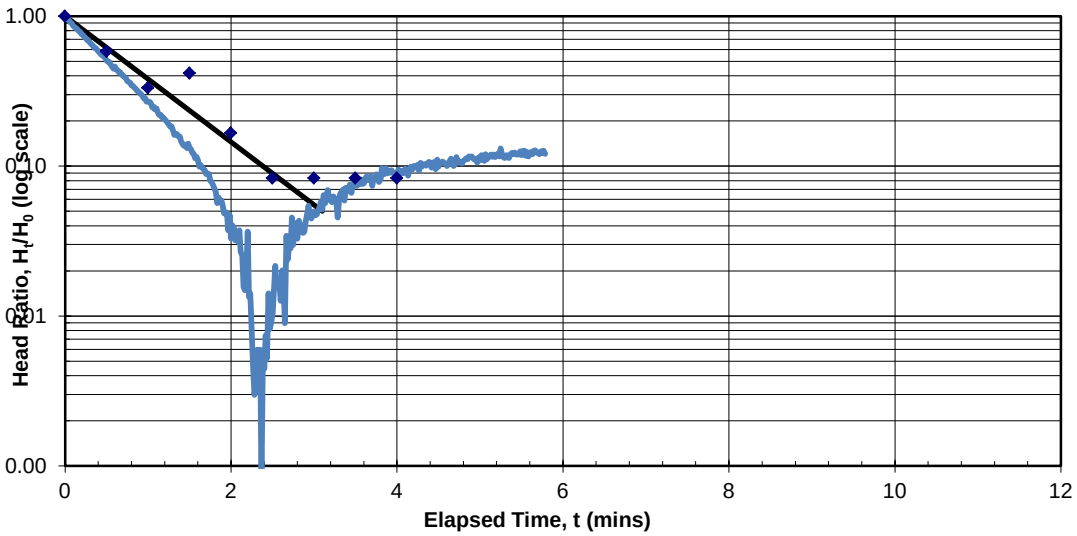
t_2 = 3.1 mins H_2/H_0= 0.050

Permeability (k) = 4.9E-06 m/sec

REMARKS

Slug testing carried out using dataloggers

Head Ratio against Time



AGS

Testing: JP/AE
Checked: RF
Approved: PH

Notes:

Project: Wynnstay Avenue, Wrexham
Project No.: F8054-18
Carried out for: Morgan Sindall

Test: BH1T5

Variable Head Permeability Test

LOCATION TYPE	Standpipe
TEST TYPE	Rising Head

DETAILS OF TEST ZONE:

Top of response zone	3.00	m BGL
Base of response zone	6.50	m BGL
Diameter of borehole (D)	150	mm
Height of tubing above ground level (datum)	0.00	m
Diameter of standpipe tubing	50	mm

BOREHOLE No.	BH1
TEST NUMBER	6
DATE OF TEST	14-Feb-19

TEST ZONE CONDITIONS

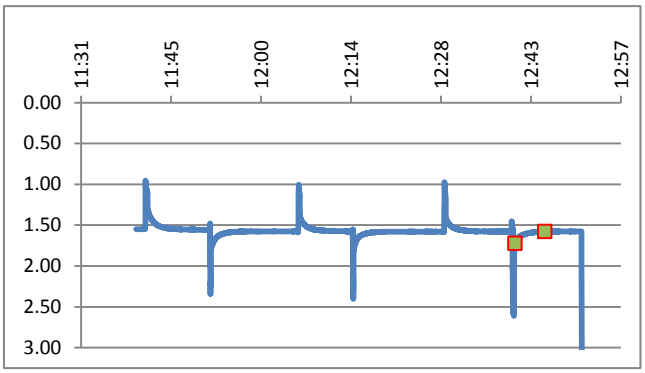
Diameter of response zone (D)	150	mm
Length of response zone (L)	3500	mm
Standpipe piezometer		
Shape factor (F) after Hvorslev (1951)	6.52	m

GROUNDWATER CONDITIONS

Depth to groundwater prior to test	1.55	m BGL
Groundwater level for analysis (Based on end of test water depth)	1.55	m BGL

TEST DATA

Elapsed time, t (minutes)	Depth to water below datum (m)	Head, H_t (m)	Head Ratio H_t/H_0
0	1.72	0.17	1.00
0.5	1.65	0.10	0.59
1	1.62	0.07	0.41
1.5	1.60	0.05	0.29
2	1.58	0.03	0.18
2.5	1.57	0.02	0.12
3	1.56	0.01	0.06
3.5	1.55	0.00	0.00
4	1.55	0.00	0.00
4.5	1.55	0.00	0.00
5	1.55	0.00	0.00
6	1.55	0.00	0.00
7	1.55	0.00	0.00
8	1.55	0.00	0.00
9	1.55	0.00	0.00
10	1.55	0.00	0.00



CALCULATED VALUES

Permeability calculation based on BS EN ISO 22282-2 : 2012 Section B.4.2 (Hvorslev method - general approach)

Differential head at start of test, H_0	0.17	m
Differential head at end of test, H_f	0.00	m
Time elapsed at end of test	10	mins
Proportion of test recovery	100	%

Coordinates of best fit line to data:

t_1 = 0.0 mins H_1/H_0 = 1.000

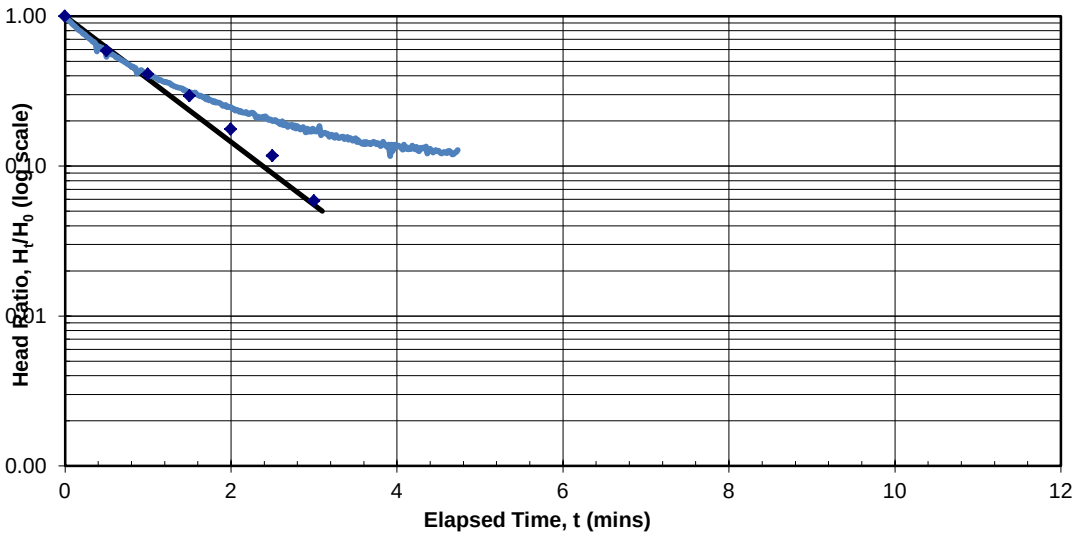
t_2 = 3.1 mins H_2/H_0= 0.050

Permeability (k) = 4.9E-06 m/sec

REMARKS

Slug testing carried out using dataloggers

Head Ratio against Time



AGS

Testing: JP/AE
Checked: RF
Approved: PH

Notes:

Project: Wynnstay Avenue, Wrexham
Project No.: F8054-18
Carried out for: Morgan Sindall

Test: **BH1T6**

ARUP

Job No. 241513		Rev. 1
Prepared by TSR	Date 06/09/2019	Checked by LB

Client: Welsh Water

Job Title: Wrexham Hydrogeological Impact Assessment

Title: BH1 - Variable head test analysis

Rising head test (BS22282-2)

Time (min)	Dip (mbd)	y (m)	yt/y0
0.0	1.72	0.17	1.00
0.5	1.65	0.10	0.59
1.0	1.62	0.07	0.41
1.5	1.60	0.05	0.29
2.0	1.58	0.03	0.18
2.5	1.57	0.02	0.12
3.0	1.56	0.01	0.06
3.5	1.55	0.00	0.00
4.0	1.55	0.00	0.00
4.5	1.55	0.00	0.00
5.0	1.55	0.00	0.00
6.0	1.55	0.00	0.00
7.0	1.55	0.00	0.00
8.0	1.55	0.00	0.00
9.0	1.55	0.00	0.00
10.0	1.55	0.00	0.00

Datum	=	unknown
BH diameter, D (m)	=	0.15
Pipe radius, r (m)	=	0.025
BH radius, R (m)	=	0.075
BH area, A (m2)	=	0.02
Initial SWL (mbd)	=	1.55
Test length, L (m)	=	3.5
L/D	=	23.33
Shape factor, F	=	5.7
Hyd. Cond., K (m/s)	=	5.72E-06

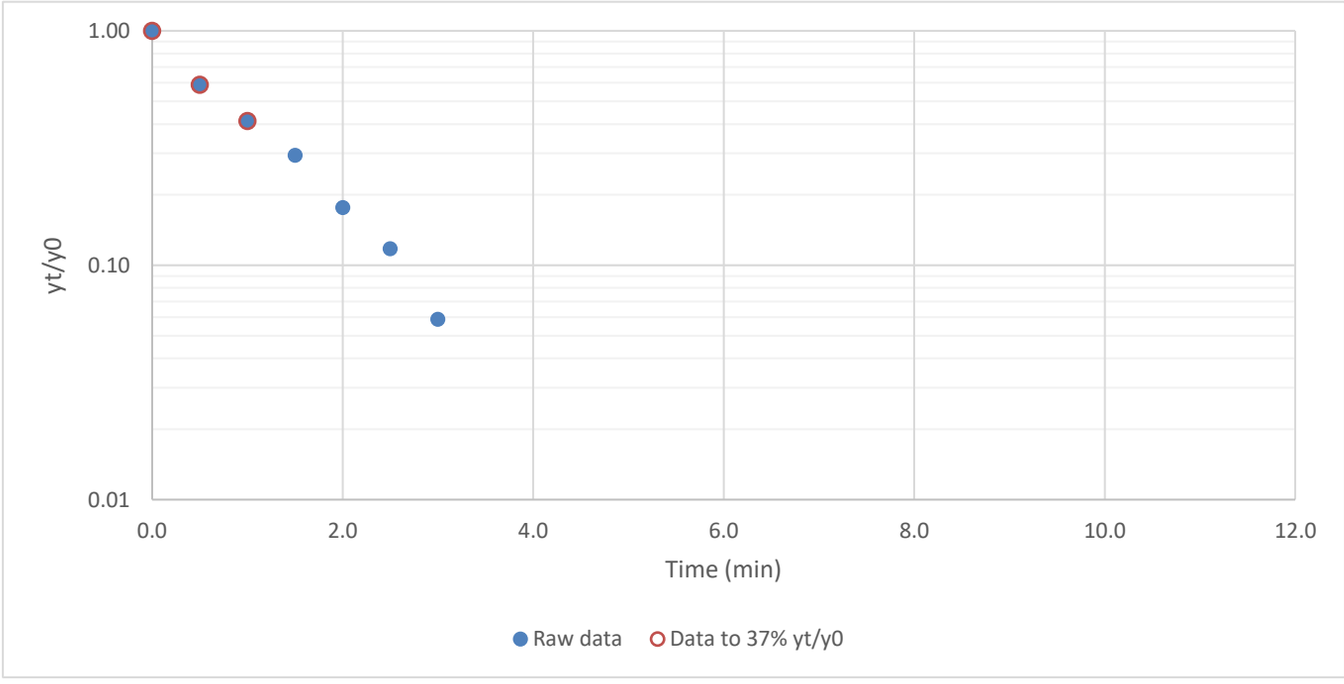
Shape factor equation adopted:

$$F = \frac{2 \cdot \pi \cdot L}{\ln\left(2 \cdot L/D\right)}$$

Valid for L/D > 10

Hydraulic conductivity

$$k = \frac{r^2 \cdot \ln\left(L/R\right)}{2 \cdot L \cdot t_o}$$



Variable Head Permeability Test

SOCOTEC

TYPE OF TEST	Borehole
	Falling Head

DETAILS OF INSTALLATION:

Depth of borehole	4.00	m BGL
Depth of casing	4.00	m BGL
Groundwater level for analysis	1.69	m BGL
Height of casing above ground level (datum)	0.50	m

Elapsed time, t (minutes)	Depth to water from datum (m)	Head, H_t (m)	Head Ratio H_t/H_0
0	0.00	2.19	1.00
0.5	0.01	2.18	1.00
1	0.01	2.18	1.00
1.5	0.01	2.18	1.00
2	0.01	2.18	1.00
2.5	0.01	2.18	1.00
3	0.02	2.17	0.99
3.5	0.02	2.17	0.99
4	0.02	2.17	0.99
4.5	0.02	2.17	0.99
5	0.02	2.17	0.99
6	0.03	2.16	0.99
7	0.03	2.16	0.99
8	0.03	2.16	0.99
9	0.04	2.15	0.98
10	0.04	2.15	0.98
15	0.05	2.14	0.98
20	0.05	2.14	0.98
25	0.05	2.14	0.98
30	0.06	2.13	0.97

BOREHOLE No.	BH2
TEST NUMBER	1
DATE OF TEST	08 Jan 2019

CONDITIONS OF TEST ZONE

Ref BS 5930:1999+A2 (2010) Figure 6

Soil flush with bottom in uniform soil (b)

Diameter of borehole (D)	150	mm
Length of response zone (L)	0	mm
Intake Factor (F)	0.41	m

REMARKS

Depth to groundwater prior to test	1.69	m BGL

Depth to water measured from top of casing

Permeability calculated using BS 5930:1999 (Section 25.4.6) (General Approach)

Permeability calculated from minimal change in head ratio, result should be treated with caution.

Test terminated after 30 minutes with client agreement.

CALCULATED VALUES

Differential head at start of test, H_0	2.19	m
Differential head at end of test, H_f	2.13	m
Time Elapsed at end of test	30	mins

General Approach

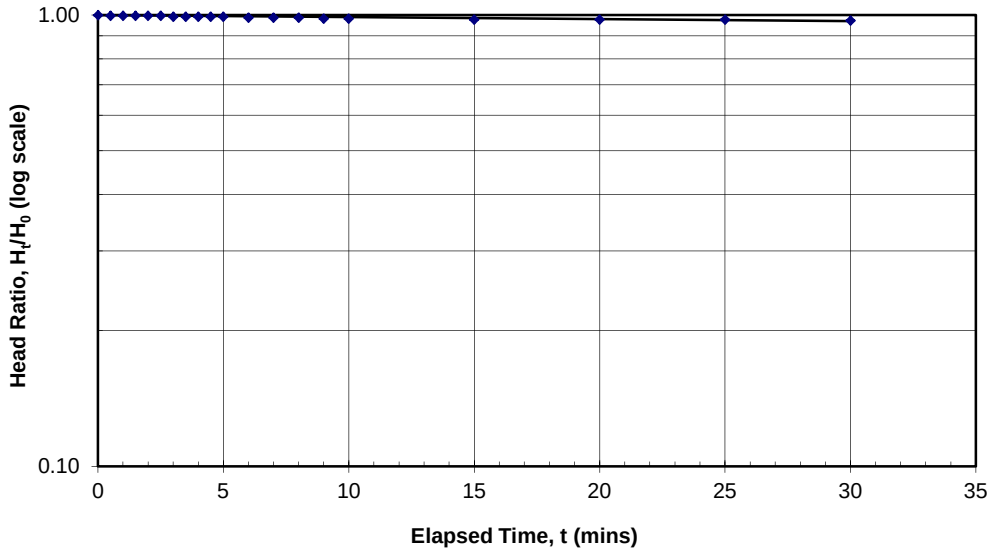
Coordinates of best fit line to data:

t_1 = 0.0 mins H_1/H_0 = 1.000

t_2 = 30.0 mins H_2/H_0 = 0.970

Permeability (k) 7.2E-07 m/sec

Head Ratio against Time



Notes:

Project	WYNNSTAY AVENUE, WREXHAM
Project No.	F8054-18
Carried out for	Morgan Sindall

Test **BH2T1**

Variable Head Permeability Test

LOCATION TYPE	Standpipe
TEST TYPE	Falling Head

DETAILS OF TEST ZONE:

Top of response zone	3.00	m BGL
Base of response zone	6.00	m BGL
Diameter of borehole (D)	150	mm
Height of tubing above ground level (datum)	0.00	m
Diameter of standpipe tubing	50	mm

BOREHOLE No.	BH2
TEST NUMBER	1
DATE OF TEST	14-Feb-19

TEST ZONE CONDITIONS

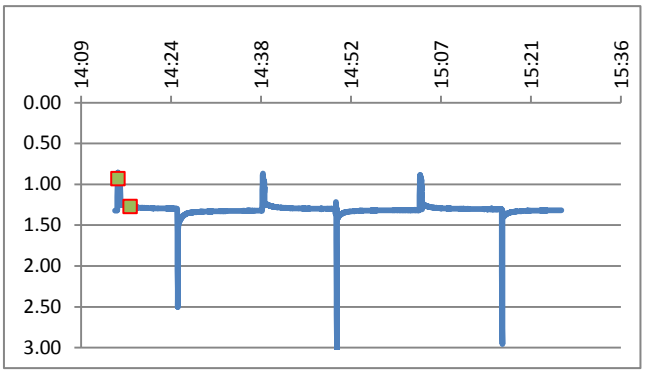
Diameter of response zone (D)	150	mm
Length of response zone (L)	3000	mm
Standpipe piezometer		
Shape factor (F) after Hvorslev (1951)	5.81	m

GROUNDWATER CONDITIONS

Depth to groundwater prior to test	1.34	m BGL
Groundwater level for analysis (Based on end of test water depth)	1.32	m BGL

TEST DATA

Elapsed time, t (minutes)	Depth to water below datum (m)	Head, H_t (m)	Head Ratio H_t/H_0
0	1.26	0.06	1.00
0.5	1.28	0.04	0.67
1	1.30	0.02	0.33
1.5	1.30	0.02	0.33
2	1.31	0.01	0.17
2.5	1.32	0.00	0.00
3	1.32	0.00	0.00
3.5	1.32	0.00	0.00
4	1.32	0.00	0.00
4.5	1.32	0.00	0.00
5	1.32	0.00	0.00
6	1.32	0.00	0.00
7	1.32	0.00	0.00
8	1.32	0.00	0.00



CALCULATED VALUES

Permeability calculation based on BS EN ISO 22282-2 : 2012 Section B.4.2 (Hvorslev method - general approach)

Differential head at start of test, H_0	0.06	m
Differential head at end of test, H_f	0.00	m
Time elapsed at end of test	8	mins
Proportion of test recovery	100	%

Coordinates of best fit line to data:

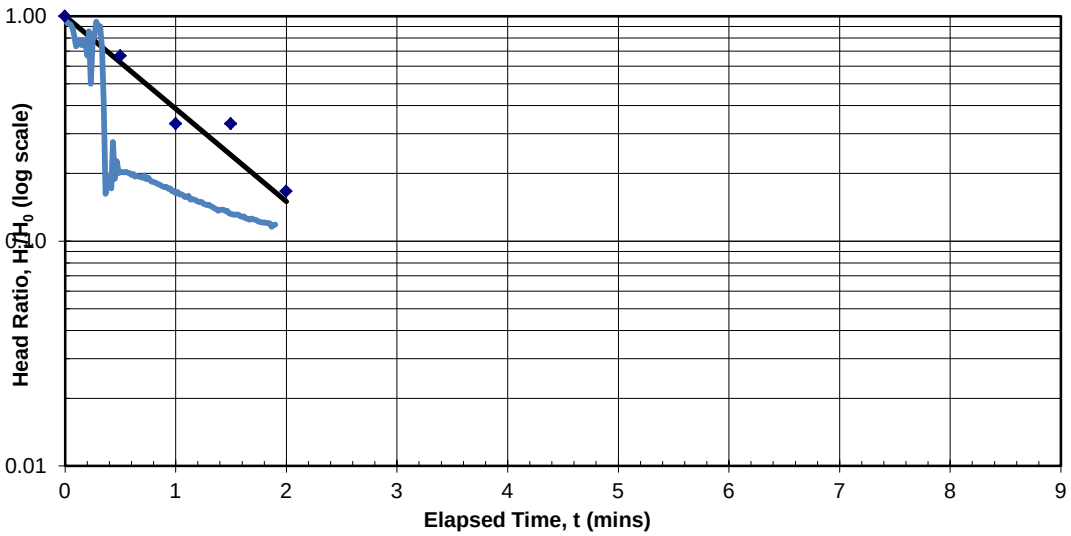
t_1 = 0.0 mins	H_1/H_0 = 1.000
t_2 = 2.0 mins	H_2/H_0= 0.150

Permeability (k) = 5.3E-06 m/sec

REMARKS

Slug testing carried out using dataloggers

Head Ratio against Time



AGS

Testing: JP/AE
Checked: RF
Approved: PH

Notes:

Project Wynnstay Avenue, Wrexham
Project No. F8054-18
Carried out for Morgan Sindall

Test BH2T1

Variable Head Permeability Test

LOCATION TYPE	Standpipe
TEST TYPE	Rising Head

DETAILS OF TEST ZONE:

Top of response zone	3.00	m BGL
Base of response zone	6.00	m BGL
Diameter of borehole (D)	150	mm
Height of tubing above ground level (datum)	0.00	m
Diameter of standpipe tubing	50	mm

BOREHOLE No.	BH2
TEST NUMBER	2
DATE OF TEST	14-Feb-19

TEST ZONE CONDITIONS

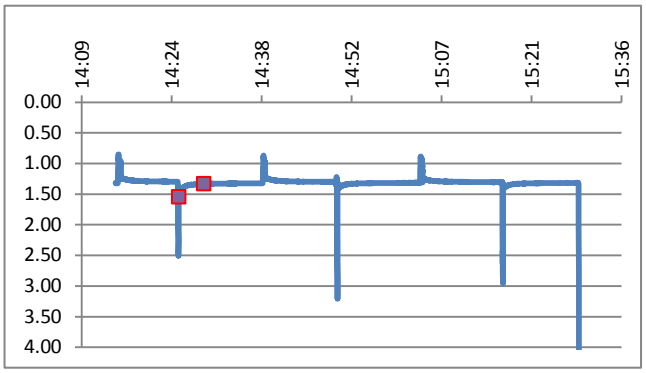
Diameter of response zone (D)	150	mm
Length of response zone (L)	3000	mm
Standpipe piezometer		
Shape factor (F) after Hvorslev (1951)	5.81	m

GROUNDWATER CONDITIONS

Depth to groundwater prior to test	1.34	m BGL
Groundwater level for analysis (Based on end of test water depth)	1.34	m BGL

TEST DATA

Elapsed time, t (minutes)	Depth to water below datum (m)	Head, H_t (m)	Head Ratio H_t/H_0
0	1.48	0.14	1.00
0.5	1.43	0.09	0.64
1	1.39	0.05	0.36
1.5	1.37	0.03	0.21
2	1.36	0.02	0.14
2.5	1.36	0.02	0.14
3	1.36	0.02	0.14
3.5	1.35	0.01	0.07
4	1.35	0.01	0.07
4.5	1.34	0.00	0.00
5	1.34	0.00	0.00
6	1.34	0.00	0.00
7	1.34	0.00	0.00
8	1.34	0.00	0.00
9	1.34	0.00	0.00
10	1.34	0.00	0.00



CALCULATED VALUES

Permeability calculation based on BS EN ISO 22282-2 : 2012 Section B.4.2 (Hvorslev method - general approach)

Differential head at start of test, H_0	0.14	m
Differential head at end of test, H_f	0.00	m
Time elapsed at end of test	10	mins
Proportion of test recovery	100	%

Coordinates of best fit line to data:

t_1 = 0.0 mins H_1/H_0 = 1.000

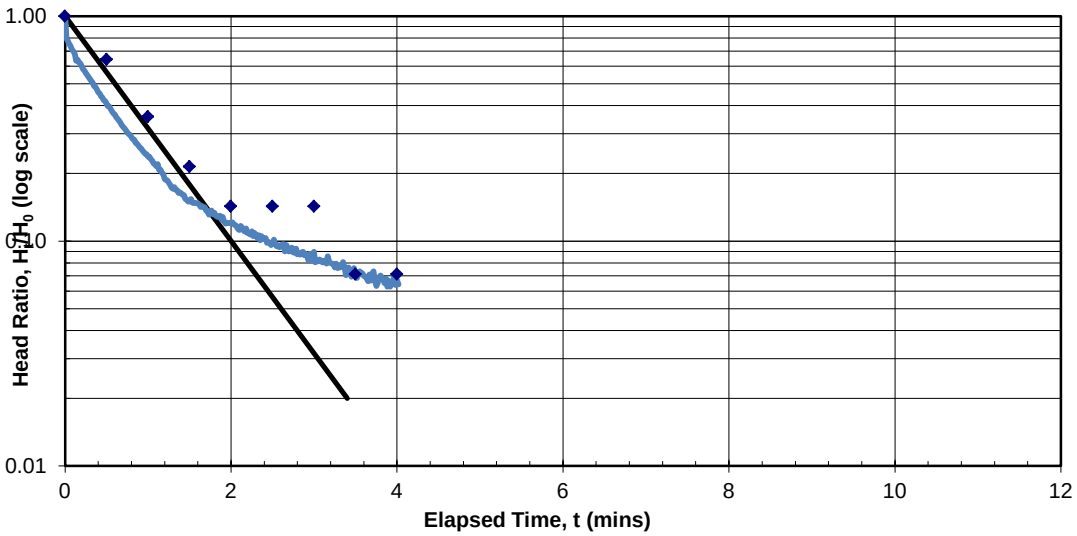
t_2 = 3.4 mins H_2/H_0= 0.020

Permeability (k) = 6.5E-06 m/sec

REMARKS

Slug testing carried out using dataloggers

Head Ratio against Time



AGS

Testing: JP/AE
Checked: RF
Approved: PH

Notes:

Project Wynnstay Avenue, Wrexham

Project No. F8054-18

Carried out for Morgan Sindall

Test BH2T1

Variable Head Permeability Test

SOCOTEC

LOCATION TYPE	Standpipe
TEST TYPE	Falling Head

DETAILS OF TEST ZONE:

Top of response zone	3.00	m BGL
Base of response zone	6.00	m BGL
Diameter of borehole (D)	150	mm
Height of tubing above ground level (datum)	0.00	m
Diameter of standpipe tubing	50	mm

BOREHOLE No.	BH2
TEST NUMBER	3
DATE OF TEST	14-Feb-19

TEST ZONE CONDITIONS

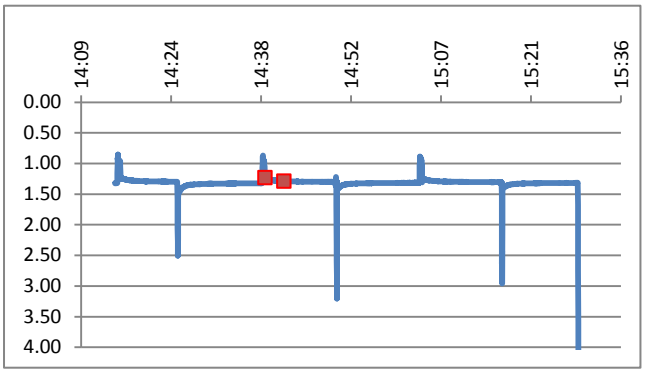
Diameter of response zone (D)	150	mm
Length of response zone (L)	3000	mm
Standpipe piezometer		
Shape factor (F) after Hvorslev (1951)	5.81	m

GROUNDWATER CONDITIONS

Depth to groundwater prior to test	1.34	m BGL
Groundwater level for analysis (Based on end of test water depth)	1.33	m BGL

TEST DATA

Elapsed time, t (minutes)	Depth to water below datum (m)	Head, H_t (m)	Head Ratio H_t/H_0
0	1.26	0.07	1.00
0.5	1.28	0.05	0.71
1	1.29	0.04	0.57
1.5	1.30	0.03	0.43
2	1.31	0.02	0.29
2.5	1.31	0.02	0.29
3	1.32	0.01	0.14
3.5	1.32	0.01	0.14
4	1.32	0.01	0.14
4.5	1.32	0.01	0.14
5	1.32	0.01	0.14
6	1.33	0.00	0.00
7	1.33	0.00	0.00
8	1.33	0.00	0.00



CALCULATED VALUES

Permeability calculation based on BS EN ISO 22282-2 : 2012 Section B.4.2 (Hvorslev method - general approach)

Differential head at start of test, H_0	0.07	m
Differential head at end of test, H_f	0.00	m
Time elapsed at end of test	8	mins
Proportion of test recovery	100	%

Coordinates of best fit line to data:

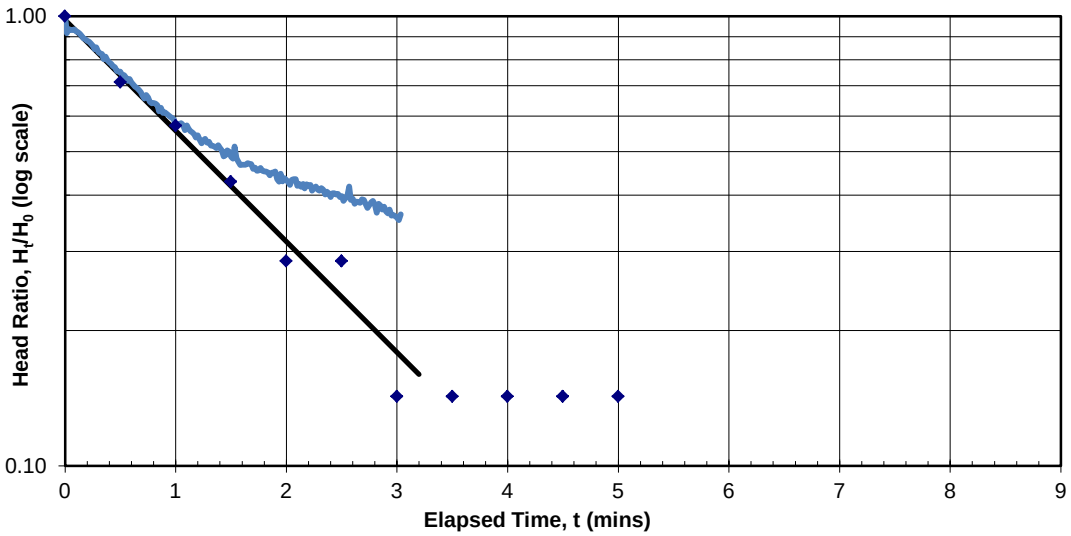
t_1 = 0.0 mins	H_1/H_0 = 0.980
t_2 = 3.2 mins	H_2/H_0= 0.160

Permeability (k) = 3.2E-06 m/sec

REMARKS

Slug testing carried out using dataloggers

Head Ratio against Time



AGS

Testing: JP/AE
Checked: RF
Approved: PH

Notes:

Project Wynnstay Avenue, Wrexham

Project No. F8054-18

Carried out for Morgan Sindall

Test BH2T1

Variable Head Permeability Test

LOCATION TYPE	Standpipe
TEST TYPE	Rising Head

DETAILS OF TEST ZONE:

Top of response zone	3.00	m BGL
Base of response zone	6.00	m BGL
Diameter of borehole (D)	150	mm
Height of tubing above ground level (datum)	0.00	m
Diameter of standpipe tubing	50	mm

BOREHOLE No.	BH2
TEST NUMBER	4
DATE OF TEST	14-Feb-19

TEST ZONE CONDITIONS

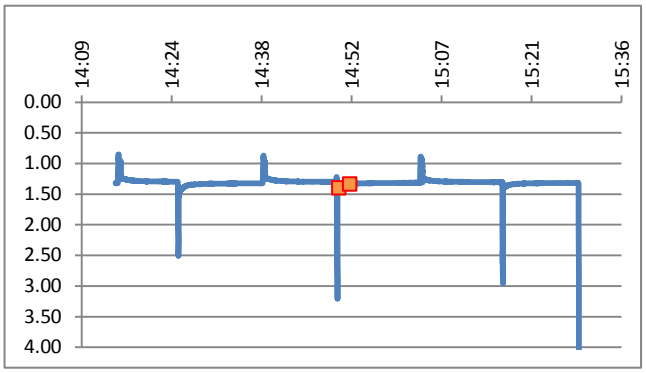
Diameter of response zone (D)	150	mm
Length of response zone (L)	3000	mm
Standpipe piezometer		
Shape factor (F) after Hvorslev (1951)	5.81	m

GROUNDWATER CONDITIONS

Depth to groundwater prior to test	1.34	m BGL
Groundwater level for analysis (Based on end of test water depth)	1.34	m BGL

TEST DATA

Elapsed time, t (minutes)	Depth to water below datum (m)	Head, H_t (m)	Head Ratio H_t/H_0
0	1.44	0.10	1.00
0.5	1.40	0.06	0.60
1	1.38	0.04	0.40
1.5	1.36	0.02	0.20
2	1.36	0.02	0.20
2.5	1.35	0.01	0.10
3	1.35	0.01	0.10
3.5	1.35	0.01	0.10
4	1.35	0.01	0.10
4.5	1.35	0.01	0.10
5	1.34	0.00	0.00
6	1.34	0.00	0.00
7	1.34	0.00	0.00
8	1.34	0.00	0.00
9	1.34	0.00	0.00
10	1.34	0.00	0.00



CALCULATED VALUES

Permeability calculation based on BS EN ISO 22282-2 : 2012 Section B.4.2 (Hvorslev method - general approach)

Differential head at start of test, H_0	0.10	m
Differential head at end of test, H_f	0.00	m
Time elapsed at end of test	10	mins
Proportion of test recovery	100	%

Coordinates of best fit line to data:

t_1 = 0.0 mins H_1/H_0 = 1.000

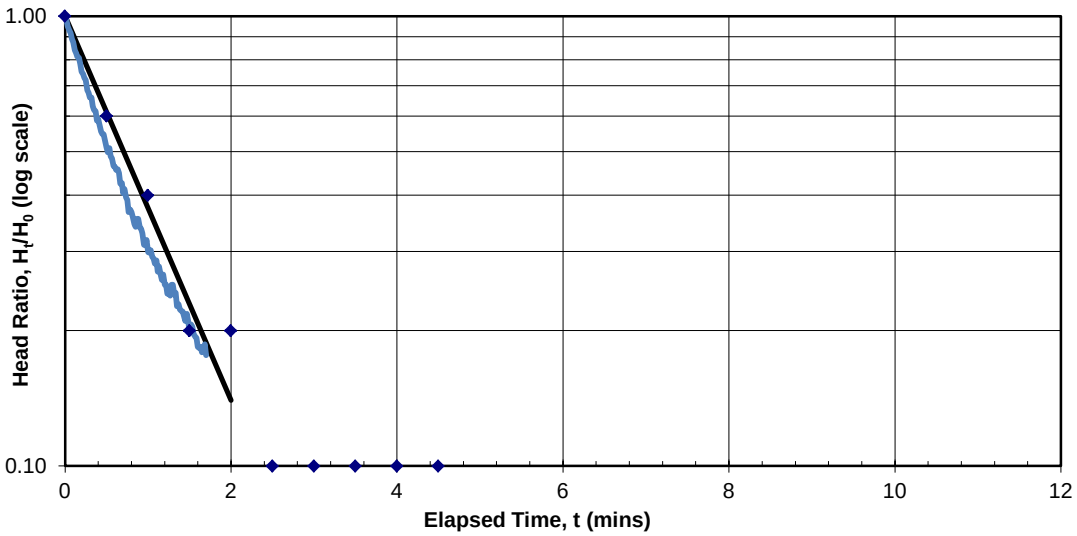
t_2 = 2.0 mins H_2/H_0= 0.140

Permeability (k) = 5.5E-06 m/sec

REMARKS

Slug testing carried out using dataloggers

Head Ratio against Time



AGS

Testing: JP/AE
Checked: RF
Approved: PH

Notes:

Project: Wynnstay Avenue, Wrexham

Project No.: F8054-18

Carried out for: Morgan Sindall

Test: **BH2T1**

Variable Head Permeability Test

LOCATION TYPE	Standpipe
TEST TYPE	Falling Head

DETAILS OF TEST ZONE:

Top of response zone	3.00	m BGL
Base of response zone	6.50	m BGL
Diameter of borehole (D)	150	mm
Height of tubing above ground level (datum)	0.00	m
Diameter of standpipe tubing	50	mm

BOREHOLE No.	BH1
TEST NUMBER	5
DATE OF TEST	14-Feb-19

TEST ZONE CONDITIONS

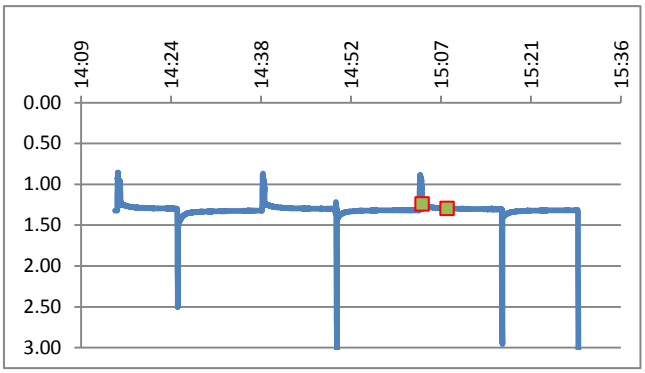
Diameter of response zone (D)	150	mm
Length of response zone (L)	3500	mm
Standpipe piezometer		
Shape factor (F) after Hvorslev (1951)	6.52	m

GROUNDWATER CONDITIONS

Depth to groundwater prior to test	1.34	m BGL
Groundwater level for analysis (Based on end of test water depth)	1.33	m BGL

TEST DATA

Elapsed time, t (minutes)	Depth to water below datum (m)	Head, H_t (m)	Head Ratio H_t/H_0
0	1.27	0.06	1.00
0.5	1.29	0.04	0.67
1	1.30	0.03	0.50
1.5	1.31	0.02	0.33
2	1.31	0.02	0.33
2.5	1.31	0.02	0.33
3	1.32	0.01	0.17
3.5	1.32	0.01	0.17
4	1.32	0.01	0.17
4.5	1.32	0.01	0.17
5	1.32	0.01	0.17
6	1.33	0.00	0.00
7	1.33	0.00	0.00
8	1.33	0.00	0.00
9	1.33	0.00	0.00
10	1.33	0.00	0.00
11	1.33	0.00	0.00



CALCULATED VALUES

Permeability calculation based on BS EN ISO 22282-2 : 2012 Section B.4.2 (Hvorslev method - general approach)

Differential head at start of test, H_0	0.06	m
Differential head at end of test, H_f	0.00	m
Time elapsed at end of test	11	mins
Proportion of test recovery	100	%

Coordinates of best fit line to data:

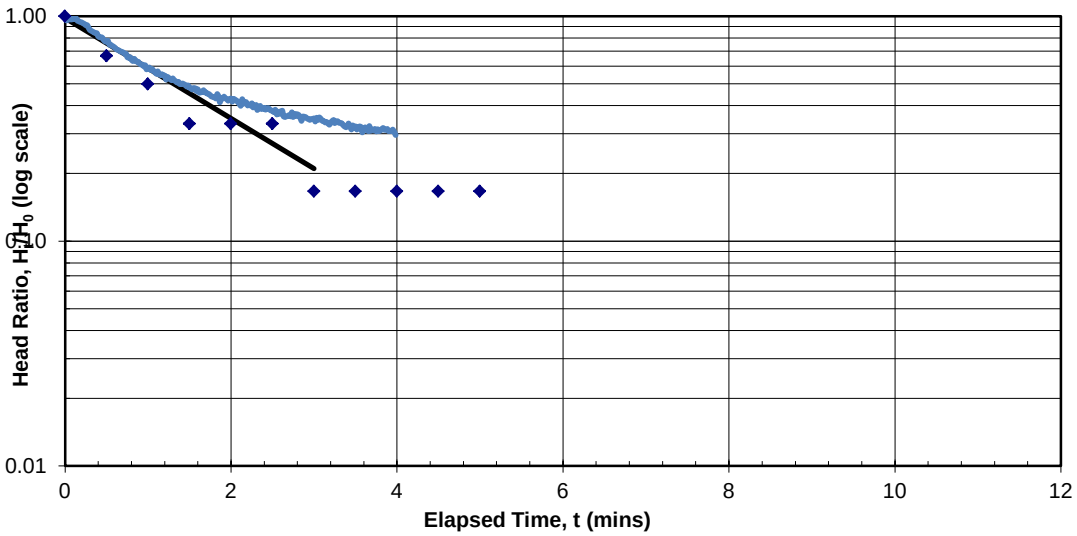
t_1 = 0.0 mins	H_1/H_0 = 0.980
t_2 = 3.0 mins	H_2/H_0= 0.210

Permeability (k) = 2.6E-06 m/sec

REMARKS

Slug testing carried out using dataloggers

Head Ratio against Time



AGS

Testing: JP/AE
Checked: RF
Approved: PH

Notes:

Project: Wynnstay Avenue, Wrexham
Project No.: F8054-18
Carried out for: Morgan Sindall

Test: BH1T5

Variable Head Permeability Test

SOCOTEC

LOCATION TYPE	Standpipe
TEST TYPE	Rising Head

DETAILS OF TEST ZONE:

Top of response zone	3.00	m BGL
Base of response zone	6.00	m BGL
Diameter of borehole (D)	150	mm
Height of tubing above ground level (datum)	0.00	m
Diameter of standpipe tubing	50	mm

BOREHOLE No.	BH2
TEST NUMBER	6
DATE OF TEST	14-Feb-19

TEST ZONE CONDITIONS

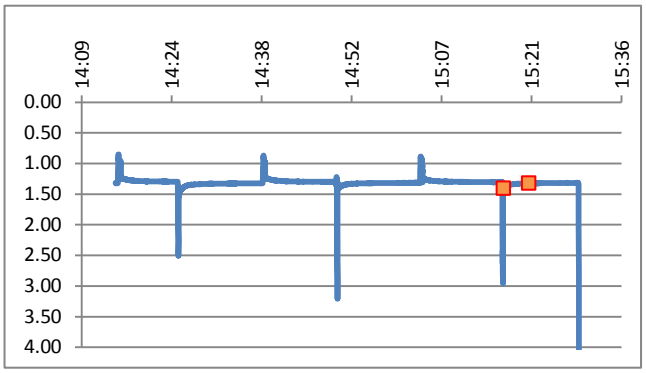
Diameter of response zone (D)	150	mm
Length of response zone (L)	3000	mm
Standpipe piezometer		
Shape factor (F) after Hvorslev (1951)	5.81	m

GROUNDWATER CONDITIONS

Depth to groundwater prior to test	1.34	m BGL
Groundwater level for analysis (Based on end of test water depth)	1.34	m BGL

TEST DATA

Elapsed time, t (minutes)	Depth to water below datum (m)	Head, H_t (m)	Head Ratio H_t/H_0
0	1.43	0.09	1.00
0.5	1.39	0.05	0.56
1	1.37	0.03	0.33
1.5	1.36	0.02	0.22
2	1.36	0.02	0.22
2.5	1.36	0.02	0.22
3	1.36	0.02	0.22
3.5	1.35	0.01	0.11
4	1.35	0.01	0.11
4.5	1.35	0.01	0.11
5	1.35	0.01	0.11
6	1.34	0.00	0.00
7	1.34	0.00	0.00
8	1.34	0.00	0.00
9	1.34	0.00	0.00
10	1.34	0.00	0.00
11	1.34	0.00	0.00



CALCULATED VALUES

Permeability calculation based on BS EN ISO 22282-2 : 2012 Section B.4.2 (Hvorslev method - general approach)

Differential head at start of test, H_0	0.09	m
Differential head at end of test, H_f	0.00	m
Time elapsed at end of test	11	mins
Proportion of test recovery	100	%

Coordinates of best fit line to data:

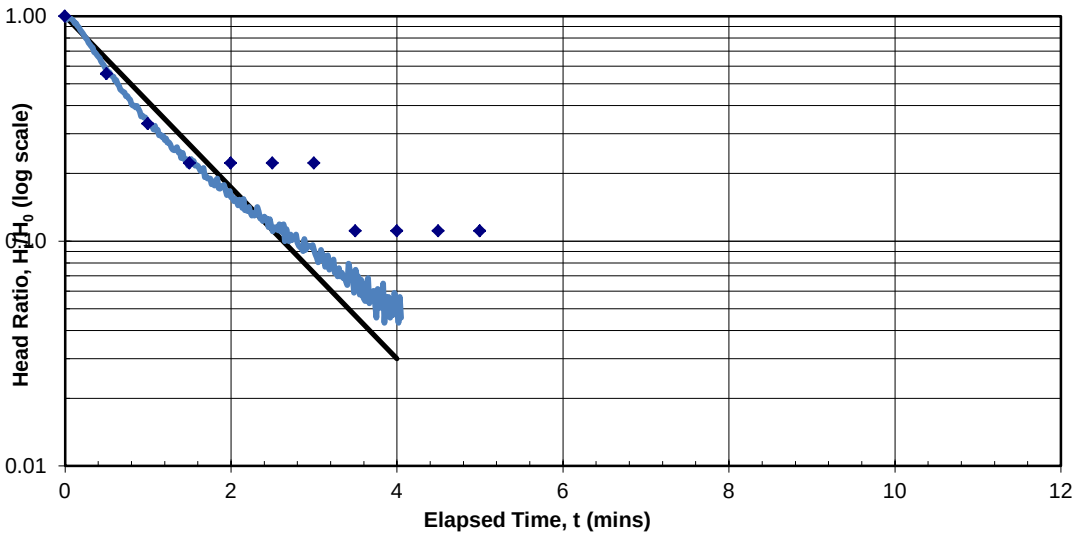
t_1 = 0.0 mins	H_1/H_0 = 1.000
t_2 = 4.0 mins	H_2/H_0= 0.030

Permeability (k) = 4.9E-06 m/sec

REMARKS

Slug testing carried out using dataloggers

Head Ratio against Time



AGS

Testing: JP/AE
Checked: RF
Approved: PH

Notes:

Project: Wynnstay Avenue, Wrexham
Project No.: F8054-18
Carried out for: Morgan Sindall

Test: **BH2T1**

ARUP

Job No. 241513		Rev. 1
Prepared by TSR	Date 06/09/2019	Checked by LB

Client: Welsh Water

Job Title: Wrexham Hydrogeological Impact Assessment

Title: BH2 - Variable head test analysis

Rising head test (BS22282-2)

Time (min)	Dip (mbd)	y (m)	yt/y0
0.0	1.43	0.09	1.00
0.5	1.43	0.09	1.00
1.0	1.39	0.05	0.56
1.5	1.37	0.03	0.33
2.0	1.36	0.02	0.22
2.5	1.36	0.02	0.22
3.0	1.36	0.02	0.22
3.5	1.36	0.02	0.22
4.0	1.35	0.01	0.11
4.5	1.35	0.01	0.11
5.0	1.35	0.01	0.11
6.0	1.35	0.01	0.11
7.0	1.34	0.00	0.00
8.0	1.34	0.00	0.00
9.0	1.34	0.00	0.00
10.0	1.34	0.00	0.00
11.0	1.34	0.00	0.00

Datum	=	unknown
BH diameter, D (m)	=	0.15
Pipe radius, r (m)	=	0.025
BH radius, R (m)	=	0.075
BH area, A (m2)	=	0.02
Initial SWL (mbd)	=	1.34
Test length, L (m)	=	3.5
L/D	=	23.33
Shape factor, F	=	5.7
Hyd. Cond., K (m/s)	=	5.72E-06

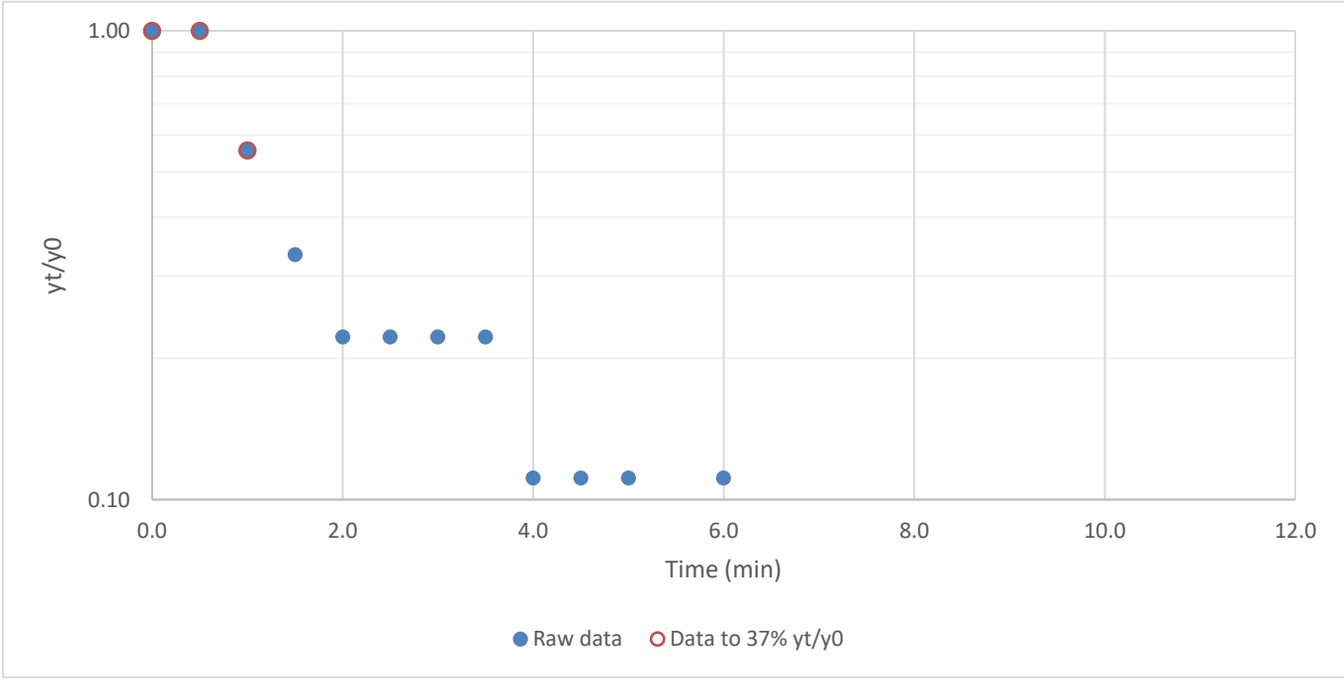
Shape factor equation adopted:

$$F = \frac{2 \cdot \pi \cdot L}{\ln\left(2 \cdot L/D\right)}$$

Valid for L/D > 10

Hydraulic conductivity

$$k = \frac{r^2 \cdot \ln\left(L/R\right)}{2 \cdot L \cdot t_o}$$



Radius of Influence and Flow Rates from a Fully Penetrating Analysis

Analysis - Confined Aquifer. Partial penetration of equivalent well. Feed by radial flow (groundwater only)

Assumptions: Radial flow to well, partially penetrating well, confined aquifer, circular source at distance Ro (Theim equation)

from Cashman and Preene, 2013

Qpp = B*Qfp where:
Qfp = (2πkD (H-hw)) /

Project: Wrexham Hydrogeological Impact Assessment

EGL (Equivalent ground level) =	0	BEGL
GWL (Groundwater level) =	1.5	BEGL
BoE (Base of Excavation) =	4.8	BEGL
EXL (Drawdown level) =	5.8	BEGL
DD req (Total Drawdown required) =	4.3	m
Saturated thickness of thickness face =	1.8	m
Top of aquifer =	2.9	BEGL
Bottom of aquifer =	15	BEGL
H =	13.5	m
hw =	9.2	m
D =	12.1	m
a (length of excavation) =	40	m
b (width of excavation) =	50	m
r (radius of wellpoints) =	0.075	m
K =	5.72E-06	m/s
Recharge, P (summer) =	0.0014	m/day
Recharge, P (winter) =	0.0027	m/day

* Assumed minimum base of aquifer. Base of aquifer not proved during ground investigations.

Used to convert a rectangular pit to a circular one.

re, Effective Radius for excavation m	a m	b m	π	re = √(ab/π)
25.23	40	50	3.14	

Radius of Influence calculator: Marinelli and Niccoli, 2000

Scenario	H m	hs m	K m/day	P m/d	re m	Ro m
Summer	4.3	1.8	4.94E-01	0.0014	25.23	84.87
Winter	4.3	1.8	4.94E-01	0.0027	25.23	69.00

Flow rate calaculator

Scenario	π	K m/s	T m2/s	H m	hw m	Ro m	re m	Q l/s	Q m3/d
Summer	3.14	5.72E-06	6.92E-05	13.5	9.2	84.87	25.23	1.54	133.20
Winter	3.14	5.72E-06	6.92E-05	13.5	9.2	69.00	25.23	1.86	160.61

Partially Penetrating Assessment

Partial Penetrating Assessment- Confined	
rw	0.08
H	13.5
rw/H	**0.0055556**
P (Top of Aquifer - Toe	5.4
D	12.1
P + D/2D	**0.7231405**
B (FROM GRAPH)	**0.8**

Assumed toe of wellpoint 2.5m below drawdown required; 2.5m suction head for wellpoint

From Preene and Cashman p203

Scenario	Qfp (l/s)	B	Qpp (BQfp) (l/s)	Qpp (m3/d)
Summer	1.54	0.8	**1.23**	**106.56**
Winter	1.86	0.8	**1.49**	**128.49**