Pumping Test Report &

Hydrogeological Impact Appraisal

Vale Resort

Hensol Rd, Hensol, Pontyclun, CF72 8JY

On Behalf of

Vale Resort

Quality Management

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Contents

Tables & Figures

Tables

Figures

Drawings

Appendices

1 Background

Hydrogeo Limited (Hydrogeo) have been commissioned to carry out abstraction borehole pump testing at The Vale Resort, Hensol Rd, Hensol, Pontyclun CF72 8JY (the Site).

This report details the following:

- Site setting and background;
- Setup of the pumping test;
- Results of the pumping test; and
- Analysis of the pumping test.
- Review of any impact to surrounding ground or surface water features.

These works were progressed under a National Resources Wales (NRW) 'Consent to Investigate a Groundwater Source' (REF: PPN-00428) issued on 20th June 2023. A Technical Memorandum prepared by Rigare dated January 2020 which provided background to the proposal and supported the WRC was also reviewed.

The pumping test and subsequent analysis and reporting has been undertaken in support of a proposed abstraction license application for 2 no. groundwater abstraction boreholes at the Site. The location of the boreholes being informed by a water features survey and consent. The boreholes were advanced and installed by Apex Drilling 24/124 – 8/2/24.

1.1 Site Setting

The Site is located at Hensol Rd, Hensol, Pontyclun CF72 8JY; approximately 3km south east of Pontyclun.

The location of the Site has been shown in Figure 1-1, with the location of the boreholes shown in Figure 1-2.

Figure 1-1 Site location and existing boreholes

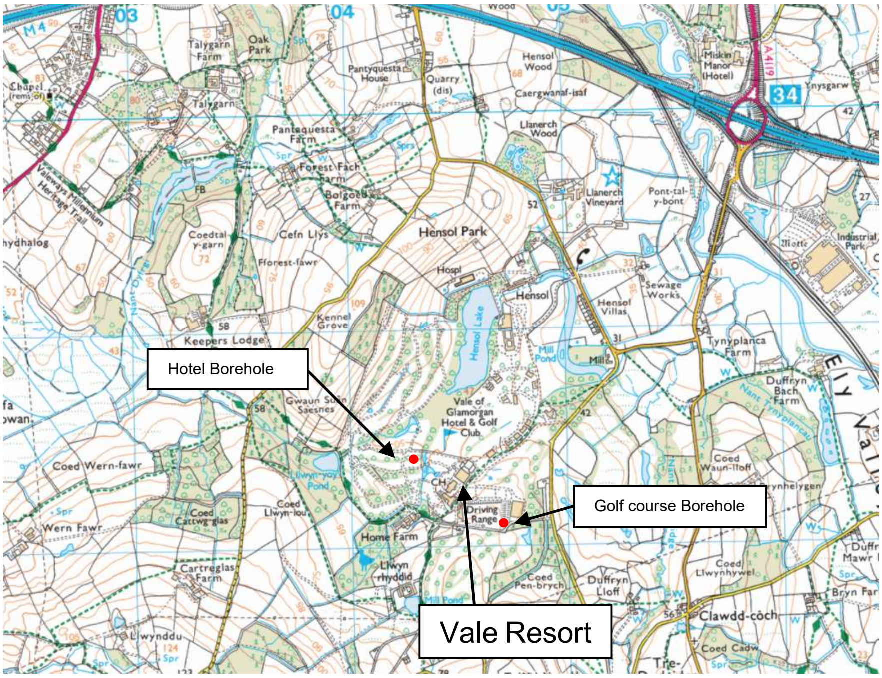
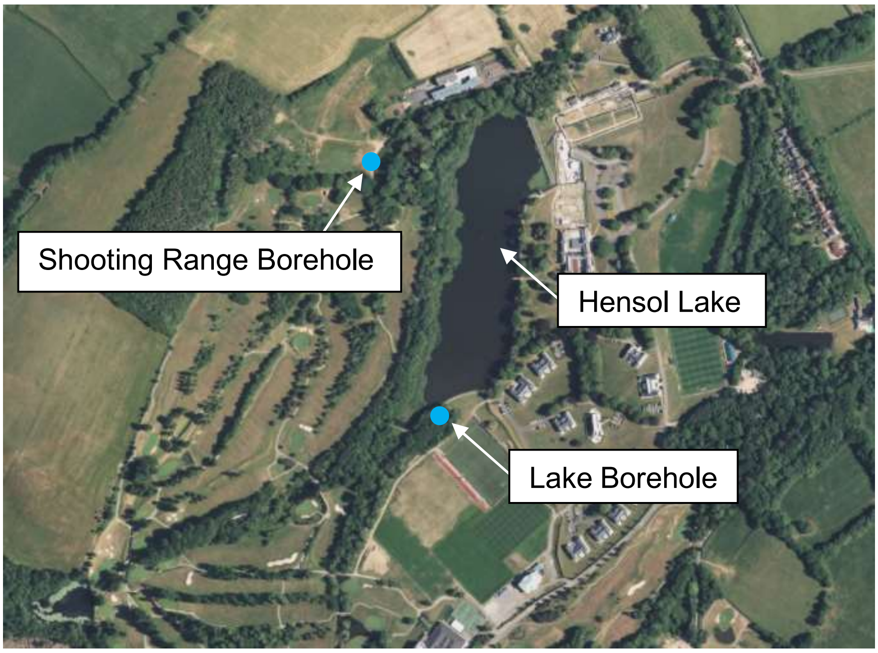


Figure 1-2 Borehole location



The Site includes a golf course, hotel and sports training areas. The Shooting Range Borehole is located at an approximate elevation of 58m above ordnance datum (mAOD) to the north west side of Hensol Lake, and the Lake Borehole is located at an elevation of approximately 45mAOD to the south of Hensol Lake.

1.2 Geology

The geology underlying the Site has been determined using British Geological Survey (BGS) data and map Sheet 262 Bridgend, Solid and Drift, 1:50,000 (1990).

The underlying superficial geology has been shown on Drawing 1 and the bedrock geology is presented shown on Drawing 2.

Artificial Ground

Artificial ground consists of any areas where ground conditions have been significantly modified by man. These include excavations, infilled ground and made ground.

BGS mapping does not indicate that artificial ground is present at the Site or in the immediate vicinity of the abstraction boreholes.

Superficial Deposits

Superficial Deposits consist of near surface unconsolidated (loose) sedimentary deposits which have not yet become lithified.

BGS mapping indicates that both boreholes are located on Till: diamicton deposited in a glacial environment during the Quaternary Period between 11,800 and 116,000 years ago.

Bedrock Geology

Bedrock consists of the main mass of rocks forming the Earth that are present everywhere, whether exposed at the surface in outcrops or concealed beneath superficial deposits or water.

BGS mapping indicates that both boreholes are located on the Brownstones Formation which the BGS describe as “Red, brown and purple fluvial sandstones with red mudstone interbeds”.

The Brownstones Formation comprise extensive sheets of sandstone laid down by seasonally flooding rivers crossing an otherwise semi-arid coastal plain. The alternation with the less-resistant mudstones and siltstones gives rise to the stepped landscape which is characteristic of the Black Mountains.

The Brownstones Formation strata are anisotropic and behave as a complex, multilayered aquifer with sandstone bands hydraulically isolated by interbedded mudstones, especially where there are no structural discontinuities. The effective saturated thickness, for most practical purposes, is considered to be approximately 40 m below ground surface beneath which fracture dilation approaches zero.

As shown on Drawing 2 the bedrock geology in the vicinity of the Site varies; a reflection faulting and angular unconformities.

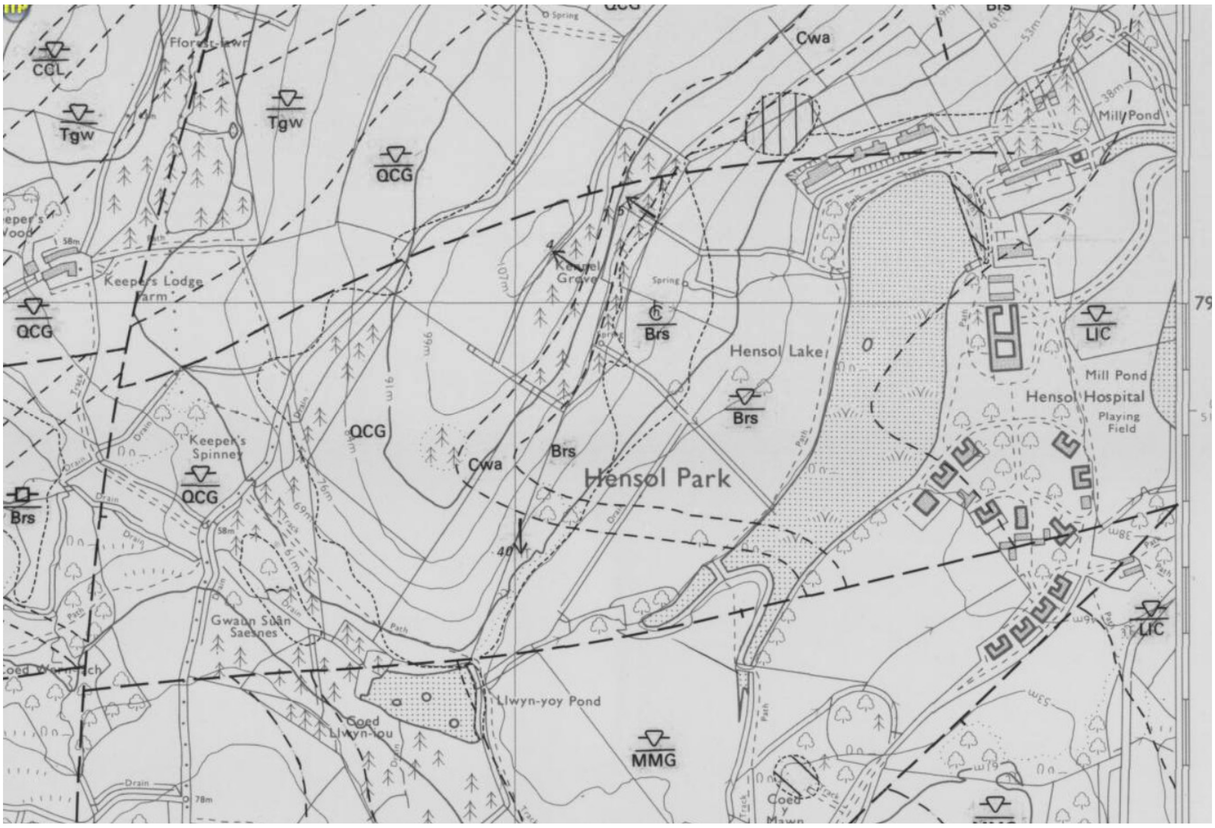
Structural Geology

The BGS 1:10,000 Series (Sheet ST 07 NW) geological mapping sheet provides further detailed information as to the geological sequence and structure of the site. Hensol Park and Lake lies within the core of the Cardiff – Cowbridge Anticline (CCA) which is an east / west trending fold being the largest in the region. The fold structure is clearly noted on the mapping extending eastwards. The rocks of the southern limb are shown dipping at 40 degrees south. A range of dips are seen on the mapping showing the dips of the northern limb being 4 - 5 degrees with a slight steepening noted to the west of the site where dips of 15 – 20 degrees are recorded.

The oldest identified the rocks in the immediate area and at the core of the anticline are the Devonian Llanishen Conglomerate (LIC). With the sequence younging westwards the conglomerates are overlain by the Brownstones Formation and in turn with the Cwrt Yr Ala Formation, Quartz Conglomerate Group, Tongwynlais Formation and Castel Coch Limestone.

The area is also controlled and deformed by a series of east – west trending faults and a later phase of faulting trending broadly north – south adding a further level of structural deformation. It appears that the site is located on a fault block being upthrown against the surrounding rocks to the north and south.

Figure 3 – British Geological Survey 1:10,000 Series (Sheet ST 07 NW)



1.3 BGS Borehole Records

The BGS GeoIndex resource has been reviewed for the availability of borehole logs in the vicinity of the Site. BGS data indicates the presence of two boreholes in the vicinity of the Site, as summarised in Table 1-1.

Table 1-1 BGS Borehole Record Summary

Borehole details	Ground conditions and additional information
▪ BGS reference: ST07NE211 ▪ Name: Hensol Castle ▪ Easting / Northing: 305090, 178950 ▪ Location: 650-700m east ▪ Date: June 1951 ▪ Depth (m): unknown	▪ No ground conditions available ▪ Pumping rate: 393m^3/day ▪ Operated 12.5 hours per day on average

Borehole details	Ground conditions and additional information
▪ BGS reference: ST07NW32 ▪ Name: Vale of Glamorgan Golf & Country Club ▪ Easting / Northing: 304680, 177100 ▪ Location*: 1.6 – 2.0km south ▪ Date: March 1996 (pump test) ▪ Depth (m): 40m	▪ 'Glacial deposits' 0m to 40mBGL ▪ RWL: 15.30mBGL ▪ Pumping rate: 180m^3/day ▪ Pumping duration: 16 days ▪ Steady state water level: 19.80mBGL

* Based on the grid reference of this borehole on BGS GeoIndex it is not clear that the location is correct

1.4 On-Site Abstraction Boreholes

Existing Boreholes

A total of 2 no. existing abstraction boreholes are present at the Site; with the groundwater in constant use by the Vale Resort complex. For the purposes of this report these boreholes will be referred to as the Hotel Borehole and the Golf Course Borehole.

The Hotel Borehole is 32m deep and the Golf Course Borehole is 40m deep, and both were completed in the superficial deposits.

The full details such as depth and drill and installation records for these 2 no. existing boreholes is not known to Hydrogeo.

Access was gained to the Hotel Borehole in order to take groundwater level measurements during pump testing. The data is discussed in Section 3.5. Access could not be gained to the Golf Course Borehole to take groundwater measurements as there was a blockage in the borehole's dip tube. However the borehole was observed to be in active use throughout the duration of the pump test.

The location of the existing Hotel Borehole and the Golf Course Borehole is marked on Figure 1-2 and Drawing 3. The Lake Borehole is located approximately 620 m NW of the existing Golf Course borehole and 360m NE of the Hotel Borehole.

The Shooting range borehole is located 1000m NNW of the golf course borehole and 700m NE of the Hotel Borehole.

Newly Completed Boreholes

NRW issued a consent to investigate a groundwater source at the site was issued. The location and construction details of the boreholes was stipulated. It is advised that during drilling it was agreed between the client and driller to advance boreholes to a greater depth than consented given the results of water strikes and blow out yield testing. NRW were advised by email following the drilling and installation of the boreholes with correspondence confirming that the boreholes were advanced and installed in to the same geology and clarifying that works had not created a pathway between two separate aquifers.

A summary of the ground conditions and installation of the Shooting Range Borehole has been provided below

Shooting Range Borehole - Ground conditions

- 0.00m – 12.80mBGL: Sandy clay gravels and cobbles
- 12.80m – 14.00mBGL: Stiff clay
- 14.00m – 24.90mBGL: Stiff clay
- 24.90m – 29.10mBGL: Sandy clay
- 29.10m – 31.20mBGL: Gravels and clay
- 31.20m – 39.30mBGL Gravels
- 39.30m – 41.20mBGL: Clay
- 41.20m – 43.00mBGL: Red silty mudstone and sandstone
- 43.00m – 110.00mBGL: Red silty mudstone and sandstone bands
- 110m – 150mBGL – Red Silty Mudstone with broken sandstone bands

- Drill records indicate that borehole wet from 43.00mBGL.

Installation Details

Steel casing installed during drilling into bedrock at 43mbgl

- 0.00m – 40.00mBGL: Plain casing (125mm)
- 40.00m – 100.00mBGL: Slotted casing (125mm) with end cap
- 0.00m – 4.00mBGL: Concrete seal
- 4.00m – 100.00mBGL: Gravel surround

A summary of the ground conditions and installation of the Lake Borehole has been provided below:

Lake Borehole - Ground conditions

- 0.00m – 10.80mBGL: Sandy clay gravel cobbles
- 10.80m – 20.00mBGL: Stiff clay
- 20.00m – 22.00mBGL: Stiff clay
- 22.00m – 23.40mBGL: Sand
- 23.40m – 26.30mBGL: Sand
- 26.30m – 28.10mBGL: Clay
- 28.10m – 36.20mBGL: Gravels
- 36.20m – 38.80mBGL: Clay
- 38.80m – 70.00mBGL: Red sandstone
- 70.00 – 150.00mBGL: Red sandstone, silty mudstone bands
- Drill records indicate borehole wet from 82.00mBGL.

Installation Details

- Steel casing installed during drilling into bedrock at 43mbgl0.00m – 50.00mBGL: Plain casing (125mm)
- 50.00m – 100.00mBGL: Slotted casing (125mm) with end cap

- 0.00m – 4.00mBGL: Concrete seal
- 4.00m – 100.00mBGL: Gravel surround

1.5 Hydrogeology

The Site is covered the BGS hydrogeological map Sheet 17 - Hydrogeological Map of South Wales, 1:125,000 (1989). The map indicates that the Site is underlain by Devonian Sandstones, which generally consist of consolidated, well-cemented, flaggy sandstones with thin sandy marls up to 750m thick in this area of south-east Wales.

The well-cemented nature of the sandstones limits intergranular flow. Groundwater movement mainly occurs within the upper 50m of the bedrock by fracture-flow therefore storage is limited and yields may decrease with time. The BGS hydrogeological map indicates that boreholes normally yield around 0.5l/s (43m^3/day). Water quality is indicated to be good but hard; with total hardness typically 220mg/l (comprising 200mg/l carbonate), and total dissolved solids less than 300mg/l. Nitrates have been recorded exceeding 45mg/l.

1.6 Hydrology

The Technical Memorandum produced by Rigare Limited (project number 1710, dated January 2020) in support of a groundwater abstraction application to NRW identifies the Hotel Borehole and Golf Course Borehole.

The main surface water feature which may potentially be affected by ground water abstraction is Hensol Lake; a large water feature located between both of the recently installed abstraction boreholes at the Site. The lake is located at an approximate elevation of 44mAOD and is a shallow surface water feature. The installation details for the Shooting Range Borehole and the Lake Borehole (Section 1.4) indicate that the superficial deposits at each location were cased out, to depths of at least 40m.

The most recent drill records indicate a 12m stiff clay between 10.8m – 22m in the lake borehole and 12.8 – 24.9m within the shooting range borehole. Further sequences of clay are evident in the superficial deposits within both the boreholes at depth interbedded with layers of gravel and sands. Based on the geological sequence including a thick and laterally extensive stiff clay layers it is not envisaged that abstraction from boreholes screened within the Brownstones Formation will impact upon Hensol Lake

A number of streams feeding Hensol Lake are marked on OS mapping and were observed by Hydrogeo during site visits flowing into the lake from the west as well as from the east. The lake itself is formed in a low lying base of a small depression with the surrounding land rising steeply to the north west of the lake and more shallowly rising locally to the south and south east. The lake is dammed to the north east and the main outflow appears as a by pass flow control valve to the north east feeding to the Mill Pond and down gradient tributaries. Recharge of the lake by local tributaries was evident during the testing and is discussed further and evidenced within Figure 3-3 of this report.

2 Pumping Test

2.1 Introduction

Pump testing was undertaken between the 18th and 28th March 2024 by Apex Drilling Services Limited with Hydrogeo in attendance during key stages of the testing in order to install level logging equipment, record data and following completion retrieve all logging equipment.

The abstraction borehole pumping test at each borehole consisted of a 4-step pump test, followed by a constant rate test. Each abstraction borehole was also monitored prior to the commencement of the pump test and following the completion of the pump test to capture steady state rest water levels and the recovery phase of the groundwater. For all testing the pumping rate was controlled by a valve in the discharge pipe at the surface, with the flow rate observable via a water flowmeter installed downstream of the valve.

All data recorded during the whole testing period has been attached at Appendix A for the Shooting Range Borehole and Appendix B for the Lake borehole.

2.2 Monitoring Points

In accordance with the NRW consent, the groundwater level in the opposite borehole to the one being tested was monitored pre-during and post pump test, as well as the water level of Hensol Lake. In addition groundwater levels within the existing Hotel Borehole and Golf Course Borehole were monitored where access could be arranged. The groundwater level in the Hotel Borehole was observed and wells confirmed to be actively pumping.

The groundwater level within the pumped abstraction borehole was monitored in line with available Pump Test Recording Sheet Guidance, with measurement intervals increasing in time as the pump test progressed.

As well as manual dips, electronic pressure transducers (level loggers) were installed at all required monitoring points, and set to record pressures at 5-minute intervals. The logger used for pump testing had a 50m head, and each of the loggers used for monitoring the opposite borehole and for Hensol Lake had a 10m head.

The data recorded by the level loggers following completion of the test were compensated against a barometric pressure logger recording data over the testing period.

Table 2-1 Additional pump test monitoring points

Reference	Location	Grid reference	Approx. depth (m)	Distance from site (m)	Monitoring parameter	Monitoring Method	Monitoring horizon
1*	Shooting Range Borehole	304408, 179099	100	On-site	Groundwater level	Water level data logger	Brownstones Formation
2*	Lake Borehole	304489, 178694	100	On-site	Groundwater level	Water level data logger	Brownstones Formation
3	Hensol Lake	304428, 178687	Unknown	On-site	Water level	Water level data logger	Lake

*The groundwater level at each of the 2 no. new boreholes was monitored while the opposite borehole was pumped

2.3 Discharge

During the pump test abstracted groundwater was discharged to ground approximately 50m away and downgradient of each borehole. This prevented any recirculation of water into the aquifer during the pump test as per Condition 6.1 of the NRW Groundwater Investigation Consent.

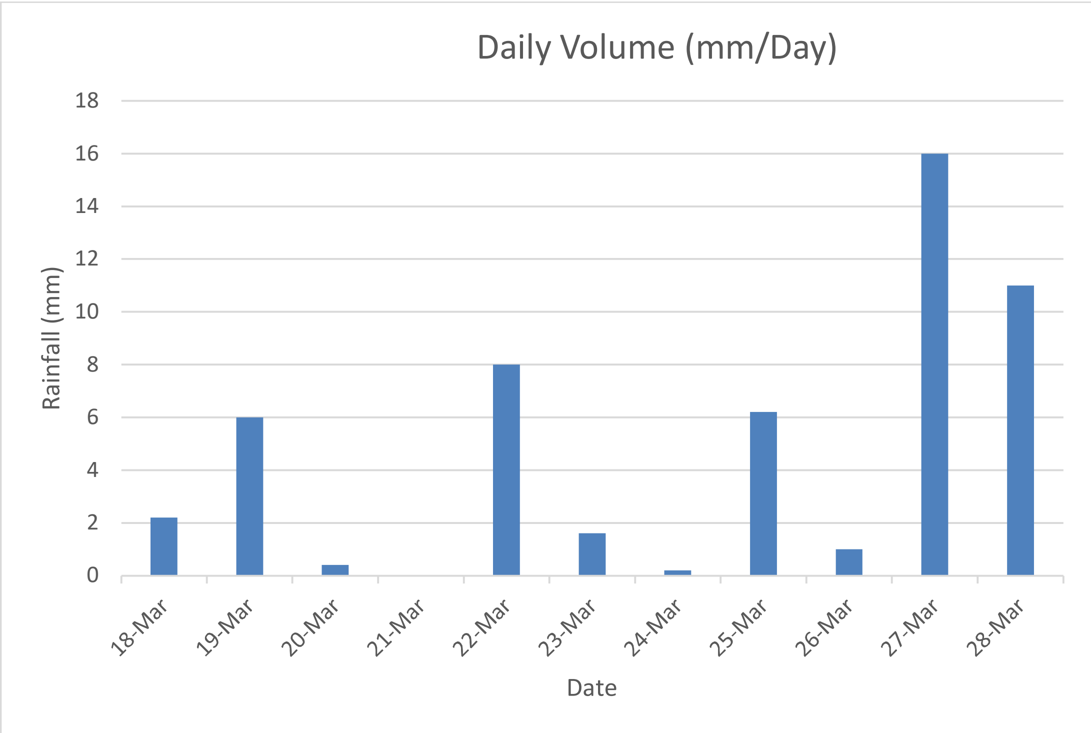
2.4 Rainfall

Rainfall data has from the NRW 'Rhiwsaeson STW' rain gauge, located approximately 4.5km north east of the Site at grid reference 307308, 182629, has been shown in

Figure 2-1.

Rainfall was recorded at the nearest available rain gauge station to the Site on all but one day across the pump testing period (21st March), with the 27th March receiving the greatest amount of rainfall at 16mm.

Figure 2-1 Rhiwsaeson STW rain gauge data throughout the test period.



2.5 Shooting Range Borehole

Step Test

The step test at the Shooting Range Borehole was progressed on the 18th March 2024. Resting water level was recorded at 15.16 mBGL at 10:49 on the morning of the test.

Within outline proposals for the Site (Rigare Ltd, January 2020) it was anticipated that the 2 no. dedicated boreholes would afford a combined abstraction rate of up to 300 m^3/day.

Step test rates were initially determined through reference to the step test approach (Clark, 1977) as set out within "*Waterwells and Boreholes, Misstear, Banks and Clark*" and early reported observations formed during setting up of the pump prior to the test.

The pumping rates at each of the 4 no. 90-minute intervals has been listed below:

- Q1: 24l/min (34.6m^3/day)
- Q2: 48l/min (69.1m^3/day)
- Q3: 72l/min (103.7m^3/day)
- Q4: 82l/min (118.1m^3/day)

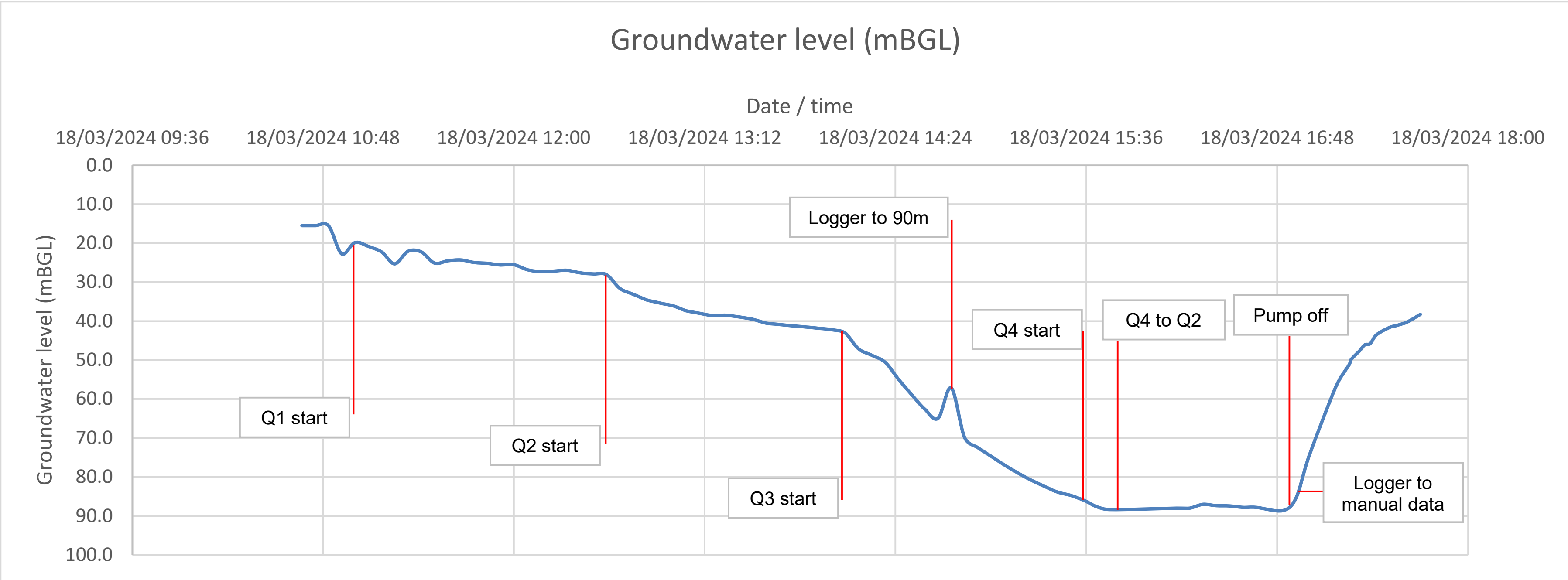
The Q1 and Q2 steps each drew down to a steady water level however the Q3 flow did not stabilise to the same extent after 90 minutes. The Q4 flow was implemented in order to capture the data however, the water level rapidly fell and Q4 was stopped after approximately 25 minutes with a water level of 88.40mBGL at 16:00 on the 18th March 2024 in order to prevent the water level reaching the pump which had been set at a depth of 100mBGL. The flow was reduced at this time back to the Q2 rate in order to continue recording data.

At 16:50 the pump was switched off to allow the groundwater level to recover to pre-test resting level. As the groundwater level logger was set to record at 5 minute intervals a series of manual groundwater dips were collected during the initial recovery. The groundwater level at the Shooting Range Borehole recovered to pre-test resting level by the morning of the 19th March 2024.

The logger groundwater level readings recorded across the step test have been shown in Figure 2-2, augmented by manual dip readings where this was necessary.

A number of aspects of the step test have been labelled in Figure 2-2 including changes between steps, changes to the logger depth where this was necessary due to rapidly falling groundwater level, changes to a previous step to collect steady-state data, and the end of the test when the pump was turned off. Some disturbance is indicated at the start of step 1 which indicates adjustments to the flow control being made in order to attain the desired pump rate.

Figure 2-2 Shooting Range Borehole step test – groundwater level (mBGL)



Constant Rate Test

The constant rate test at the Shooting Range Borehole was progressed for a minimum of 48 hours starting on the 19th March 2024 and ending on the 21st March 2024. Resting water level was recorded at 15.81mBGL on the morning of the test after recovering from the step test the previous day.

The pumping rate was initially set at the Q2 flow rate (48 l/min or 69.1m^3/day) from the step test as this was the final step that the borehole was able to sustain over a 90-minute period without the groundwater level falling significantly (see Figure 2-2).

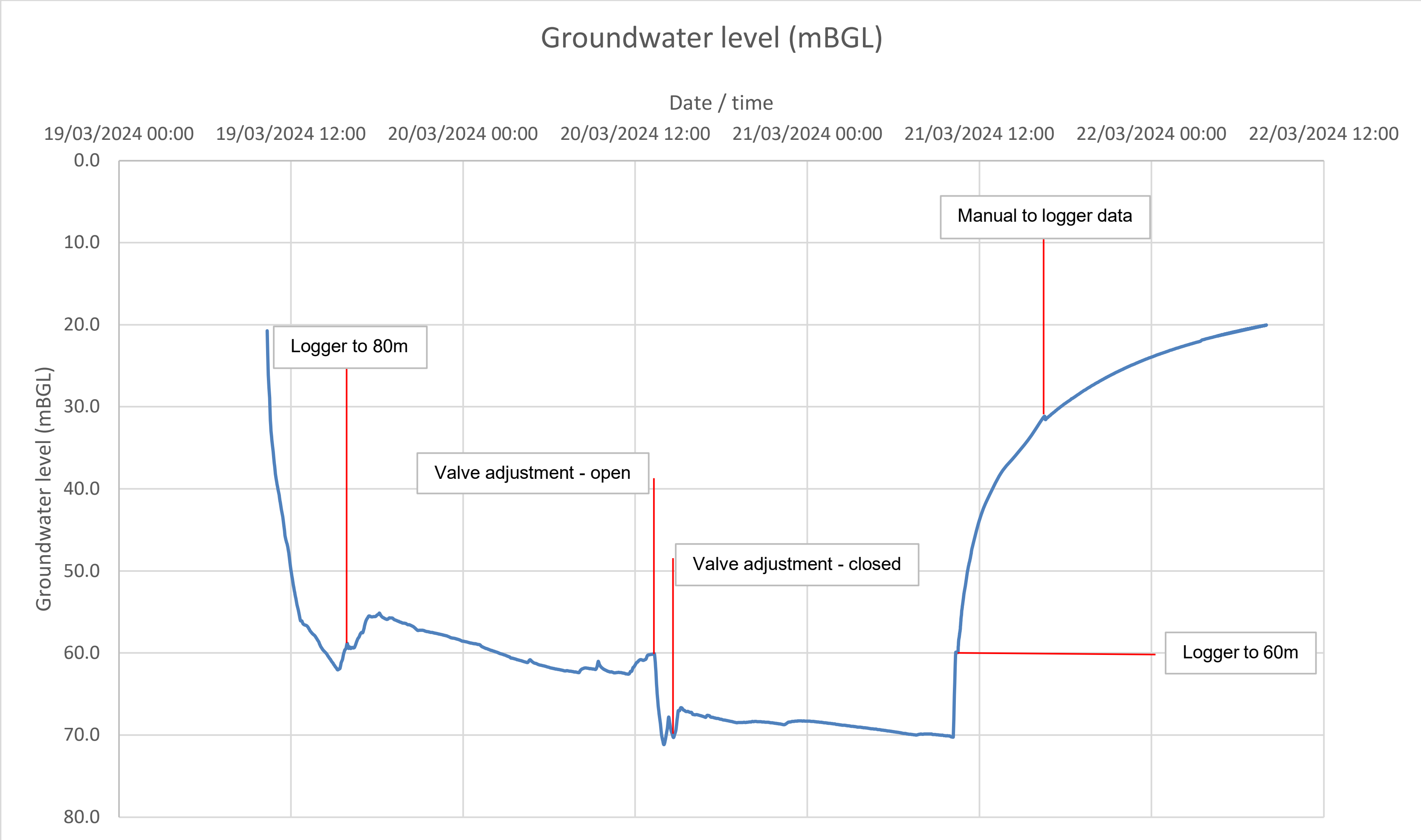
The groundwater levels recorded by the logger across the Shooting Range Borehole constant rate pump test have been shown in Figure 2-3, augmented by manual dip readings where this was necessary.

Through the course of the constant rate test it was observed that the pump rate initially set was decreasing gradually, and then more significantly on the 20th March 2024, therefore an attempt was made to reset back to and maintain the original rate. However, any slight adjustment proved difficult with the flow control valve installed and it was decided to leave the pump rate as it was without further adjustment. This event has been marked on Figure 2-3 along with other events such as changes to the logger depth.

The total volume of water pumped from the borehole over 48 hours was recorded at approximately 83.7m^3, therefore the average pumping rate at the Shooting Range Borehole was 29l/min or 41.85m^3/day.

The initial groundwater level drawdown was rapid, from a pre-test resting level of 15.81mBGL to over 60mBGL after approximately 4 hours. The groundwater level was drawn down to a maximum level of 70.22mBGL (or 54.41m drawdown) at the end of the constant rate test on the 21st March 2024.

Figure 2-3 Shooting Range Borehole constant rate test - groundwater level (mBGL)



Recovery Period

Following the cessation of pumping at the Shooting Range Borehole at 10:30 on the 21st March 2024, the groundwater level was allowed to recover until the morning of the 22nd March 2024.

The logger was initially removed from the borehole after the pump was stopped to adjust its depth in order to capture the recovery. During the period of time the logger was removed from the borehole manual dips were taken during the initial recovery; this event has been marked on Figure 2-3. Following re-installation of the logger at the adjusted depth, it was left in place until the following morning of the 22nd March 2024.

The groundwater level recovery followed a steady curve, recovering approximately 30m in approximately three hours. The groundwater level was manually recorded at 21.19mBGL at 08:00 on the 22nd March 2024 just prior to removal of the logger.

Test Summary

A summary of the monitoring and pump test procedures at the Shooting Range Borehole are shown in Table 2-2. All pump test data has been attached at Appendix A.

Table 2-2 Test summary – Shooting Range Borehole

Date	Time	Comment
18/03/2024	10.40	Electronic pressure transducer installed into borehole (65mBGL)
18/03/2024	11:04	Start of step test
18/03/2024	14:49	Logger to 90mBGL
18/03/2024	16:50	End of step test (Q4 step partial completion)
19/03/2024	09:30	Water level recovered
19/03/2024	10:17	Start of constant rate test (logger at 65mBGL)
19/03/2024	16:00	Logger to 80mBGL
21/03/2024	10:30	End of constant rate test and recovery start
21/03/2024	10:20	Logger to 60mBGL
22/03/2024	08:00	Electronic pressure transducer removed from borehole

The hydrograph in Figure 2-2 indicates that the step test resulted in a maximum drawdown of 73.45m, with the groundwater level falling from a resting level of 15.16mBGL to a maximum depth of 88.61mBGL.

Following the conclusion of the step test steady groundwater level recovery was measured. The step test data were then used to determine the constant rate test flow rate;

initially set at 48l/min (69.1m^3/day). Due to the gradual slowing of the pump rate caused by the nature of the valve, the average pumping rate at the Shooting Range Borehole over 48 hours was 29 l/min or 41.85 m^3/day.

Over the duration of the constant rate test the groundwater level reduced from an initial 15.81mBGL to a maximum level of 70.22 mBGL; a drawdown of 51.41m.

The level logger remained in the borehole until the morning of the 22nd March 2024 when it was removed to be swapped into the Lake Borehole. By this time the groundwater level in the Shooting Range Borehole had recovered to 21.19mBGL.

2.6 Lake Borehole

Step Test

The step test at the Lake Borehole was progressed on the 22nd March 2024. Resting water level was manually recorded at 5.28mBGL at 08:22 on the day of the test.

Step test rates were initially determined through reference to the step test approach (Clark, 1977) as set out within “Waterwells and Boreholes, Misstear, Banks and Clark” and early observations during setting up of the pump prior to the test and available data from pumping the Shooting Range Borehole. The pumping rates at each of the 4 no. 90-minute steps are listed below:

- Q1: 11.5l/min (16.6m^3/day)
- Q2: 22l/min (31.7m^3/day)
- Q3: 35l/min (50.4m^3/day)
- Q4: 46l/min (66.2m^3/day)

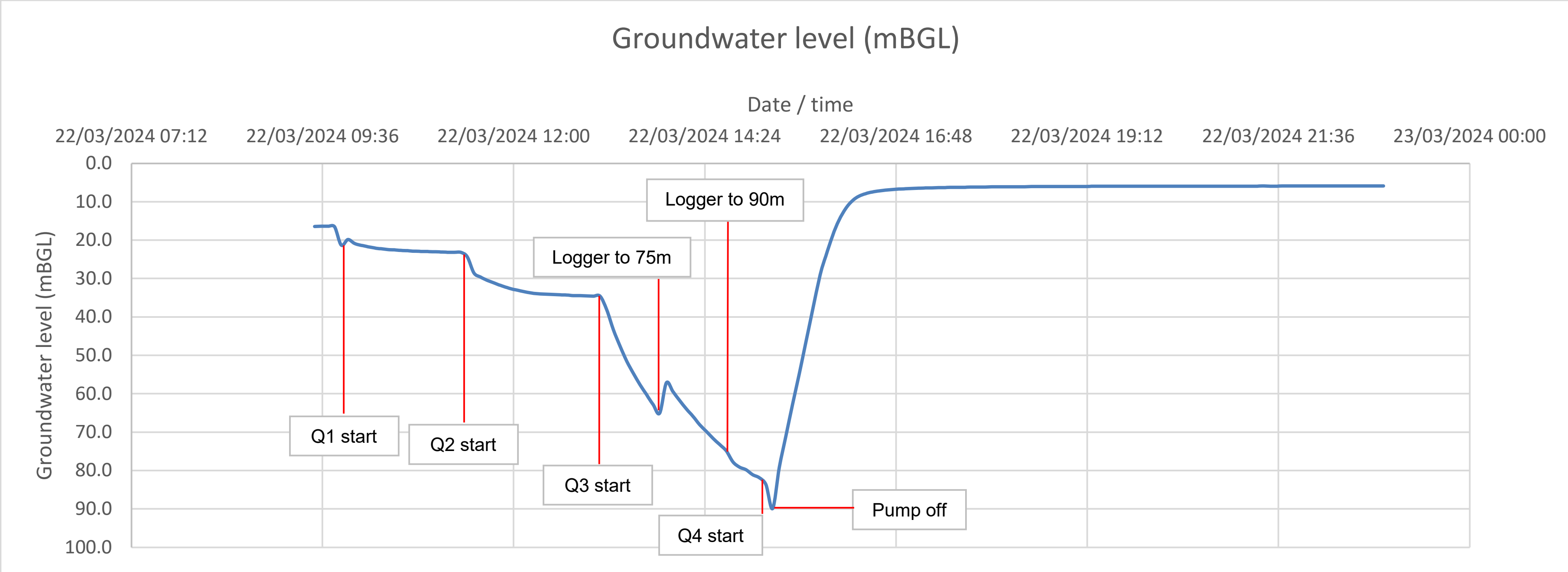
Similar to the Shooting Range Borehole, the Q1 and Q2 steps at the Lake Borehole each drew down to a steady water level. A different flow control valve was installed during the equipment set up allowing for finer adjustment to the pumped groundwater flow rate. As with the shooting range borehole the Q3 flow did not stabilise to the same extent after 90 minutes. The Q4 flow was implemented in order to capture the data however, the water level rapidly fell and Q4 was stopped with a water level of 89.84mBGL at 16:15 on the 22nd March 2024 in order to prevent the water level reaching the pump which had been set at 100 mBGL.

At this time the pump was switched off to allow the groundwater level to recover to pre-test resting level. The groundwater level at the Lake Borehole recovered to pre-test resting level by the morning of the 25th March 2024, prior to the commencement of the constant rate test. The step test and constant rate test at the Lake Borehole were undertaken either side of a weekend.

The logger groundwater level readings recorded across the step test have been shown in Figure 2-4, augmented by manual dip readings where this was necessary. The steps in this test are improved over the previous which is considered largely down to the greater level of control on the flow control valve.

A number of aspects of the step test have been labelled in Figure 2-4 including changes between steps, changes to the logger depth where this was necessary due to rapidly falling groundwater level, and the end of the test when the pump was turned off.

Figure 2-4 Lake Borehole step test - groundwater level (mBGL)



Constant Rate Test

The constant rate test at the Lake Borehole was progressed for a minimum of 48 hours starting on the 25th March 2024 and ending on the 27st March 2024. Resting water level was manually recorded at 5.97mBGL at 07:35 on the morning of the test after recovering from the step test three days prior.

The pumping rate was initially set at (27.8 l/min, 40 m^3/day) from the step test as this was close to the final step (Q2) that the borehole was able to sustain over a 90-minute period without the groundwater level falling significantly (see Figure 2-4).

The groundwater levels recorded by the logger across the Lake Borehole constant rate pump test have been shown in Figure 2-3, augmented by manual dip readings where this was necessary.

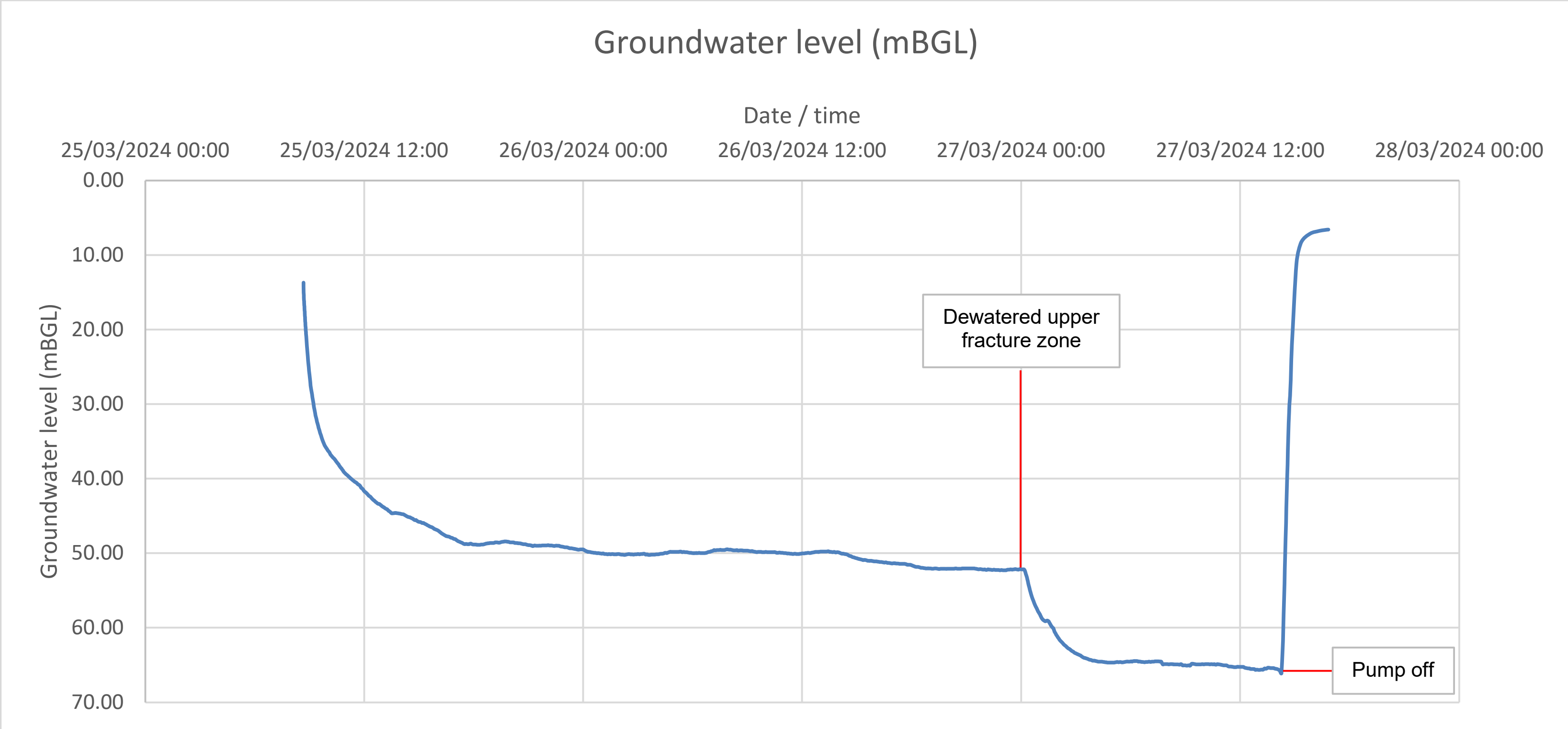
On the morning of the 27th March 2024 manual dips revealed that there had been an overnight fall of the groundwater level compared with the preceding afternoon. There was a marked change noted on the level logger data at midnight, no changes in the pump flow rate / valve adjustment were made by the project team at this time. Flow rates from 26th March were equating to approximately 34.5 m^3/d at 16:15 with a groundwater level manually dipped at 51.4 mbgl, compared to a rate of 32.8 m^3/d at 08:45 27th March with groundwater dipped at 64.8 mbgl.

Given the observed change in levels it was decided to continue the constant rate test through most of the day to verify that the groundwater level had stabilised at the new lower level. Following manual dips to confirm this, the pump was turned off at 14:20 on the 27th March 2024.

The total volume of water pumped from the borehole over 54 hours was recorded at approximately 73.9 m^3, therefore the average pumping rate at the Shooting Range Borehole was 23 l/min or 32.8 m^3/day.

The initial groundwater level drawdown was rapid, from a pre-test resting level of 5.97 mBGL to over 30 mBGL after approximately 45 minutes. The groundwater level was drawn down to a maximum level of 66.07mBGL (60.01m drawdown) at the end of the constant rate test on the 27th March 2024.

Figure 2-5 Lake Borehole constant rate test - groundwater level (mBGL)



Recovery Period

Following the cessation of pumping at the Lake Borehole at 14:20 on the 27th March 2024, the groundwater level was allowed to recover until the morning of the 28th March 2024 with the logger remaining in place through this time.

The groundwater level recovery was rapid, recovering approximately 55m in approximately one hour, with the remaining few metres to resting level occurring more slowly. The groundwater level was manually recorded at 6.08mBGL at 08:00 on the 28th March 2024 just prior to removal of the logger.

Test Summary

A summary of the monitoring and pump test procedures at the Lake Borehole are shown in Table 2-3. All pump test data has been attached at Appendix B.

Table 2-3 Test summary – Lake Borehole

Date	Time	Comment
22/03/2024	09:30	Electronic pressure transducer installed into borehole (55mBGL)
22/03/2024	09:53	Start of step test
22/03/2024	13:55	Logger to 75mBGL
22/03/2024	14:44	Logger to 90mBGL
22/03/2024	15:15	End of step test (Q4 step partial completion)
25/03/2024	07:35	Water level recovered
25/03/2024	08:34	Start of constant rate test (logger at 80mBGL)
27/03/2024	14:20	End of constant rate test and recovery start
28/03/2024	08:00	Electronic pressure transducer removed from borehole

The hydrograph in Figure 2-4 indicates that the step test resulted in a maximum drawdown of 84.56m, with the groundwater level falling from a resting level of 5.28 mBGL to a maximum depth of 89.84 mBGL.

Following the conclusion of the step test rapid groundwater level recovery was measured. The step test data were then used to determine the constant rate test flow rate; initially set at 27.8l/min (40 m^3/day). Due to the gradual slowing of the pump rate caused by the nature of the valve, the average pumping rate at the Lake Borehole over 54 hours was 23 l/min or 32.8 m^3/day.

The constant rate test was progressed over the course two days where the groundwater level reduced from an initial 5.97 mBGL to a maximum level of 66.07 mBGL; a drawdown of 60.01 m.

The level logger remained in the borehole until the morning of the 28th March 2024 when it was removed as all site pumping operations ceased. By this time the groundwater level in the Lake Borehole had recovered to 6.08 mBGL.

3 Monitoring Points Data Review

3.1 Introduction

As discussed in Section 2.2 the NRW consent required monitoring of a number of identified water features at the Site. These features were monitored using an electronic pressure transducer (logger) over the same period as the borehole subject to abstraction pump testing.

The compensated level logger data for the Shooting Range Borehole during the time it was not subject to pump testing has been attached at Appendix C. The compensated level logger data for the Lake Borehole during the time it was not subject to pump testing has been attached at Appendix D. The compensated level logger data for Hensol Lake has been attached at Appendix E.

3.2 Lake Borehole

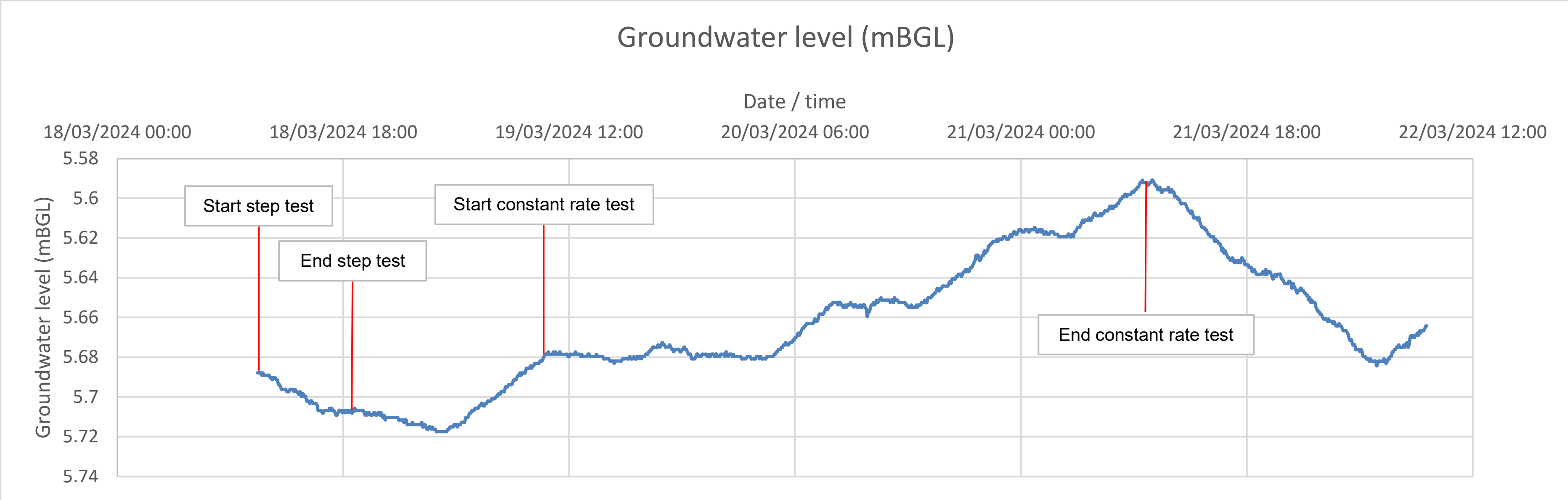
The opposite borehole to the one subject to pump testing was monitored for the duration of pump testing; the first borehole to be monitored was the Lake Borehole.

The monitoring level logger was installed in the Lake Borehole at 09:30 on the 18th March 2024 at a depth of 10mBGL, and was removed at 08:27 on the 22nd March 2024. The logger data has been shown in Figure 3-1.

At the start of the Shooting Range Borehole step test at 11:04 on the 18th March 2024 the groundwater level in the Lake Borehole was recorded at 5.69mBGL. By the end of the Shooting Range Borehole step test at 16:50 on the 18th March 2024 the groundwater level in the Lake Borehole was recorded at 5.71mBGL. The groundwater level in the Lake Borehole increased by 0.02m over the course of the Shooting Range Borehole step test.

At the start of the Shooting Range Borehole constant rate test at 10:17 on the 19th March 2024 the groundwater level in the Lake Borehole was recorded at 5.68mBGL. By the end of the Shooting Range Borehole constant rate test at 10:30 on the 21st March 2024 the groundwater level in the Lake Borehole was recorded at 5.59mBGL. The groundwater level in the Lake Borehole decreased by 0.08m over the 48-hour duration of the Shooting Range Borehole constant rate test.

Figure 3-1 Lake Borehole monitoring - groundwater level (mBGL)



Changes to the groundwater level at the Lake Borehole can be seen in Figure 3-1 however there is not considered to be a strong correlation to the pumping tests at the Shooting Range Borehole.

During the Shooting Range Borehole step test the groundwater in the Lake Borehole falls however this continues after the pump has been turned off. Additionally, the groundwater in the Lake Borehole rises throughout the constant rate test at the Shooting Range Borehole.

It should be noted that the difference between the minimum and maximum groundwater levels in the Lake Borehole over the four days of monitoring was just 0.13m; ranging between 5.72mBGL in the early morning of the 19th March 2024 and 5.59mBGL in the late morning of the 21st March 2024.

It is considered that the small fluctuations in groundwater level at the Lake Borehole represent natural variation in response to other factors such as rainfall and groundwater recharge.

3.3 Shooting Range Borehole

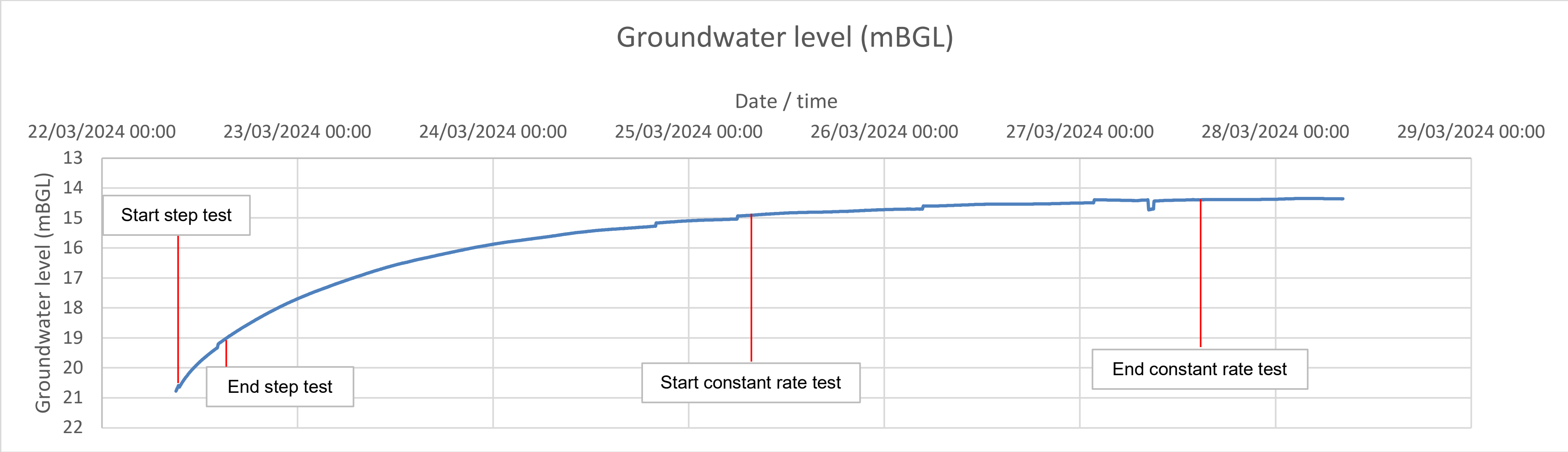
The opposite borehole to the one subject to pump testing was monitored for the duration of pump testing; the second borehole to be monitored was the Shooting Range Borehole.

The monitoring level logger was installed in the Shooting Range Borehole at 09:05 on the 22nd March 2024 at a depth of 25mBGL, and was removed at 08:15 on the 28th March 2024. The logger data has been shown in Figure 3-2.

At the start of the Lake Borehole step test at 09:53 on the 22nd March 2024 the groundwater level in the Shooting Range Borehole was recorded at 20.49 mBGL. By the end of the Lake Borehole step test at 15:15 on the 22nd March 2024 the groundwater level in the Shooting Range Borehole was recorded at 19.01 mBGL. The groundwater level in the Shooting Range Borehole were noted to have risen by 1.48 m over the course of the Lake Borehole step test.

At the start of the Lake Borehole constant rate test at 08:24 on the 25th March 2024 the groundwater level in the Shooting Range Borehole was recorded at 14.89 mBGL. By the end of the Lake Borehole constant rate test at 14:20 on the 27th March 2024 the groundwater level in the Shooting Range Borehole was recorded at 14:39 mBGL. The groundwater level in the Shooting Range Borehole was recorded to have risen by 0.50 m over the course of the Lake Borehole constant rate test.

Figure 3-2 Shooting Range Borehole monitoring - groundwater level (mBGL)



A change of the groundwater level at the Shooting Range Borehole can be seen in Figure 3-2 however there is not considered to be a correlation to the pumping tests at the Lake Borehole.

The groundwater data for the Shooting Range Borehole shows a steady recovery throughout the whole monitoring period, reflecting the remaining ~5m recovery at the end of the constant rate test. This agrees well with the constant rate groundwater level data shown in Figure 2-3 where the recovery had not completed the final ~5m before the logger was removed.

If the monitoring data shown in Figure 3-2 for the Shooting Range Borehole do not show any influence of the pumping taking place at the marked times from the Lake Borehole, it follows that any correlating fluctuation in the Lake Borehole monitoring data (Figure 3-1) during pumping at the Shooting Range Borehole must be from other factors, such as rainfall.

3.4 Hensol Lake

Hensol Lake was monitored during pump testing at each of the two abstraction boreholes.

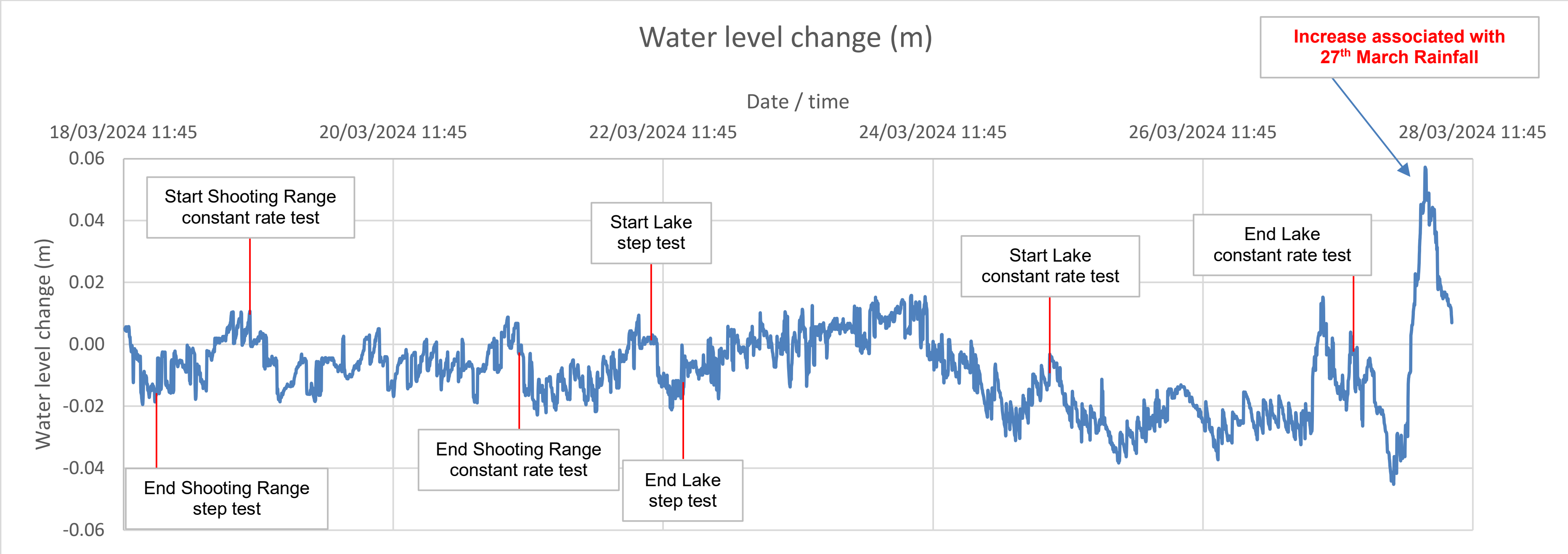
The monitoring level logger was placed in Hensol Lake at 12:00 on the 18th March 2024, slightly after pumping has started at the Shooting Range Borehole step test. The monitoring level logger was removed at 08:00 on the 28th March 2024. The logger data has been shown in Figure 3-3.

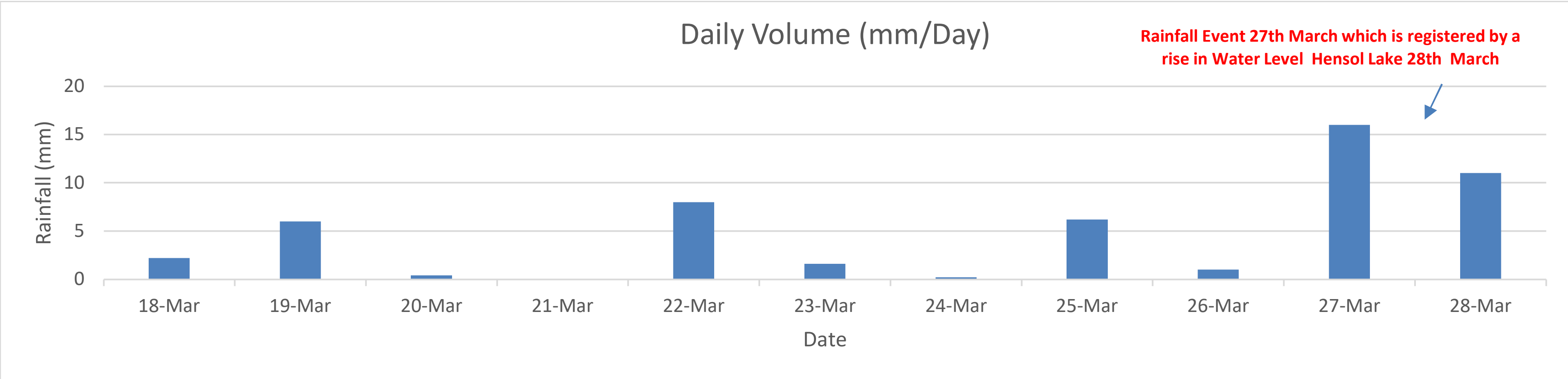
The data have been shown as variation from a known depth of the logger (0.13m below the surface, taken as a zero point) measured at 09:00 on the 22nd March 2024.

The pumping tests at each abstraction borehole have been marked on the graph. The maximum fluctuation from the baseline level was recorded at +0.06m around 03:20 on the 28th March 2024, and the minimum was recorded at -0.04m at around 21:30 on the 27th March 2024.

The total fluctuation in water level at Hensol Lake over the monitoring period was 0.1m, however this was constrained to a ~6 hour period near the end of monitoring; the majority of the time the total fluctuation was recorded at less than 0.04m. The largest fluctuation seen in Hensol Lake related to the recharge of the lake levels following an intense rainfall event recorded on the Rhiwsaeson STW' rain gauge 27th March as shown in Figure 3-3.

Figure 3-3 Hensol Lake monitoring – water level change (m)





The monitoring of Hensol Lake during the step and constant rate testing at the Lake and Shooting Range Borehole indicates that the lake is not in continuity with the underlying bedrock from which groundwater was being abstracted. The lake water level is therefore not influenced by abstraction from either of the newly installed abstraction boreholes.

3.5 Existing Hotel Borehole and Golf Course Borehole

Limited access was available to 2 no existing groundwater boreholes at the Vale Resort in order to collect manual groundwater level dips during pumping tests. The boreholes are in constant use and supply the Vale Resort with groundwater from the superficial deposits.

The location of the 2 no existing boreholes has been shown on Drawing 3.

The groundwater level at the Golf Course Borehole could not be determined as there was a blockage in the dip tube. However, it was observed that the borehole was in use with the pump operating (and pulsing on and off) during the monitoring period. The Hotel Borehole was also in use and the pump could not be stopped to take steady level readings. The groundwater levels recorded at this borehole are affected by the pump which was actively abstracting groundwater from the shallow superficial deposits for site use; the observations have been summarised in Table 3-1.

Table 3-1 Hotel Borehole - groundwater level (mBGL)

Date	Time	Groundwater level (mBGL)
27/03/2024	13:40	4.6m +/-0.1m (pumping fluctuation)
28/03/2024	09:47	4.5m to 4.9m (pumping fluctuation)

The groundwater level reading taken on the 27th March 2024 was recorded during constant rate testing at the Lake Borehole. The groundwater level reading taken on the 28th March 2024 was recorded after the pump at the Lake Borehole had been switched off for approximately 18 hours and the resting water level in the Lake Borehole had returned to the pre-pumping level.

The groundwater level data for the Hotel Borehole in Table 3-1 does not indicate that there was any drawdown impact caused by pumping at the Lake Borehole.

4 Pumping Test Analysis

4.1 Introduction

The pump tests at both the Shooting Range Borehole and the Lake Borehole have been analysed within AquiferWin32 using the Hantush and Jacobs (1955) Leaky Aquifer analysis and the Hantush (1960) Leaky Aquifer.

The aquifer underlying the Site has been considered as 'Leaky' based upon the ground conditions encountered during drilling of both boreholes. The bedrock aquifer is overlain by superficial deposits (sandy clays, and gravels) which are likely to be somewhat permeable and allow flow into or out of the aquifer. The clays immediately overlying the bedrock are likely acting as an aquitard between the upper (superficial aquifer) and the lower bedrock aquifer.

During pumping of the borehole, the hydraulic head within the bedrock is lowered, creating a hydraulic gradient not only within the bedrock aquifer itself, but also within the overlying aquitard, therefore drawing water vertically downwards from the overlying superficial sands and gravels. The flow in the aquifer is assumed to be horizontal, with vertical flow assumed within the aquitard.

Pumped borehole drawdown readings can be used to derive transmissivity values. However, no observation boreholes were included in the test to facilitate calculation of representative values for storage.

The following sections of the Report present the results of the analysis for both of the newly completed boreholes.

4.2 Shooting Range Borehole - AquiferWin32 Analysis

Constant Rate Test

AquiferWin32 has been used to calculate the transmissivity from the constant rate test at the Shooting Range Borehole. The constant rate pumping phase has been analysed using the Hantush and Jacobs (1955) Leaky Aquifer analysis and the Hantush (1960) Leaky Aquifer analysis, with the aquifer parameters calculated from both methods compared to each other and literature values.

Transmissivity values outputted vary depending on the method of analysis used. Where storage within the aquitard layer is considered the transmissivity of the underlying aquifer is 0.69 m^2/day. Where no storage within the aquitard is considered a transmissivity of 0.66 m^2/day is calculated.

A comparison of all calculated transmissivity values is provided as Table 4-1.

Figure 4-1 Hantush Leaky AquiferAnalysis

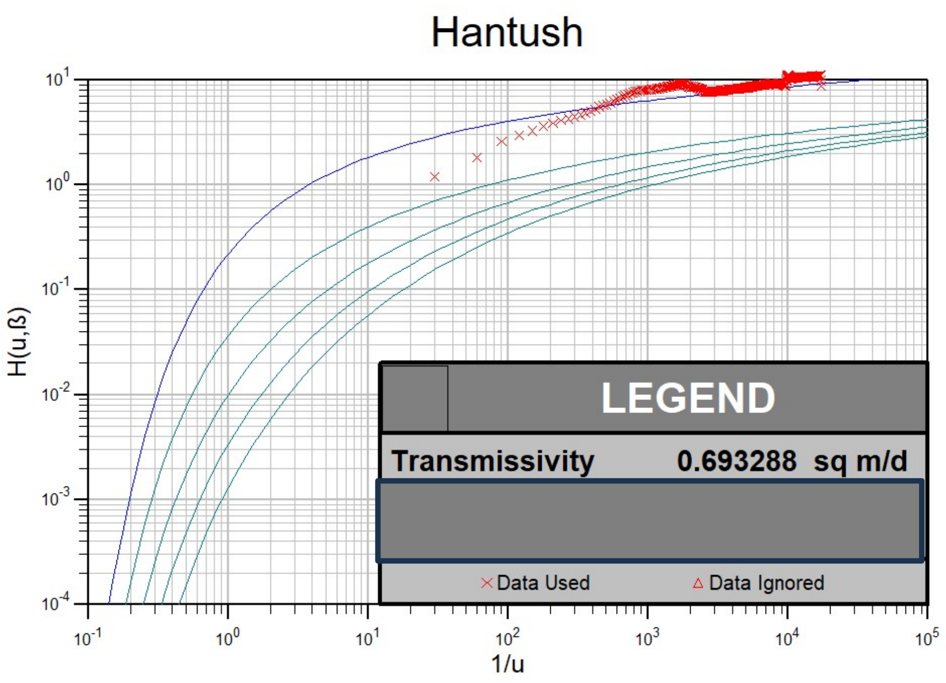
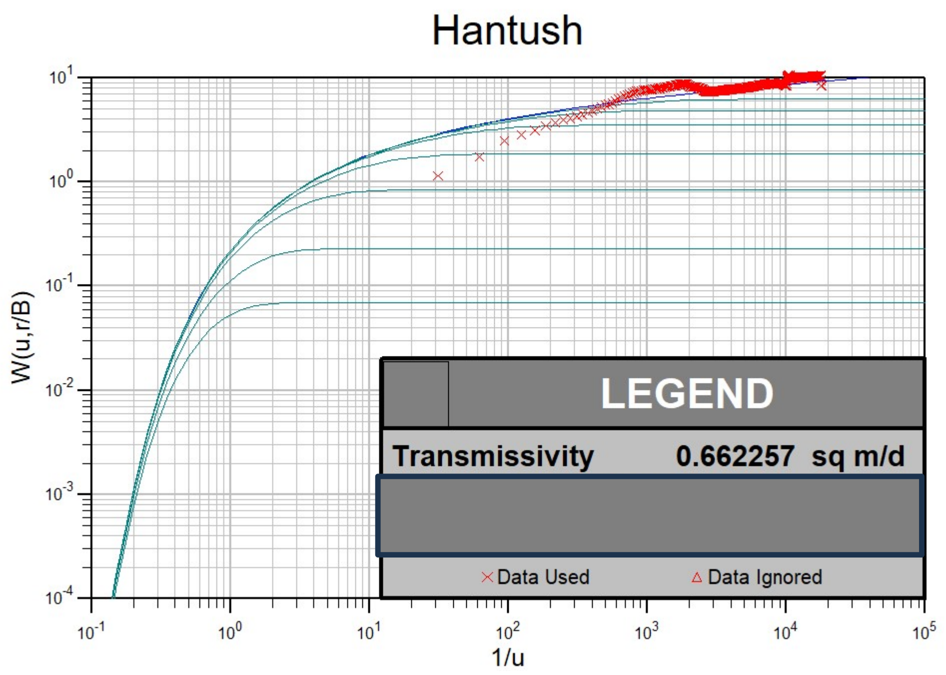


Figure 4-2 Hantush & Jacob Leaky Aquifer Analysis



The Environment Agency Technical Report WD/00/04, (2000), 'The physical properties of minor aquifers in England and Wales' literature indicates that there is a large range of transmissivity values for Devonian aquifers in this region, with the literature providing 25th and 75th percentile transmissivity values from 66 no. borehole tests within the Old Red Sandstone geology of Wales and the Welsh Borders. The literature states that the 25th percentile is 4 m^2/d, with a 75th percentile of 52.8 m^2/day. The AquiferWin analysis therefore indicates the calculated transmissivity for the Shooting Range Borehole is lower.

Recovery Phase

The recovery phase of the test at the Shooting Range Borehole was analysed in AquiferWin32 using the Theis recovery method, shown in Figure 4-3 to Figure 4-5.

Figure 4-3 Shooting Range Borehole recovery test analysis – Theis (whole dataset optimised)

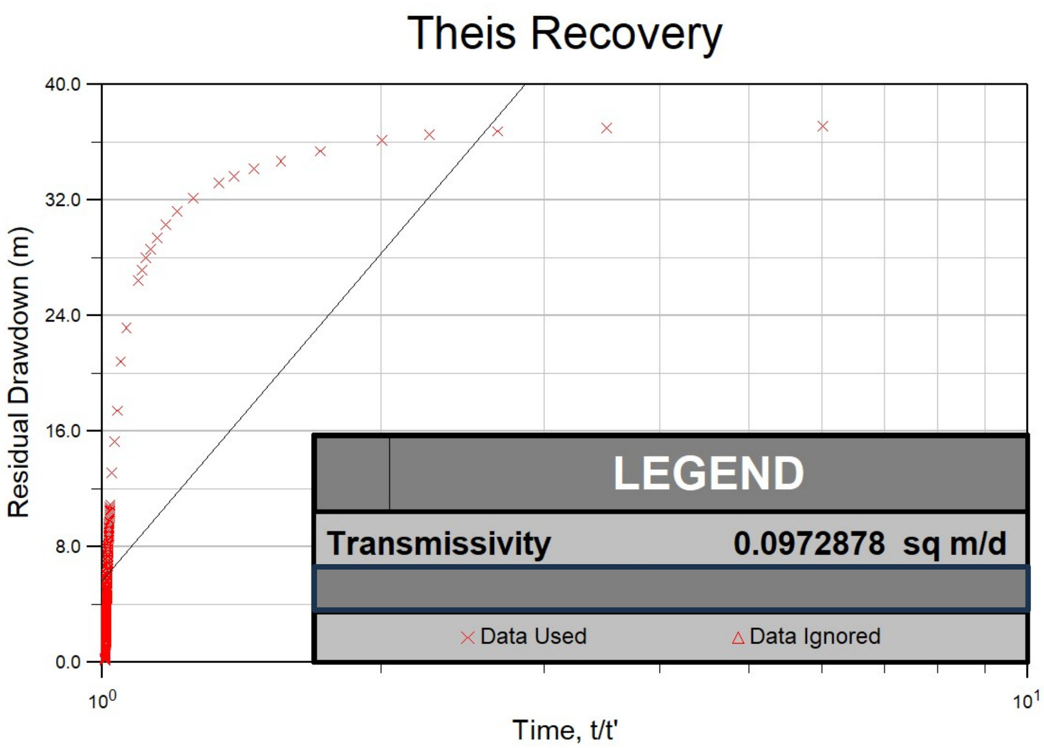


Figure 4-4 Shooting Range Borehole recovery test analysis – Theis (early data optimised)

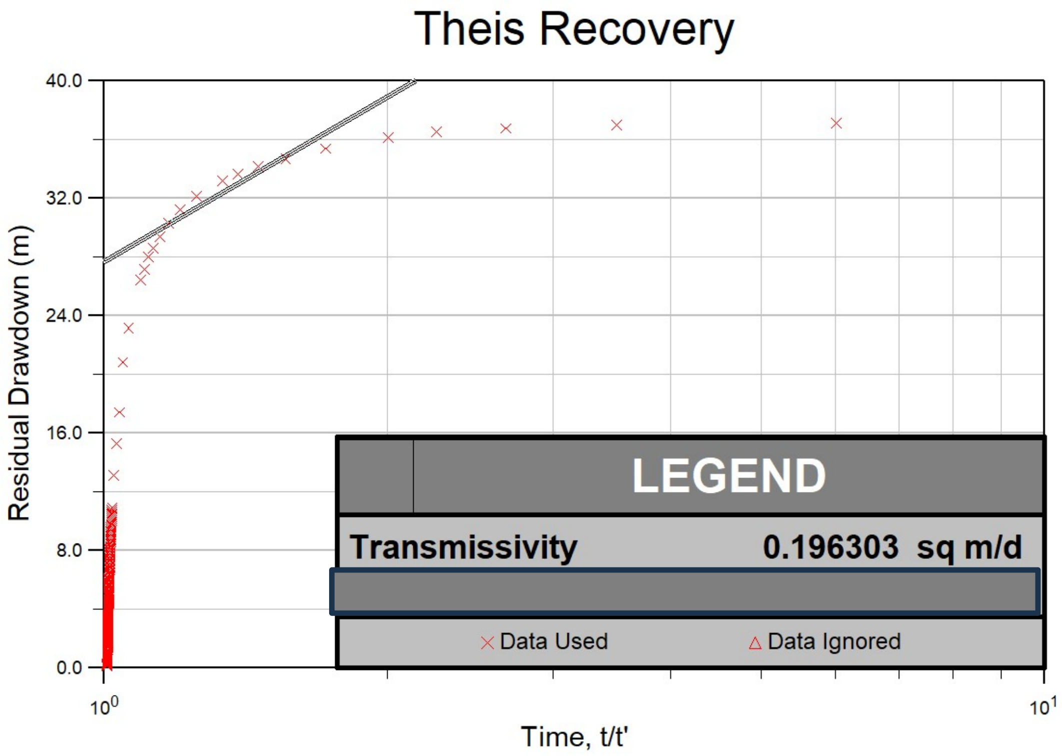
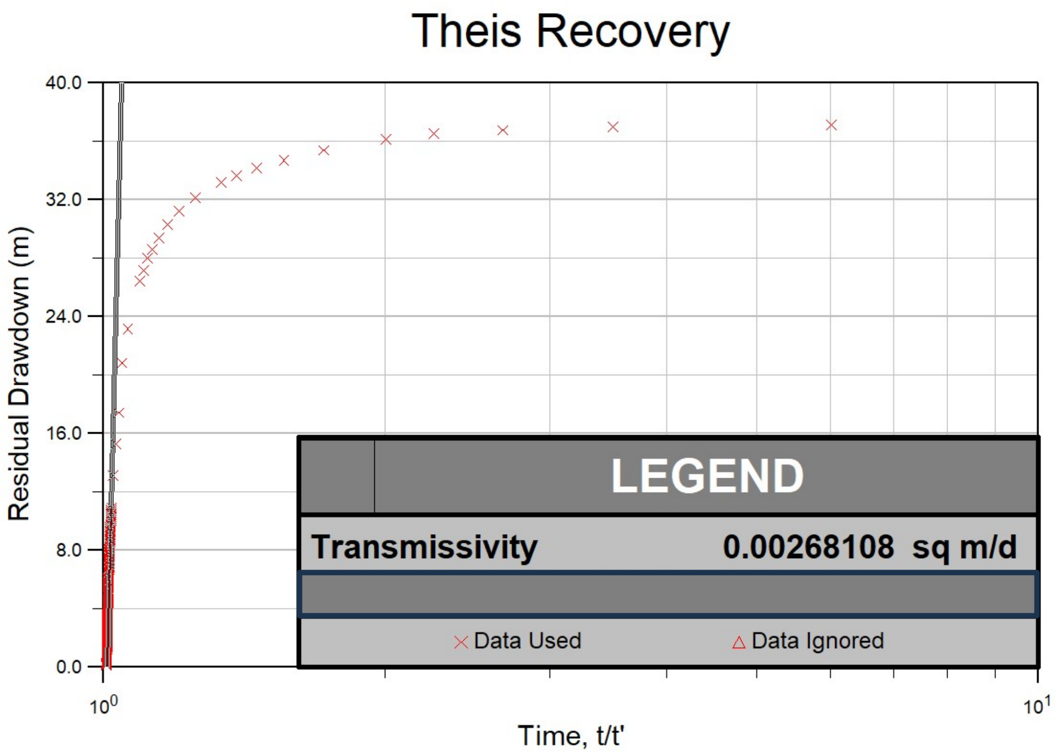


Figure 4-5 Shooting Range Borehole recovery test analysis – Theis (late data optimised)



4.3 Lake Borehole - AquiferWin32 Analysis

Constant Rate Test

AquiferWin32 has been used to calculate the transmissivity from the constant rate test at the Lake Borehole. The constant rate pumping phase has been analysed using Hantush and Jacobs (1955) Leaky Aquifer analysis and the Hantush (1960) Leaky Aquifer analysis, with the aquifer parameters calculated from both methods compared to each other and literature values.

Transmissivity values outputted vary depending on the method of analysis used. Where storage within the aquitard layer is considered the transmissivity of the underlying aquifer is 0.17 m^2/day. Where no storage within the aquitard is considered a transmissivity of 0.73 m^2/day is calculated.

A comparison of all calculated transmissivity values is provided as Table 4-1.

Figure 4-6 Hantush Leaky Aquifer Analysis

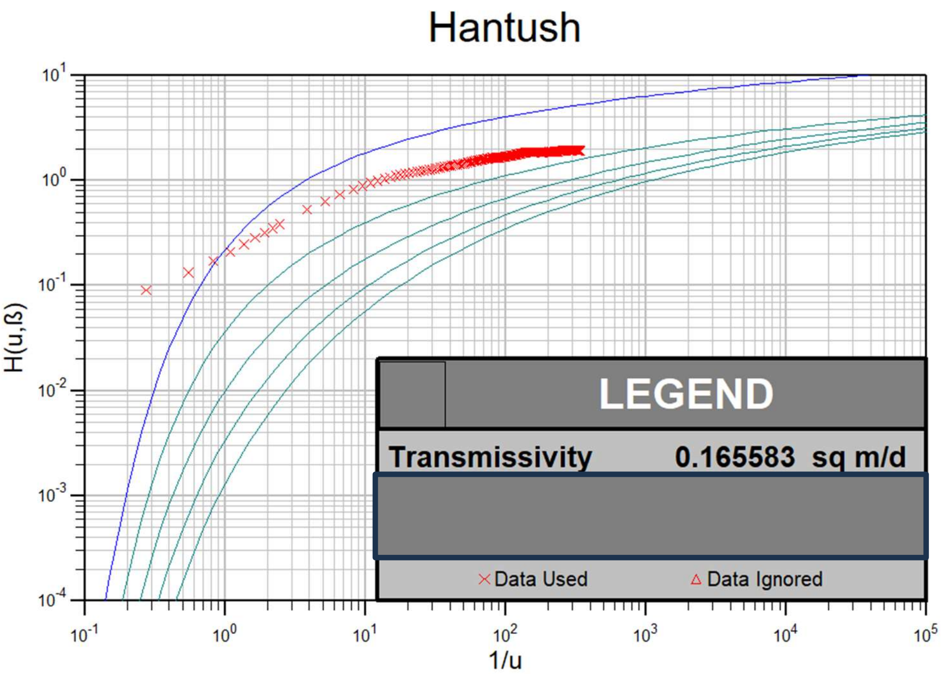
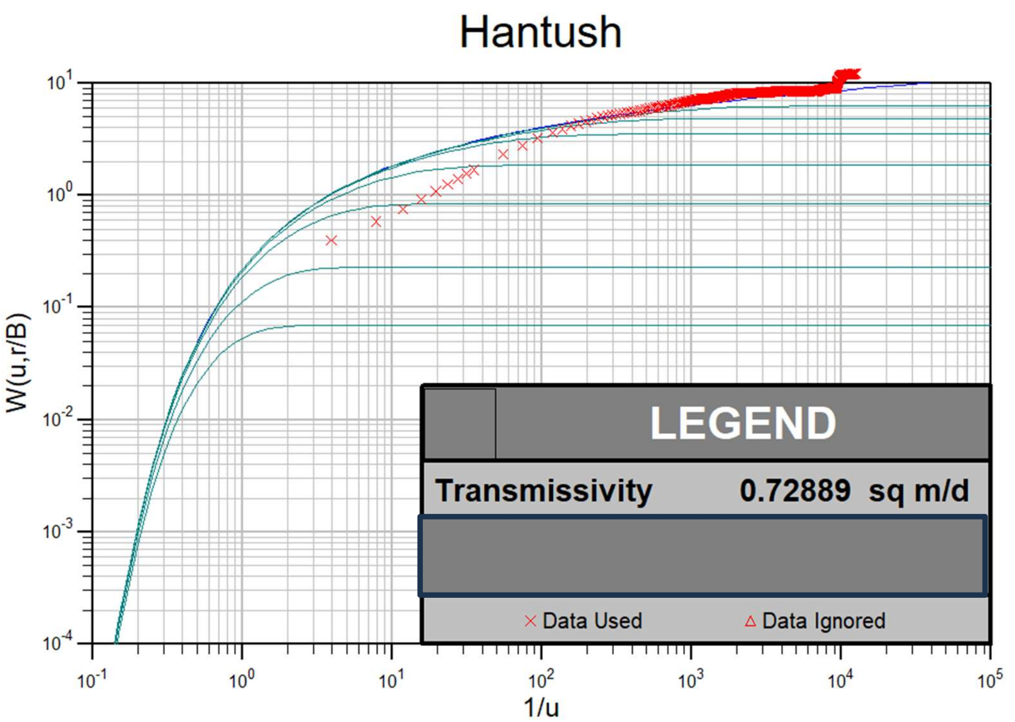


Figure 4-7 Hantush & Jacob Leaky Aquifer Analysis



The AquiferWin32 analysis indicates that the calculated transmissivities for the Lake Borehole using both methods is lower than the EA Technical Report WD/00/04 data 25th percentile of 4 m^2/day.

Recovery Phase

The recovery phase of the test at the Lake Borehole was analysed in AquiferWin32 using the Theis recovery method, shown in Figure 4-8 to Figure 4-10.

Figure 4-8 Lake Borehole recovery test analysis – Theis (whole dataset optimised)

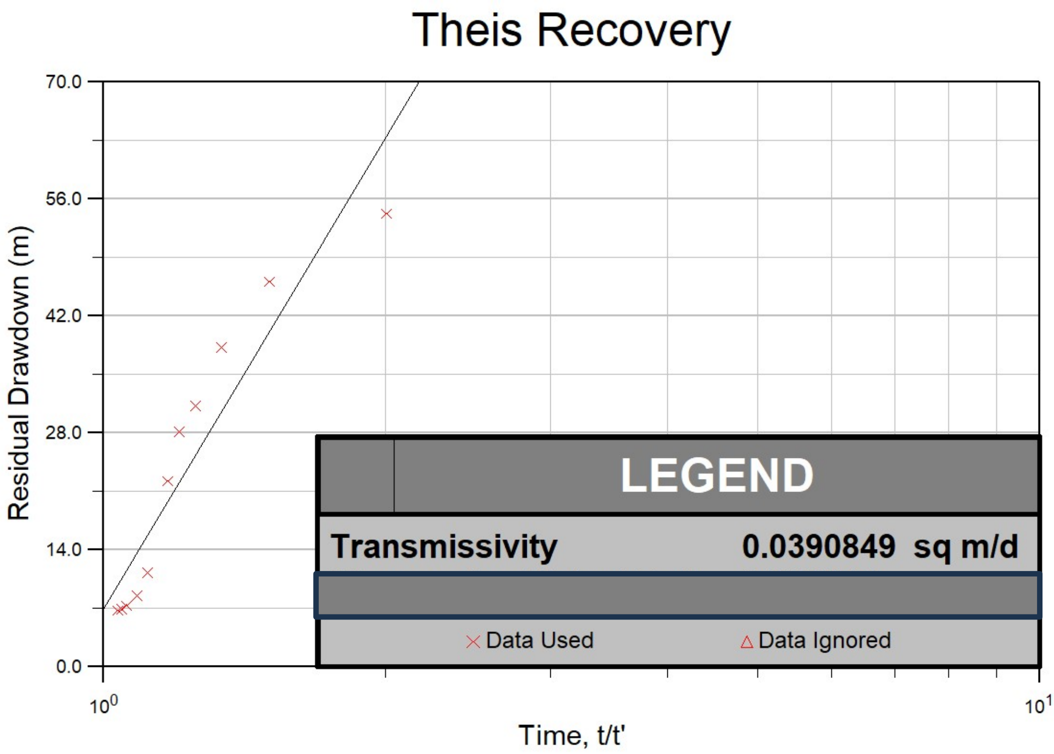


Figure 4-9 Lake Borehole recovery test analysis – Theis (early data optimised)

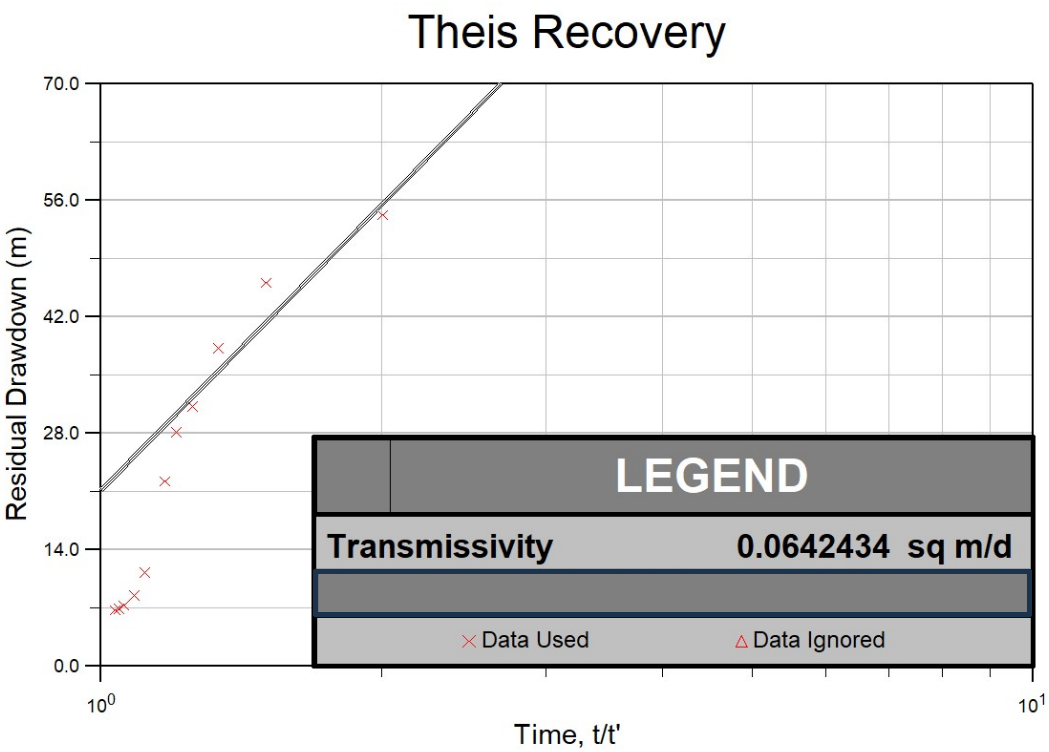
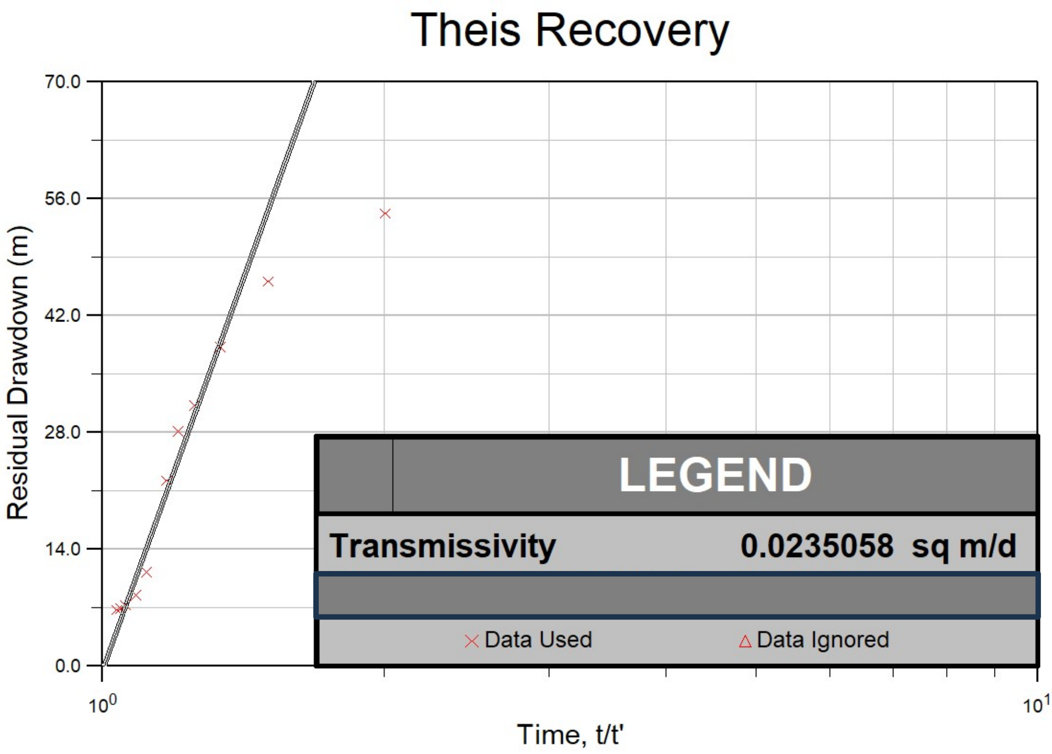


__Figure 4-10 Lake Borehole recovery test analysis – Theis (late data optimised)__



4.4 Analysis Summary

The pump test analysis (including recovery) has been progressed considering the aquifer as a 'Leaky Aquifer'. Therefore the Hantush and Jacob (1955) Leaky Aquifer, and the Hantush (1960) Leaky Aquifer analysis within AquiferWin32 was applied to the constant rate test, with the Theis Recovery (1946) method applied to the recovery phase data.

The calculated aquifer properties including the transmissivity and specific capacity are presented in Table 4-1. Also included are transmissivity and specific capacity values from the Environment Agency Technical Report WD/00/04, (2000) 'The physical properties of minor aquifers in England and Wales' for the Devonian aquifers, to allow comparison to published aquifer properties.

Table 4-1 Comparison of aquifer properties

Source	Value (Shooting Range Borehole)	Value (Lake Borehole)
Transmissivity		
Pumping Phase – Hantush & Jacob	0.66m^2/day	0.73m^2/day
Pumping Phase – Hantush	0.69m^2/day	0.17m^2/day
Recovery Phase – Theis	0.097m^2/day	0.039m^2/day
Recovery Phase – Theis (early / late)	0.20 / 0.0027m^2/day	0.64 / 0.024m^2/day
Literature Value - Geometric Mean	51 / 10.7m^2/day	
Literature Value – Min / Max	0.000001 / 350m^2/day	
Literature Value - 25/75 Percentile	4 / 52.8m^2/day	
Specific Capacity		
Pumping Phase	0.81m^3/day/m	0.55m^3/day/m
Literature Value – Geometric Mean	39.3 / 8.29m^3/day/m	
Literature Value – Min / Max	0.000001 / 1,226 m^3/day/m	
Literature Value - 25/75 Percentile	2.4 / 29.8m^3/day/m	

4.5 Impact Assessment – Summary

Monitoring of key water features was progressed during the pump test in line with the NRW Consent and schedule of conditions. The features included groundwater boreholes and Hensol Lake. It was noted by the records during drilling of the boreholes within the overlying superficial deposits vast thicknesses of clay (of 12m thickness) which was laterally continuous within the superficial deposits underlying the site. These thicknesses would afford protection to the shallow superficial abstractions as well as Hensol Lake.

It should be noted that no complaints were logged by nearby landowners or water users during the test pumping period. Groundwater was not recirculated back into the aquifer during the pumping test so as not to impact upon any monitoring results.

Monitoring included Hensol Lake, available shallow superficial abstraction boreholes which were in constant use by the Vale through the test period. The groundwater levels within the Brownstones Formation, being the opposite newly installed borehole to the one being pumped were also carefully monitored. All features were measured using electronic pressure transducers set to record pressures.

The pumping test has demonstrated no impact to groundwater within the Superficial Deposits, underlying Brownstones Formation or the Surface Water within Hensol Lake. Hensol Lake was shown to respond to local rainfall, with the lake level recharged by localised rainfall falling across the catchment area 27th March 2024.

The pumping test was progressed for a period of > 48 hrs of constant pumping within each of the newly competed boreholes. It is considered that any abstraction from the Brownstones Formation would not impact upon Hensol Lake or the Shallow Superficial groundwater aquifer across the site and wider area. The proposed use of the boreholes is for irrigation which will likely involve pumping and storing groundwater this is to be confirmed by the client team.

5 Conclusions

Groundwater abstracted by the on-site abstraction boreholes is drawn from sandstone horizons within the Brownstones Formation. Hydrogeo have been advised by the client team that during borehole installation the overlying superficial deposits have been screened out with steel casing advanced and driven / sealed into the underlying Brownstones Formation.

The Brownstones Formation at the Site appears to exhibit predominantly a fracture-flow regime, evidenced by the stepped drawdown during the constant rate test at the Lake Borehole, and backed up by literature sources.

As per the associated NRW Consent to Investigate a Groundwater Source, monitoring of a number of identified water features was progressed during pump testing of the abstraction boreholes, including Hensol Lake and the opposite borehole to the one being pumped. All features were measured using electronic pressure transducers set to record pressures at 5-minute intervals. Additionally, observation of the existing onsite Golf Course and Vale Hotel groundwater abstraction boreholes installed in the shallow superficial deposits beneath the Site was also progressed during the monitoring period. This monitoring was able to confirm no impact during the testing period with observations that water levels and abstraction (for hotel complex) of the shallow superficial continued and remaining consistent.

Continuous pumping of the abstraction boreholes for at least 48 hours at average rates of 41.85m^3/day for the Shooting Range Borehole and 32.8m^3/day for the Lake Borehole resulted in a maximum drawdown of 51.41m and 60.01m, respectively.

Aquifer parameters have been derived from the pumping test data, as well as the recovery test data within AquiferWin32. Transmissivity results were found to be lower than the 25th percentile of typical published literature values for the Devonian Old Red Sandstone strata of Wales and the Welsh Borders.

Across both the boreholes, transmissivity values ranged from 0.19m^2/day – 0.73m^2/day (Lake Borehole) and 0.66m^2/day – 0.69m^2/day (Shooting Range Borehole). The specific capacity has been calculated at 0.81m^3/day/m for the Shooting Range Borehole and 0.55m^3/day/m for the Lake Borehole.

The Vale Hotel are installing semi-artificial hybrid grass/plastic/nylon training pitches. The irrigation requirement is slightly higher than standard grass pitches. It is proposed groundwater is abstracted and stored for use across the sports pitches. Waters required will comprise combination of abstracted groundwater and also surface water abstraction (Hensol Lake); the application for which is being progressed by others.

It is considered that a proposed abstraction rate in the order of 35m^3/day from either of the boreholes is not expected to impact upon any of the identified water features, or result in extensive drawdown impacts on the groundwater, based on the results of the pumping test.

This report will be issued to NRW to support the application for an abstraction licence.

Drawings

Drawing 1

Geology map – superficial deposits

HYDROGEO

HYG1279 Vale Resort

DRAWING 1

Geological Map - Superficial Deposits

KEY

Abstraction borehole

Head
Clay, silt sand and gravel

Till
Diamicton

100 0 100 200 m

N

Date	By	Paper	Scale	Rev
04 2024	TP	A3	1:5,000	1

Drawing 2

Geology map – bedrock

HYDROGEO

HYG1279 Vale Resort

DRAWING 2

Geological Map - Bedrock

KEY

Abstraction borehole

Fault

Triassic

Blue Lias Formation

Penarth Group

Mercia Mudstone Group

Lower Carboniferous (unconformity)

Barry Harbour Limestone Formation

Cwmyniscoy Mudstone Formation

Castell Coch Limestone Formation

Tongwynlais Formation

Upper Devonian

Quartz Conglomerate Group

Cwrt-yr-ala Formation

Lower Devonian (unconformity)

Brownstones Formation

Llanishen Conglomerate

100 0 100 200 m

N

Date	By	Paper	Scale	Rev
04 2024	TP	A3	1:5,000	1

Drawing 3

Borehole location plan

HYDROGEO

HYG1279 Vale Resort

DRAWING 3

Borehole location plan

KEY

- Abstraction borehole (new)
- Abstraction borehole (existing)

Locations of existing boreholes informed by BGS data and Techincal Memorandum by Rigare Limited, January 2020

50 0 50 100 150 200 m

N

Date	By	Paper	Scale	Rev
04 2024	TP	A3	1:4,000	1

Appendices

Appendix A

Pump test data – Shooting Range Borehole

Appendix B

Pump test data – Lake Borehole

Appendix C

Monitoring data – Shooting Range Borehole

Appendix D

Monitoring data – Lake Borehole

Appendix E

Monitoring data – Hensol Lake