Portintruan Distillery - Proposed Water Supply Boreholes 2023

BH5 & 7 Pumping Test Report

January 2024 (HighWater Ref Singh-Port Ellen)

FLOW-5

HighWater Private Water Supplies

Portintruan Distillery: Proposed Water Supply Boreholes 2023

BH5 & 7 Pumping Test Report

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1 Introduction

1.1 Project Background

This document contains a report of pumping tests completed on two water supply boreholes for the new Portintruan Distillery development on Islay (HighWater Project Ref: Singh-Port Ellen). This report includes basic interpretation and comment on pumping test results (including potential impacts to receptors) and water quality test results. This report has been written to accompany and support a CAR abstraction licence application that will be made to SEPA.

The water supply boreholes (referred to as ***BH5 and BH7***) were drilled and installed in January 2015 (BH5) and April 2023 (BH7), with pumping tests completed in October 2023. The water abstracted from these boreholes is intended to be used as the primary source of process water for the new whisky distillery site, which is under development. It is understood that the site will require a maximum of 200 m^3 per day (2.31 l/s). The site area and borehole locations are shown on **Figure 1**.

Registration of the drilling and testing activity (CAR/R/5004458), a water features survey and consultation with SEPA was completed in the first half of 2023.

1.2 Works Completed

Table 1 *- Summary timeline of works completed*

Date	Activity
09/01/15	BH5 Drilling and Installation
04/04/23	BH7 Drilling and Installation
13/09/23 – 17/10/23	Pre-Pumping Test Monitoring
17/10/23 – 21/10/23	Pumping Tests (BH5 and BH7)
21/10/23 – 27/10/23	Post-Pumping Test Monitoring

A detailed timeline of pumping tests completed is provided in **Section 3.1**.

2 Borehole Drilling and Installation

A total of ten boreholes have been drilled at the site during two drilling campaigns, the first being in 2015 and the second in 2023. For the purposes of the pumping tests reported here, monitoring was completed at the two pumping boreholes (BH5 and BH7) and also at two monitoring boreholes (BH6 and BH8). Grid references are listed in **Table 2**, with locations shown on **Figure 1**.

2.1 Borehole Drilling and Installation

Table 2 *- Drilling diameter and depth*

Borehole ID	Grid Reference	Depth (mbgl)	Diameter (mm)	Installation Type	Steel Casing (m below ground)	Open Hole (m below ground)
BH5	NR 38202 45942	45	140	Open Hole	0 to 9m	9m to 45m
BH7	NR 38233 45900	63	190	Open Hole	0 to 3m	3 to 63m
BH6	NR 3816345832	45	116	Open Hole	0 to 6m	6 to 45m
BH8	NR 37834 45785	90	190	Open Hole	0 to 9m	9m to 90m

All of the boreholes are 'open hole' type installations, with steel casing installed to the upper part of the borehole to isolate and stabilise the overlying sediment deposits. The rest of the length of the borehole (through solid bedrock) to the base being left open to allow maximum inflow to the hole from any fractures that have been intersected.

Pumping boreholes BH5 and BH7, located 52m from each other in the north-east of the site area were found to be productive (tests after drilling indicated yields of >5m^3/h). BH8 (located 420m from BH7 and 400m from BH5) was found to have a lower yield (<3m^3/h). BH6 was drilled as a monitoring borehole, to be used to identify potential impacts to an existing private water supply borehole in the vicinity of the site (as described below in **Section 3.1.3**). BH6 is 97m south of BH7. All borehole locations are shown on **Figure 1**.

2.1.1 Borehole Development

Upon completion of drilling, the two pumping boreholes reported here were developed by pumping with a submersible pump until the discharge water ran clear and free of sediment.

- BH5 was pumped for 3 days at 6.9m^3/h.
- BH7 was pumped for 6 hours at 7.3m^3/h.

This development is completed to clear the borehole of any debris remaining from the drilling process, maximise the yield of the borehole by clearing inflow pathways and to ensure the discharge water is clear and free of sediment. Data collected during this development pumping was also useful to estimate borehole yields prior to the full pumping tests reported here.

2.1.2 Borehole Completion

The final headworks and pump installation has not been completed at the time of writing this report. It is anticipated that this will be completed after an abstraction licence has been successfully obtained for this site.

2.2 Geology and Hydrogeology

2.2.1 Regional Geology and Hydrogeology

The bedrock and superficial geology underlying the site area is shown on **Figure 2** and **Figure 3** (showing 1:50,000 British Geological Survey (BGS) mapping, accessed through BGS Geology 50K WMS Layer).

Bedrock

The available BGS mapping shows that the site is largely underlain by the Port Ellen Phyllite Formation, comprised of Pelite, Metalimestone and Quartzite. These rocks were sedimentary in origin, possibly deposited in a shallow-marine environment and have subsequently undergone low-grade metamorphism. These are part of the Easdale Subgroup which are expected to be up to 3km thick. The Laphroaig Quartzite lies to the south of the site. This was also originally a sedimentary rock which has undergone low-grade metamorphism.

The area has many east-west trending Amphibolite dykes with occasional northwest-southeast trending Microgabbro (as seen on **Figure 2**) (BGS, 2023).

These rocks are generally hard and of low permeability, except in areas where they have been significantly weathered, faulted and fractured (this typically occurs most strongly in the upper 50m below ground level).

Superficial

The available BGS mapping shows that the site and most of the surrounding area has minimal superficial cover (as seen on **Figure 3**). Drilling logs indicate that the site does has some superficial cover of peat and head deposits (weathered sandy, gravel material) overlying bedrock however this is typically thin and does not appear to be laterally extensive. To the southeast of the site there is a cover of Raised Marine Deposits, consisting of Gravel, Sand and Silt, associated with an ancient shoreline.

2.2.2 Drilling Log and Observations

Information collected during the drilling of BH5, BH7, BH6 and BH8 are provided below. These logs indicate that the geology encountered typically consists of thin superficial cover, underlain by Dolerite or Pelite bedrock with varying degrees of fracturing and occasional Quartzite bands.

***Table 3** – Drilling Logs*

BH5 Drilling Log

From (mbgl)	To (mbgl)	Geological Description	Groundwater Strikes / Observations
0	0.5	Black PEAT	
0.5	6.5	SAND and GRAVEL	Damp
6.5	9	Grey weathered DOLERITE	
9	21	Heavily Fractured DOLERITE	
21	30	Hard grey DOLERITE	
30	33	Fractured DOLERITE	Wet
33	42	Hard QUARTZITE	Airlifting 2 l/s

BH7 Drilling Log

From (mbgl)	To (mbgl)	Geological Description	Groundwater Strikes / Observations
0	0.5	CLAY, SAND and GRAVEL	
0.5	0.8	Heavily Fractured DOLERITE	
0.8	3	Competent DOLERITE	
3	12	DOLERITE	
12	30	Heavily fractured DOLERITE	
30	34	Hard DOLERITE	Airlifting 2.5-3l/s
34	36	Fractured DOLERITE	
36	63	Hard unfractured DOLERITE	Airlifting 3-3.5l/s

BH6 Drilling Log

From (mbgl)	To (mbgl)	Geological Description	Groundwater Strikes / Observations
0	0.3	Brown CLAY SOIL	
0.3	1.8	Fine Till with GRAVEL	
1.8	2.4	Weathered BEDROCK	
2.4	4.6	Soft Grey PELITE	
4.6	6.0	Hard QUARTZITE	
6.0	12.5	QUARTZITE	
12.5	18.0	Soft Red PELITE	Fracture 14.5m, airlift 0.15m^3/h
18.0	27.0	Hard Grey PELITE	
27.0	34.0	Very Soft Grey PELITE	Dolerite Lumps at 31-32m
34.0	39.0	Dark Red Soft PELITE	
39.0	40.5	Hard Grey QUARTZITE	
40.5	45.0	Light Red PELITE	Airlifting 0.25m^3/hr from base of hole

BH8 Drilling Log

From (mbgl)	To (mbgl)	Geological Description	Groundwater Strikes / Observations
0.0	0.3	Black SOIL	
0.3	2.8	SAND, GRAVEL, CLAY	
2.8	4.4	Weathered BEDROCK	
4.4	12.0	Hard AMPHIBOLITE	
12.0	32.0	AMPHIBOLITE	Fractured. Airlift 1.3-1.8m^3/h
32.0	53.0	AMPHIBOLITE	
53.0	53.5	(Large Fracture)	
53.5	69.0	AMPHIBOLITE	
69.0	70.0	(Fracturing)	
70.0	90.0	PHYLLITE	Airlifting 2.8m^3/hr from base of hole

2.2.3 Hydrogeological Conceptualisation

Local Geology and Hydrogeology:

BH5 and BH7 have been drilled into Dolerite (intrusive dykes), while BH6 has been drilled into Pelite (metamorphosed sedimentary bedrock) and BH8 has been drilled into Amphibolite. These differences in bedrock geology, even over short lateral and vertical distances demonstrates the complex bedrock geology of this area.

For the purposes of this investigation, we are primarily interested in the hydrogeological properties of the bedrock, rather than the rock type and composition. The hard bedrock will support groundwater flow and storage only in areas where local fracturing and / or weathering is extensive. This is principally driven by local structural movements (causing fracturing, faulting), as well as local topography and landform (causing weathering), rather than being driven principally by the rock type.

Groundwater Occurrence and Hydraulic Properties:

BH5 and BH7 observed a significant water strike at approximately 30m depth (around 2 to -8 mAOD), a similar water strike was not observed in BH6 or BH8 or other boreholes drilled by HighWater in the vicinity. This is indicative of a strongly fractured area of rock at 30m depth in the vicinity of BH5 and BH7 that is not laterally extensive across the whole area.

Fracturing and associated groundwater strikes were observed at different depths in BH6 and BH8, as well as other boreholes drilled in the area, however, were found not to yield as much water.

This supports the hypothesis that local groundwater occurrence is driven by localised fracturing and weathering in the bedrock, which is highly localised and variable, even over short distances.

The fact that fracturing and water strikes were observed to some extent in all boreholes in the area in the upper 50m of bedrock mass (albeit at different depths) means that groundwater flow pathways across the rock mass are likely to all be hydraulically interconnected to some extent. This means that the bulk bedrock unit can be described as a fractured rock ‘aquifer’ which can support some level of groundwater flow and storage across the ‘bulk’ of the rock mass.

These ‘fractured rock’ type aquifers typically have high hydraulic conductivity in fractured zones, but generally have a low hydraulic conductivity across the unit as a whole (bulk hydraulic conductivity). These aquifers also typically have a low storage capacity (total volume of water stored in the rock mass).

Groundwater Levels:

Groundwater levels observed in all boreholes are seen to be close to ground surface (within 10m). Observed static groundwater levels are shown on cross sections shown on **Figure 5** (north-south) and **Figure 6** (west – east). This demonstrates that the bedrock ‘aquifer’ as described above, generally has a significant saturated thickness.

It is noteworthy that these static groundwater levels have been measured in November, when levels are likely to be relatively high. It is not known how far groundwater levels may drop during long dry periods (summer); however, we note that the west of Scotland does typically receive a significant amount of rainfall year-round, with few long dry periods, therefore it is likely that groundwater levels remain relatively high year-round. This is discussed further in **Section 3** below.

Groundwater Flow:

As described above, this bedrock unit is likely to support some level of groundwater flow through interconnected void spaces (fractured and weathered zones) across the rock unit. Given that observed static groundwater levels are typically high and close to ground surface, it is expected that groundwater flow will follow local topography and landform, generally flowing towards and discharging at areas of lower elevation.

In this case, the areas of lower elevation are the coastline to the south and the stream (Sruthan na Cille) running north-south through the site area. These are indicated on **Figure 5** and **Figure 6**.

The flow velocity and total volumes of groundwater flowing and discharging across the site area will be dictated by the bulk hydraulic conductivity of the bedrock unit as a whole, which is likely to be low.

Inference for Impact at Receptors:

The hydrogeological conceptualisation of the site area in relation to the private water supply and the stream (potential receptors identified in the Water Features Survey) is discussed in detail below in detail in **Section 3.1.3**.

3 Pumping Tests

Pumping tests were completed on BH5, BH7 and BH8 in October 2023. This document reports on the pumping tests completed on **BH5 and BH7 only**, the pumping test of BH8 has been documented separately to ensure that this document is focussed upon BH5 and BH7.

These boreholes are 52m away from each other (as shown on **Figure 1**), and therefore would be classed as one abstraction activity for the purpose of a CAR abstraction licence application to SEPA.

Both boreholes were subjected to 1) step test (4 x 60 min steps), 2) 24-hour constant rate test, and 3) 24-hour recovery monitoring; these tests were completed separately one after the other.

Water levels were also monitored at BH6, BH8 and a stage board in the stream (Sruthan na Cille) adjacent to the site through the test period, for reasons as described below.

Full data from the pumping tests is included in Appendix 1. A plot of all water level data collected through the entire testing period is shown on **Figure 7** (BH5, BH6, BH7) and **Figure 8** (Stream Stage Board).

3.1 Test Detail and Requirements

3.1.1 Timeline of Tests Completed

Table 4 – *Timeline of tests completed*

Test	From	To	Duration
Pre-test Monitoring	13/10/2023	17/10/2023	4 days
Step Test BH5	17/10/2023	17/10/2023	240 mins (4x 60 min steps)
Step Test BH7	18/10/2023	18/10/2023	240 mins (4x 60 min steps)
BH7 Constant Rate Test	19/10/2023	20/10/2023	24 hours
BH7 CRT Recovery	20/10/2023	21/10/2023	24 hours
BH5 Constant Rate Test	21/10/2023	22/10/2023	24 hours
Recovery / Post-Test Monitoring	22/09/2023	27/09/2023	5 days

3.1.2 Data Collection at Pumping Boreholes (BH5 and BH7)

The following data was collected from the pumping boreholes BH5 and BH7 during their respective pumping tests:

- Manual water level measurements taken with a dip-meter, as per the timing and intervals presented in SEPA guidance document WAT-RM-24 (within daytime / site access hours).
- Automatic water level and temperature recorded by a datalogger installed into each borehole (set to record every 1 hour in pre-test and post-test), set to record every 30 seconds during pumping.
- Automatic Electrical Conductivity (EC) was recorded via data-logger in BH7 (not BH5: Only one down-hole logger was available for use during testing, BH7 was chosen as it is deepest and closest to the sea. EC of BH5 water was measured at point of discharge).
- Flow rate (instant and cumulative) taken from an in-line mechanical flowmeter.
- Flow rate spot checks at discharge point.

- Field water quality (pH, TDS, temperature, EC).

A full record of all data collected is provided in Appendix 1.

3.1.3 Receptor Monitoring

A Water Features Survey (WFS) was completed to identify potential receptors in the area that could potentially be impacted by the proposed abstraction.

Two potential receptors were identified in the WFS:

- Private Water Supply (at Laphroaig View Guest House B&B)
- Stream (Sruthan na Cille)

The locations of these potential receptors are shown on **Figure 1**.

Potential Receptor 1: Private Water Supply (PWS)

An existing private water supply borehole was identified in the vicinity of the site at Laphroaig View Guest House B&B (as shown on **Figure 1**; 145m southwest of BH7). Monitoring of this water supply has been recommended by SEPA to ensure that any potential impacts to this water supply that may arise from the pumping of BH5 and BH7 can be detected.

This PWS borehole was originally identified in 2015 when BH5 was drilled. At that time the owner was contacted to ask if it would be possible to inspect and monitor this private water supply during the testing of the boreholes. The owner did not agree to this on multiple occasions. Since 2015 it is understood that the Portintruan Distillery have made further attempts to discuss this with the owner and no further agreements have been made.

The following is known about the PWS borehole:

- Private Water Supply for the Guest House and B&B.
- Registered with the Council as a Domestic Level (Type B) supply.
- Abstraction is presumed to be less than 10m^3 per day.
- The borehole is understood to be 36m deep (from previous conversations with owner).

After further consultation with SEPA on this matter, SEPA advised that in the light of not having permission to directly monitor the PWS borehole, a monitoring borehole could be installed between the PWS borehole and the abstraction boreholes (BH5 and BH7) as a way of detecting potential impacts to the PWS borehole.

Monitoring borehole BH6 was drilled in 2023 to be used for this purpose. BH6 is located between BH5/BH7 and the PWS borehole, being 45m north of the PWS borehole, locations are shown on **Figure 1**. This borehole intersects the bedrock unit up to 45m depth and has been left 'open hole' to ensure that the groundwater level in the borehole is representative of the bedrock unit as a whole over this depth.

We are confident that any potential impact (decline in water levels) that may occur at the PWS induced by the pumping of BH5 or BH7 would also be detected at BH6. BH6 has been drilled only 45m north of the PWS to a greater depth than the PWS, therefore if any hydraulic connection (conductive fracture or permeable rock unit) exists between BH5/7 and the PWS, this would also have been intersected by BH6.

The water level in BH6 was monitored by a datalogger installed set to record every 1 hour through the whole testing period. Manual water level measurements were taken at this borehole through the test period and used to corroborate and calibrate the hourly datalogger data. Water level data from BH6 is presented on **Figure 13** and discussed in **Section 3.3.2**.

Potential Receptor 2: Stream / Burn (Sruthan na Cille)

A stream running through the site area (named Sruthan na Cille) was identified as a potential receptor. The stream flows north to south approximately 280m west of BH5 and BH7 (marked on **Figure 1**).

Monitoring of the water level in this stream has been recommended by SEPA to ensure that any potential impact to the water level of the stream caused by the pumping of BH5 and BH7 can be detected.

The water level in the stream was measured using a stage board installed at the location marked on **Figure 1** (Grid Reference NR 37962 45802). Water levels were measured through the entire test period measurements taken once per hour by a vented data logger. Manual water level measurements were taken from the stage board throughout the testing to corroborate the logger values against manual measurements. A water level hydrograph from the stream is presented on **Figure 8** and is discussed below in **Section 3.3.3**. In this report we refer to level only and not flow rate.

Additional Monitoring: BH8

In addition to the above two receptors, water levels were also monitored in BH8 throughout the entire testing period. This borehole lies 400m west of BH7 and BH5 on the other side of the burn, as shown on **Figure 1**.

Water levels were recorded every 1 hour using a datalogger with periodic manual measurements. Water level data from BH8 is presented on **Figure 7**.

3.1.4 Saline Intrusion Monitoring

The electronic conductivity (EC) of the water in BH7 and BH5 was monitored through the testing as a method of detecting potential saline intrusion. SEPA did not explicitly instruct monitoring for potential saline intrusion, however as the boreholes are between 600 and 700m from the coastline this was completed anyway as a conservative approach.

This monitoring was completed to detect any increase in EC (a proxy for salinity) through the testing that could indicate that saline water is being drawn inland by the pumping (saline intrusion).

A down-hole logger able to monitor EC was installed into BH7 through the entire duration of testing (as this borehole is deeper and closer to the sea than BH5). In addition to this, the EC of the discharge water from both BH5 and BH7 was monitored throughout the testing using a handheld water quality meter.

3.2 Pumping Test Results

3.2.1 Pre-test Background Monitoring

Pre-test background monitoring was completed at the 2 x pumping boreholes (BH5, BH7), the stream stage board, the dedicated monitoring borehole (BH6) and BH8. Background monitoring was completed to establish baseline conditions at all monitoring points before the pumping commenced so general trends and potential influences on groundwater levels in this area can be understood.

There was heavy rainfall prior to the pre-test monitoring period (between 10th -12th October), which is likely to have resulted in the water levels at the start of the pre-test monitoring period being high. During the pre-test monitoring period (13th to 17th October) there was relatively little rainfall, this has resulted in a decline in water levels observed during the pre-test period as can be seen on **Figure 7** and summarised in the below table.

Table 5 *- Decline in water levels during pre-test period*

Borehole ID	Decline in Water Level Observed during pre-test period (13 to 17 October)	Rate of Decline (m per day)
BH5	-0.77m	-0.19m
BH7	-0.74m	-0.18m
BH6	-0.52m	-0.13m
BH8	-0.35m	-0.09m

There are no SEPA rainfall gauges on Islay, therefore the rainfall data (as shown on **Figure 7**) is taken from the Amod Farm Rainfall Gauge, approximately 44km Southeast of the site (SEPA station number: 115501). Although this rainfall gauge is not a perfect match for Islay, it is the closest approximation available. This data is explored further in **Section 3.3.1** below.

3.2.2 Step Tests

A step test was completed separately on each pumping borehole. The tests were completed to establish each borehole's pumping capacity and efficiency and establish a suitable pumping rate for the following constant rate test. **Figure 9** and **Figure 10** show plots of drawdown during the step tests of BH7 and BH5, respectively. Full data from the step tests is contained in Appendix 1.

Table 6 *- Step test details*

Borehole	Step Length	No Steps	Step Rates	Date	Time Start	Time End	Duration
BH7	60 mins	4	1.6/1.9/2.5/2.8 l/s (5.8/6.8/9.0/10.1 m^3/h)	18/09/2023	09:20	13:20	240 mins
BH5	60 mins	4	1.1/1.4/1.7/1.8 l/s (4.0/5.0/6.1/6.5 m^3/h)	17/10/2023	10:00	14:00	240mins

General remarks:

In the BH7 test, the water level stabilised within the 60-minute step when pumped at each of the tested rates as shown above. BH7 had a total drawdown of 3.32m at the end of Step 4 (10.1m^3/h).

In the BH5 Test, the water level stabilised during the first 2 steps (up to 5m^3/h). However, during steps 3 and 4 the water level did not show signs of stabilising in the 60-minute period. At the end of the test a total drawdown of 14.76m was observed, although it is noted that the water level in the pumping borehole was still steadily declining at the end of the test Step 4.

For both step tests, no drawdown was recorded in the non-pumping borehole or monitoring borehole, as shown on **Figure 9** and **Figure 10**.

As the step tests were completed using 60-minute steps the results can only be used to demonstrate borehole yield capacity in the short term, and this data cannot be used to confidently draw any conclusions of borehole capacity over longer-terms. The constant rate tests reported below give a better indication of borehole pumping capacity and potential impacts to receptors over long pumping periods.

Analysis of the step tests (drawdown vs pumping rate, as per Rorabaugh (1953) method) has not been completed for this project, as the outputs of this analysis (linear, non-linear losses and borehole efficiency) are not appropriate for the type of borehole installation used here.

3.2.3 Constant Rate and Recovery Test

Following the step tests, a 24-hour Constant Rate Test (CRT) was completed at each borehole along with 24 hours of monitored recovery. Each pumping borehole was tested separately, allowing water level in the non-pumped borehole to be monitored for reference (as well as monitoring at BH6 and the stream stage board).

Details of the CRTs completed are provided below. **Figure 11** and **Figure 12** show a plot of water levels measured during the CRTs on BH7 and BH5 respectively. Full data is contained in Appendix 1.

Table 7 - *Constant rate test details*

Borehole	Average Pumping Rate	Start Time and Date	End Time and Date	Pumping Duration	Recovery Monitoring Duration
BH7	Consistent rate of 2.47l/s (8.9m^3/h) over 24-hour period	10:00 19/09/2023	10:00 20/09/2023	24 hours	24 hours
BH5	1.4l/s (5.0m^3/h) for first 10 hours, Then 0.75l/s (2.7m^3/h) for the remaining 14 hours after flow adjustment	10:00 21/10/2023	10:00 22/10/2023	24 hours	5 days

3.2.4 BH7 Constant Rate Test

For BH7, the average pumping rate achieved during the 24-hour CRT was 8.9m^3/h (213.6m^3/d). There was a total drawdown of 5.98m observed in the pumping borehole at the end of the test. Most of the drawdown occurred within the first 10 minutes. After this the water level continued to decline, albeit at a reduced but consistent rate until the end of the test. The water level declined consistently at a rate of approximately 14cm per hour for the final 12 hours of the test.

After the cessation of pumping, the water level in BH7 recovered quickly in the first 2 hours, after this the rate of recovery then slowed for the remainder of the monitoring period and had not fully recovered within the allocated 24-hour recovery period; after 24 hours the water level had recovered to 5.3mbgl, representing 89% recovery. After 24 hours recovery monitoring the team needed to start the constant rate test on BH5, so the recovery monitoring ended.

The drawdown and recovery curves observed here are typical of boreholes drilled into hard bedrock with water inflows from defined fractures / fracture zones.

Comment on BH7 Pumping Capacity

These CRT results demonstrate that the borehole can sustain pumping at 8.9m^3/h (213.6m^3/d) through a 24-hour period without the water level in the borehole dropping significantly.

However, the fact that the water level was continuing to decline at a steady rate throughout the test without stabilising and that the borehole did not recover to pre-test levels indicates that the borehole may not be able to sustain pumping at this rate for longer periods.

If a licence is granted for this abstraction, it would be advisable for the client to undertake further testing and monitoring of borehole water levels to confirm a long-term sustainable pumping rate.

Further analysis of the constant rate test results from BH7 has been completed (using Cooper and Jacob (1946) method along with Theis (1935) Recovery method) to make some initial approximations of the hydraulic properties of the aquifer at this location. This analysis is contained in Appendix 1 for reference but is not discussed further here.

Observation at Monitoring Boreholes

Table 8 - *Decline in Water levels During BH7 CRT*

Borehole ID	Decline in Water Level Observed during BH7 CRT period (10:00 19/09/2023 to 10:00 20/09/2023)
BH5	-1.41m
BH6	-0.10m
BH8	-0.06m

As expected, there is a notable drawdown in water level in BH5 (shown clearly in **Figure 7**) during the BH7 CRT. Hydraulic connection between these boreholes is expected as they are only 52m apart and both struck water strikes at approximately 30m depth. The hydraulic connection between these boreholes and the effect to the wider aquifer of pumping these boreholes is discussed further in **Section 3** of this report.

No drawdown was observed at BH6 or BH8 that could be attributed to the pumping of BH7. The decline of water levels observed during the CRT (shown in **Table 7** above) is in line with the daily rate of decline in water level noted during pre-test background monitoring (as shown in **Section 3.2.1**).

Potential impact to the PWS borehole receptor in the vicinity of the site is discussed further in Section 3.3 below.

Observation at Stream / Burn: Sruthan na Cille

There was a small rise in water level in the stream (as recorded at the stage board) at the start of the CRT on BH7. This is caused by a period of rainfall (Shown on **Figure 8**). There is a drop of 0.017m during the test. This aligns with the overall declining trend in explained in **Section 3.3.3**.

Therefore, there was no drawdown or reduction in the water levels in the stream during the constant rate test on BH5 that could be attributed to the pumping test.

Electronic Conductivity Monitoring

The down-hole EC logger recorded measurements of between 430 µS/cm to 450 µS/cm through the CRT. These measurements remained stable through the test, with no clear increasing or decreasing trend.

3.2.5 BH5 Constant Rate Test

At the beginning of the BH5 CRT the pumping rate was set to 5m^3/h (1.4l/s). At this rate the water level was declining rapidly. Around 3 hours through the CRT it was decided to lower the rate to 4m^3/h (1.1l/s). The water level recovered for a period of time then continued to decline. At around 10 hours through the test the flow rate was reduced to 2.7m^3/h (0.75 l/s) for the remaining 14 hours of pumping. An annotated graph of water levels through the test is shown on **Figure 12**.

When pumping at 2.7m^3/h (0.75 l/s) the water level in the pumping borehole stabilised at a level of 12.24m below ground level (7.09m drawdown) by the end of the test. This is well above the base of the borehole at 45m depth. There was a total of 0.56m of drawdown observed in the final 10 hours of pumping.

After the cessation of pumping, full recovery to pre-test level was observed within 24 hours.

Comment on BH5 Pumping Capacity

These CRT results demonstrate that BH5 can sustain pumping at a rate of at least 2.7m^3/h (64.8m^3/d) for 24 hours with water levels stabilising after 2 hours of pumping at this rate. However, the test results also show that this borehole cannot sustain pumping at 4m^3/h or higher without significant drop in water levels.

Further pumping test analysis has not been completed upon the CRT results for BH5 due to difficulties in interpretation caused by the changes in pumping rate though the test.

Observation at Monitoring Boreholes

Table 9 *- Decline in water levels during BH5 CRT*

Borehole ID	Decline in Water Level Observed during BH5 CRT period (10:00 21/09/2023 to 10:00 22/09/2023)
BH7	-0.49m
BH6	-0.10m
BH8	-0.04m

As expected, there is a notable drawdown in water level in BH7 (shown clearly in **Figure 7**) during the BH5 CRT. Hydraulic connection between these boreholes is expected as they are only 52m apart and both struck water strikes at approximately 30m depth. The hydraulic connection between these boreholes and the effect to the wider aquifer of pumping these boreholes is discussed further in **Section 3** of this report.

No drawdown was observed at BH6 or BH8 that could be attributed to the pumping of BH5. The decline of water levels observed during the test (shown in the table above) is in line with the daily rate of decline in water level noted during pre-test background monitoring (as shown in **Section 3.2.1**).

Potential impact to the PWS borehole in the vicinity of the site is discussed further in **Section 3.3.2** below.

Observation at Stream/ Burn: Sruthan na Cille

There is a drop in water level in the stream of 0.004m during the Test. This aligns with the overall declining trend in explained in **Section 3.3.1**.

Therefore, there was no drawdown or reduction in the water levels in the stream during the constant rate test on BH5 that could be attributed to the pumping test.

Electronic Conductivity Monitoring

The EC was measured through the test using a handheld probe, recording EC levels of between 310 µS/cm to 335 µS/cm through the test. The EC levels remained relatively stable through the test, with no clear increasing or decreasing trend in EC noted.

3.3 Discussion of Pumping Test Results

3.3.1 Background Water Level Trends and Rainfall Influence During Testing

There was heavy rainfall prior to the pre-test monitoring period (from 10th-12th October), which is likely to have resulted in the water levels observed at the start of the monitoring and testing period being especially high.

There were small, interspersed periods of rainfall through the monitoring and testing period (See **Figure 8**) though these are separated by dry periods. This has resulted in a general decline in water levels observed through the test period. This can be seen clearly in the graph for monitoring BH6 in **Figure 13**.

Ideally pumping tests would be completed during summer, when regional groundwater levels and surface water flows would most likely be at their lowest. However, due to project constraints (timeline, travel, budget) it is not always possible to complete all testing during the mid-summer period.

3.3.2 Potential Impacts to PWS Receptor (BH6 Monitoring)

As described above in **Section 3.1.3**, the existing PWS borehole in the vicinity of the site could not be monitored directly during the tests. To overcome this, a monitoring borehole (BH6) was installed between the PWS borehole and the pumping boreholes to collect groundwater level measurements as a proxy for the PWS and detect any potential impacts.

As described in **Section 3.1.3**, we are confident that groundwater level recorded at BH6 (monitoring borehole) is a good proxy of groundwater levels at the neighbouring PWS, and any potential impacts arising from the pumping tests reported here to the PWS would also be detected at BH6.

As described in the hydrogeological conceptualisation in **Section 2.2.3** above, we expect the bedrock unit as a whole to be acting as one 'fractured rock' type aquifer with some degree of hydraulic connection across the whole bedrock unit through interconnected fractures and weathered zones, although the extent of localised fracturing and weathering is expected to be highly heterogeneous within this unit (e.g. localised fracturing observed at 30m depth only in the vicinity of BH5 and BH7). All of the boreholes discussed here (BH5, BH7, BH6 and the PWS borehole) have been drilled into this same bedrock 'aquifer' unit. Therefore, we would expect that if any decline (drawdown) in water levels induced by the pumping of BH5 and BH7 has propagated into the aquifer, this would be detected at BH6 (and by proxy the PWS borehole).

During the two constant rate tests, there was no drawdown or reduction in water levels observed at the monitoring borehole (BH6) that could be attributed to the pumping tests completed (see detail in above section).

This leads to the conclusion that the pumping tests completed at BH5 and BH7 did not induce any drawdown in water level at BH6 (and by proxy the PWS borehole). We speculate that the reason for this may be that; 1) BH5 and BH7 are pumping water from fractures at 30m depth which were not intersected by BH6, meaning that there is not a strong, direct hydraulic connection between these points so no significant impact to water level (if any) would be expected to be seen immediately at BH6 (and by proxy the PWS), and 2) the relatively low expected bulk hydraulic conductivity of the bedrock 'aquifer' unit would mean that any 'cone of depression' in water levels propagating away from the pumping of these fractures into the surrounding bulk 'aquifer' unit (if any) would be of limited extent and take time to appear; therefore may not have propagated as far as BH6 during the test period.

3.3.3 Observation at Stream (Sruthan na Cille)

Figure 8 shows the water level hydrograph from the stage board installed in the stream through the pumping test period (including pre-test and post-test). Rainfall and markers for the start / end of each CRT are also shown on this figure.

It should be noted that the rainfall gauges used (Amod Farm Rainfall Gauge and Dippen Rainfall Gauge) are situated on the mainland of Scotland (a distance of 45km Southeast and 42km East of the site respectively). While these are the closest available approximation for the rainfall on Islay, there are some discrepancies. For example, the rise in the stream level recorded on the stage board logger occurs prior to the rainfall events recorded by the rainfall gauges. This is likely due to the rainfall weather front hitting Islay before passing Southeast and reaching the rainfall gauge. There is also a large rainfall event recorded by the gauge on the 22nd of October however does not have any effect on the river level in the burn. It is assumed that this was a period of localised rainfall over the gauge area and did not fall on Islay.

The hydrograph shows that the stream level responds quickly to rainfall. The burn level does not rise by much during these rainfall events, the largest increase being 1.4cm. An overall declining trend was observed through the whole monitoring period at the stage board with occasional small increases due to small episodes of rainfall. The declining trend is attributed to a general decline in water levels observed across the area through this period, as discussed above.

During the two constant rate tests, there was no change in water level observed at the stage board that could be attributed to the pumping tests completed. We can speculate that the reason for this may be that the low bulk hydraulic conductivity of the bedrock 'aquifer' unit would mean that any drawdown in water levels propagating away from the pumping borehole into the surrounding aquifer during the test would be of limited extent and may not have propagated as far as the burn (approximately 280m from BH5 & 7) in the test period.

We also note that the burn likely only receives a very small portion of its total flow from baseflow from the fractured aquifer, with the vast majority of its flow coming from rainfall runoff and shallow groundwater flow in superficial sediments. Any change to the amount of baseflow from the bedrock unit would likely to be too small to detect in these tests.

3.3.4 Comment on Distance-Drawdown and Radius of Influence of BH5 and BH7 abstraction

There was a notable drawdown of water level in BH5 during the pumping of BH7 and vice versa, as discussed above in **Sections 3.2.4** and **3.2.5**. This level of hydraulic connection between these boreholes is expected as both boreholes are pumping water from the same set of fractures encountered at around 30m depth and are in close proximity to each other (52m apart). This drawdown is a short-term hydraulic response induced by the pumping, limited to this area of fracturing in the vicinity of the boreholes, and is not representative of drawdown in water levels induced across the bedrock aquifer unit as a whole.

There was no drawdown in water level observed at the monitoring borehole (BH6, 97m south) that could be attributed to the pumping tests of BH5 and BH7. This apparent lack of hydraulic connection is explained by the fact that BH6 has not intersected the same set of fractures as the pumping boreholes, and any drawdown in water level ('cone of depression') propagating away from the pumping of these fractures into the surrounding bedrock 'aquifer' unit (if any) would be limited and take time to emerge (see **Section 3.3.2** above).

To give an estimate of the expected extent of a *cone of depression* of water level drawdown that could be induced in the bedrock aquifer unit as a whole from the proposed abstraction, the Sichardt equation has been used. This equation allows the radius of influence (ROI) of an abstraction to be estimated based on drawdown and permeability data. Calculations have been made here using input parameters obtained from the BH7 constant rate test (drawdown and permeability) with results presented and discussed below (see full calculation sheet in Appendix 3).

Before presenting these calculations, we note that all outputs (ROI distances) presented here should be treated as initial estimates only for reference and discussion in the context of this wider assessment. There are limitations associated with the use of the Sichardt equation, and it's use in the context of this site may not be entirely appropriate based on:

- Equation assumes the aquifer is homogeneous, isotropic, and uniform thickness: the bedrock aquifer unit in question here does not fully meet these criteria (hard rock, fracture flow dominant aquifer)

- Equation assumes flow into the well is in steady state: the input parameters used here are based on data from the constant rate test of BH7 run at 213m^3/d for 24-hours which does not appear to have reached fully steady state conditions.

We do however note that we have chosen conservative input parameters, likely to give higher ROI estimates. The input parameters are described and justified in more detail on the calculation sheet presented in Appendix 3.

These calculations give a radius of influence (ROI) of **56m**, based on the input parameters as given on the calculation sheet presented in Appendix 3.

This indicates that BH6 (and by proxy the PWS borehole) would be outside of the radius of influence of this proposed abstraction and therefore unlikely to be impacted. However, as discussed above, this ROI calculation is an initial estimate only and should be treated with caution.

3.3.5 Comment on Saline Intrusion

The test results presented in **Section 3.2** show there was no increasing trend in Electronic Conductivity (EC, a proxy for salinity) observed in BH7 or BH5 during testing. The EC of water in both boreholes remained low through testing (around 300 µs/cm in BH5 and 450 µs/cm in BH7). There is no indication from the data collected that the groundwater has been impacted by saline intrusion.

As described above in **Section 3.3.2**, given the relatively low pumping rate and (expected) relatively low bulk hydraulic conductivity of the bedrock 'aquifer' unit, it is unlikely that any drawdown in water levels in the aquifer would have propagated as far as the coastline (approximately 700m away) during the test period and therefore no saline intrusion would be expected to have occurred.

Although the fractured rock aquifer is expected to have a low bulk hydraulic conductivity, and therefore a relatively low risk of future saline intrusion overall, there remains a risk that saline intrusion (or at least a limited increase in salinity) could occur in the aquifer over the long term (perhaps along higher conductivity fracture zones or pathways). To guard against this risk, it is recommended that any future abstraction at this location is monitored closely for salinity, as recommended in **Section 5** below.

4 Water Quality

4.1 Field Water Quality

Measurements of field water quality parameters (Electronic Conductivity, pH, and temperature) were taken with a calibrated handheld meter through the pumping tests. In addition to this, the automatic water level logger installed in BH7 recorded Electronic Conductivity and Temperature.

The Electronic Conductivity measurements taken at both BH5 and BH7 were found to be within acceptable levels (typically 300 µS/cm to 450 µS/cm). There was no significant change in field EC readings during the testing of either of the pumping boreholes.

Turbidity was consistently below 5 NTU in throughout all of the testing on BH7. Turbidity was below 5 NTU during the CRT and steps 1 and 2 on BH5 however, during the turbidity rose to 15 NTU during step 3 and to 50 NTU during step 4. The borehole could not sustain these pumping rates anyway due to a quick decline in water level. Therefore, if pumping at a sustainable rate turbidity should not be an issue.

The pH measurements taken at both BH5 and BH7 were found to be neutral, typically between 7.2 to 7.6.

All field water quality data is contained in Appendix 1.

4.2 Laboratory Water Quality

Laboratory water quality samples were taken from each borehole at the end of drilling, these samples were tested for a full suite of analytes in Scottish Water's Inverness Laboratory. The results show that all of the parameters tested were within the threshold values specified by the requirements set out in The Water Intended for Human Consumption (Private Supplies) (Scotland) Regulations 2017.

It should be noted that some of the determinands were analysed out with stability time and the results may not represent the level at time of sampling. There is a note against each determinant which this may affect. This is due to the timing of the tests and staffing availability to return to the mainland of Scotland to deliver samples to the Inverness laboratory.

Full laboratory water quality test results are presented in Appendix 2.

5 Comments on Abstraction Viability

Based on the information above, the client wishes to make an abstraction licence application to SEPA for up to 200m^3/d. Due to their close proximity (52m), BH5 and BH7 would be classed as one abstraction for the purpose of the abstraction licence application. The site would look to pump a combined maximum of 200m^3/d from the two boreholes together, likely approximately 150m^3/d from BH7 and 50m^3/d from BH5.

The above report and attachments show 24-hour pumping data from BH7 at over the application rate of 200m^3/d (in line with test duration guidance given Table 1 of in SEPA document WAT-RM-24).

We acknowledge at this site that there are potential longer-term risks relating to the neighbouring PWS, saline intrusion and long-term viability of the suggested abstraction rate. We do not think that these potential risks can be fully assessed through pumping tests, even tests of longer duration, as it may take months for any potential impacts from this abstraction to be detected (if any).

To tackle this uncertainty, we recommend long-term permanent monitoring for the following:

- Groundwater level in BH7 and BH5 to be recorded hourly with a datalogger (or similar) to ensure both static and dynamic water levels can be tracked over time.
- Groundwater level in BH6 (monitoring borehole) to be recorded daily with a datalogger (or similar), to detect any potential impact to the neighboring PWS borehole.
- Electronic Conductivity (EC) of the discharge water from both BH7 and BH5 should be monitored daily with a datalogger (or similar), to detect any potential saline intrusion.

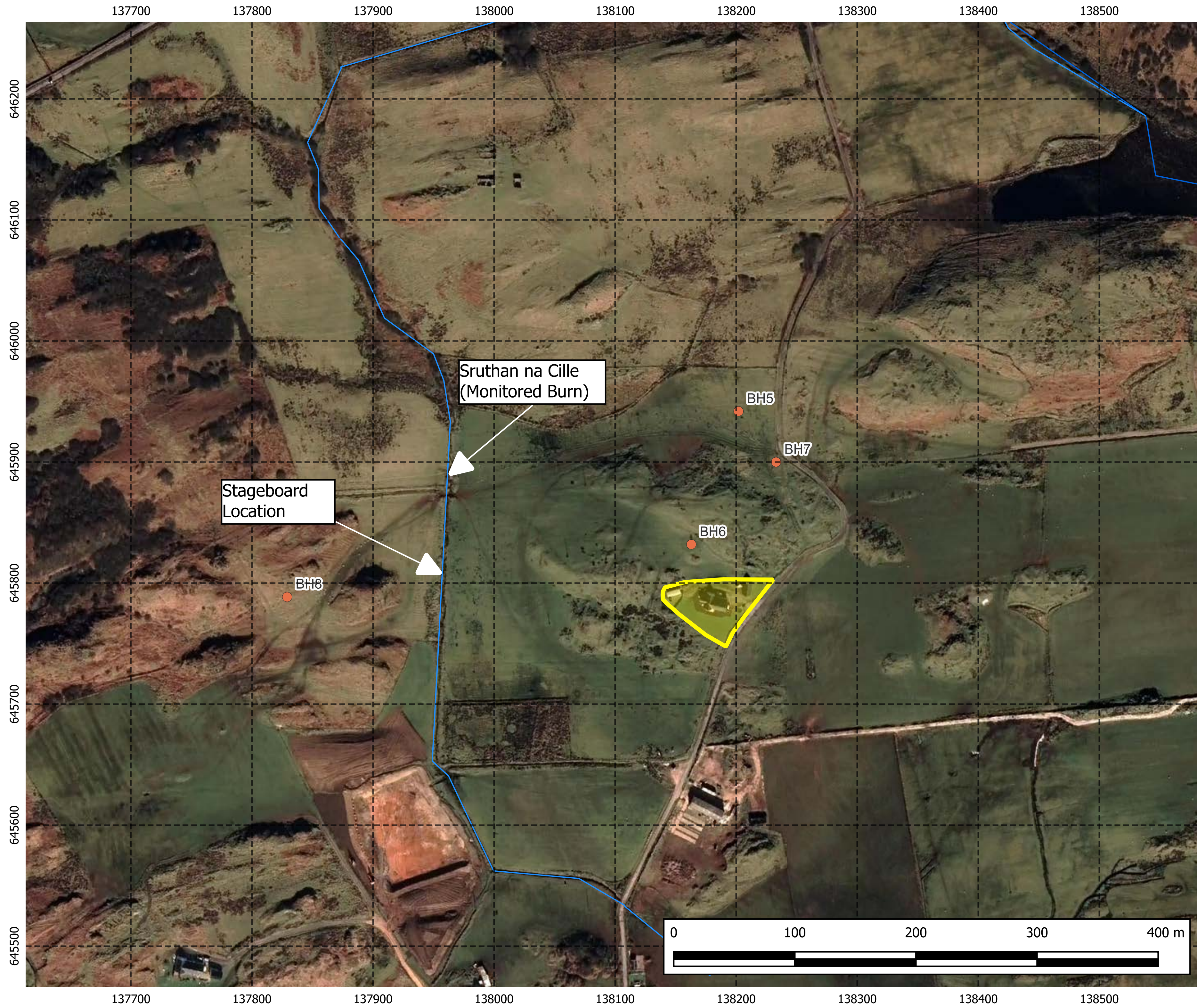
The incoming monitoring data should be reviewed on an ongoing basis by suitably qualified and experienced personnel. Where possible, real-time 'alarms' should be set to send notification when pre-defined trigger levels are exceeded.

Monitoring of these key parameters is in the interest of both the distillery (to understand long term performance and viability of this abstraction) as well as SEPA (to detect any long-term impacts to receptors, and / or saline intrusion).

6 Key Findings

- Pumping tests were completed on BH5 and BH7 in October 2023, with monitoring completed at an observation borehole (BH6) and a stage board in the adjacent stream.
- BH5 and BH7 are approximately 50m apart and would be classed as one abstraction activity for the purposes of a SEPA CAR abstraction licence application.
- BH7 can sustain pumping at 8.9m^3/h (213.6m^3/d) for 24 hours; borehole pumping capacity discussed further in Section 3.
- BH5 sustained pumping at 2.7m^3/h (64.8m^3/d) for 24 hours; borehole pumping capacity discussed fully in Section 3.
- Background groundwater and surface water levels observed through the testing period were generally in recession (steadily declining) due to heavy rainfall before the monitoring period commencing, and little rainfall during the test period, discussed fully in Section 3.
- Two potential receptors were monitored through the testing period to detect potential impacts to water levels induced by the pumping tests reported here: 1) an adjacent PWS (monitored via a dedicated monitoring borehole, BH6, constructed for these tests) and 2) the stream (Sruthan na Cille) running through the site area.
- No impacts were detected at the two receptors that could be attributed to the pumping tests reported here, discussed fully in Section 3.
- Field and laboratory water quality testing shows that the water from both BH5 and BH7 is generally of good quality with no major points of concern, discussed fully in Section 4.
- Electronic conductivity was monitored at BH7 and BH5 through the testing to detect any potential increasing trend that could indicate saline intrusion into the aquifer. There is no indication of saline intrusion during the testing period.
- Comments on the general viability of abstraction of 200m^3/d from these boreholes in the context of a SEPA CAR abstraction licence application are made in Section 5.
- Report recommends permanent, long-term monitoring of key parameters to ensure that long-term trends in water level and water quality can be assessed on an ongoing basis, and any potential negative impacts (e.g. to receptors, pumping boreholes or saline intrusion) can be detected early.

7 Figures



FLOW-5

Figure 1: Site map

Date: 07/11/2023

Project: HW004

Report: HW004

Version: A

Status: SEPA Submission

Prepared by: [redacted]

Legend

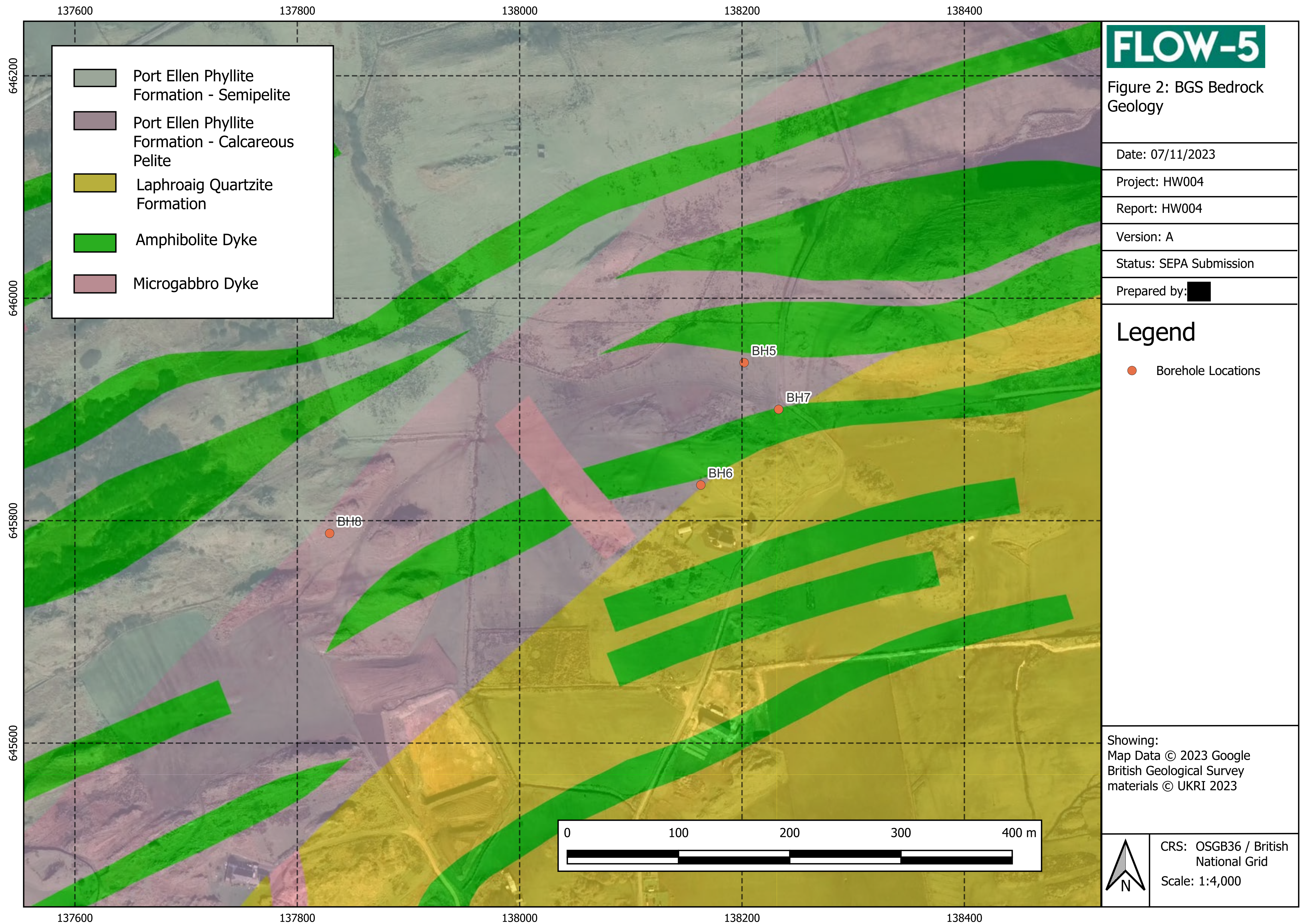
- Borehole Locations
- Surface Water
- B&B land (PWS is within this area)

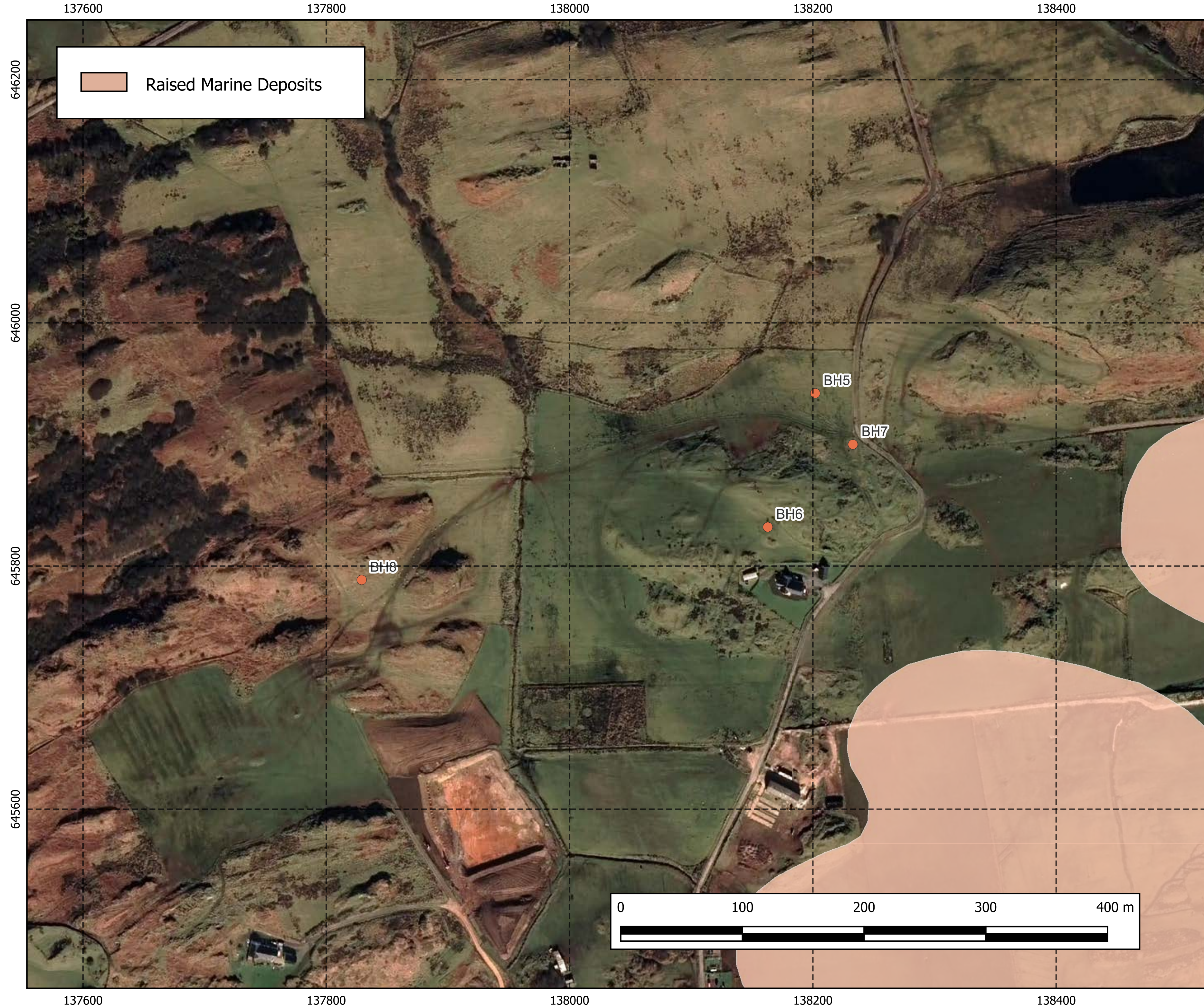
Showing:
Map Data © 2023 Google

N

CRS: OSGB36 / British National Grid

Scale: 1:4,000


FLOW-5
Figure 2: BGS Bedrock Geology
Date: 07/11/2023
Project: HW004
Report: HW004
Version: A
Status: SEPA Submission
Prepared by: [redacted]
Legend
Borehole Locations
Port Ellen Phyllite Formation - Semipelite
Port Ellen Phyllite Formation - Calcareous Pelite
Laphroaig Quartzite Formation
Amphibolite Dyke
Microgabbro Dyke
BH5
BH7
BH6
BH8
137600
137800
138000
138200
138400
646200
646000
645800
645600
0
100
200
300
400 m
N
Showing:
Map Data © 2023 Google
British Geological Survey materials © UKRI 2023
CRS: OSGB36 / British National Grid
Scale: 1:4,000



FLOW-5

Figure 3: BGS Superficial Geology

Date: 07/11/2023

Project: HW004

Report: HW004

Version: A

Status: SEPA Submission

Prepared by: [redacted]

Legend

Borehole Locations

Showing:
Map Data © 2023 Google
British Geological Survey materials © UKRI 2023

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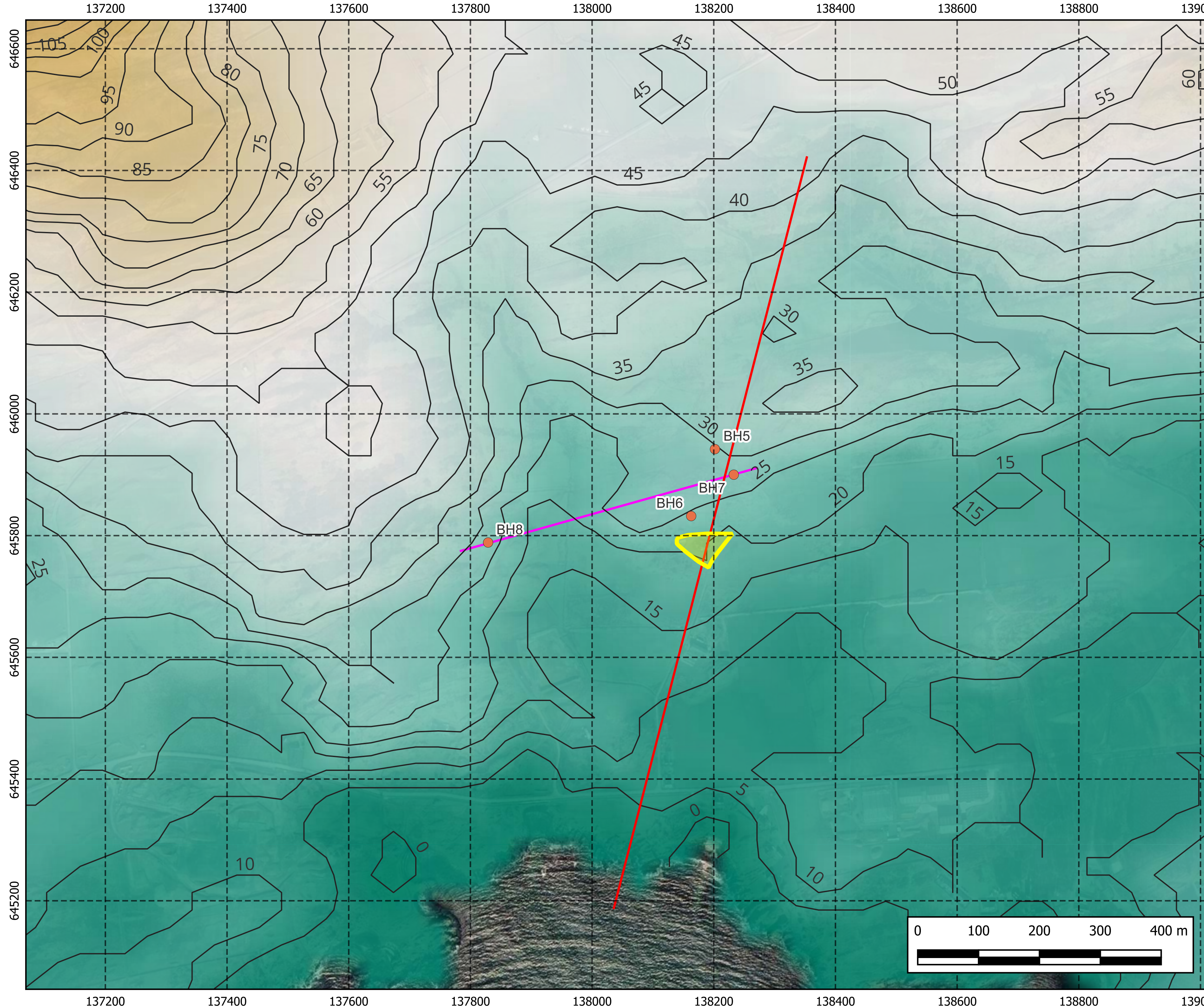
CRS: OSGB36 / British National Grid

Scale: 1:4,000



FLOW-5

Figure 4: Topography and Cross Section Lines

Date: 07/11/2023

Project: HW004

Report: HW004

Version: A

Status: SEPA Submission

Prepared by: [redacted]

Legend

- Borehole Locations
- 5m Contours (Topography - STRM Ground Elevation)
- East West Cross Section Line (As seen on Figure 6)
- North South Cross Section Line (As seen on Figure 5)
- B&B's Land (PWS is within this area)

Showing:
Map Data © 2023 Google
NASA Shuttle Radar Topography Mission (SRTM)(2013)

CRS: OSGB36 / British National Grid

Scale: 1:8,000

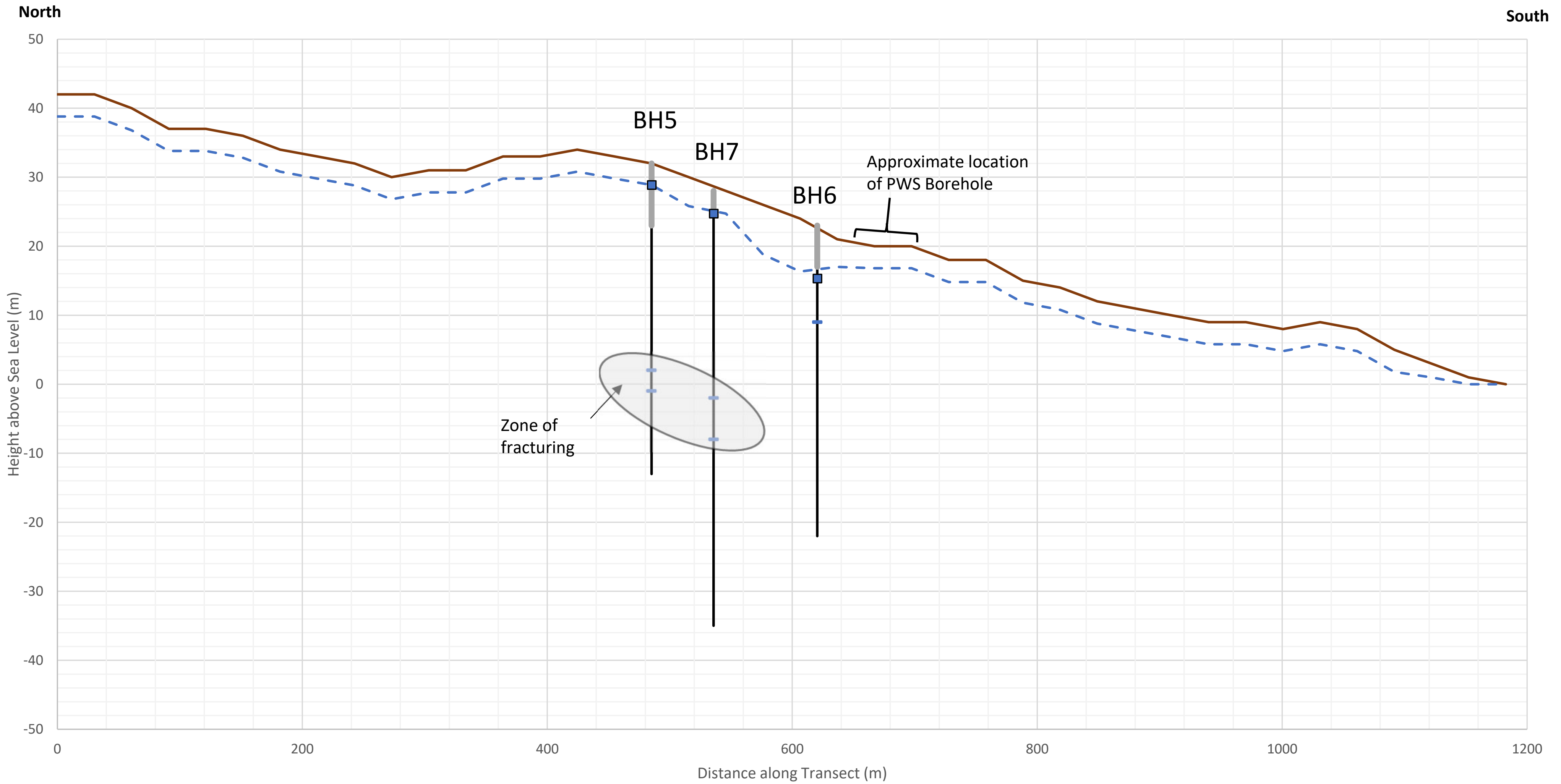


Figure 5: North South Conceptual Geological Cross-Section	Date: 9/11/23	Prepared by: [redacted]
	Project: HW004	Report: HW004

Ground Surface Elevation
Measured Static Water Level
BH Casing
Water Strikes
Inferred Saturated Water Level

FLOW-5

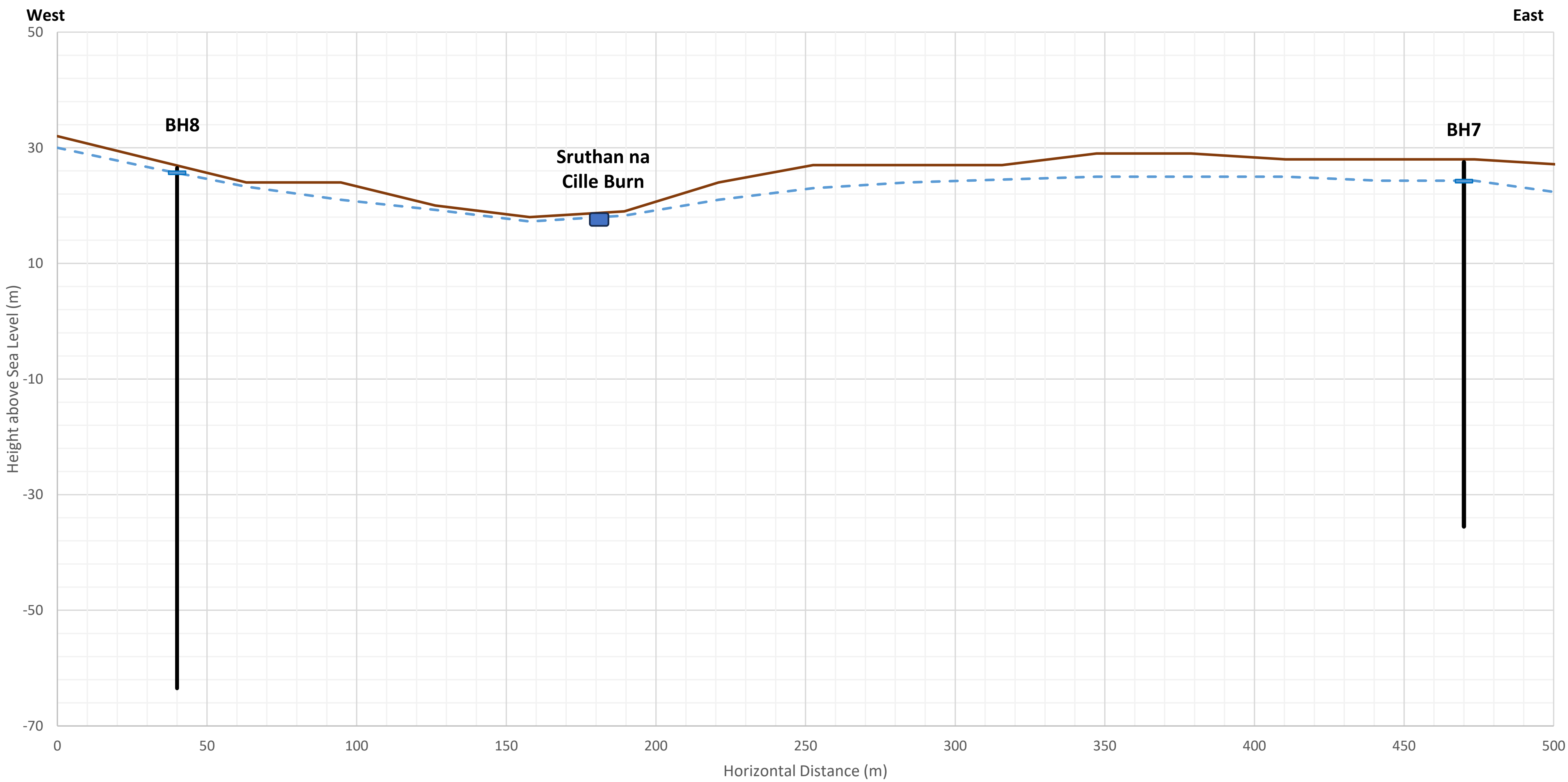


Figure 6: West East Conceptual Geological Cross-Section

Date: 9/11/23

Prepared by: [redacted]

Project: HW004

Report: HW004

Ground Surface Elevation

Inferred Saturated Water Level

Measured Static Water Level

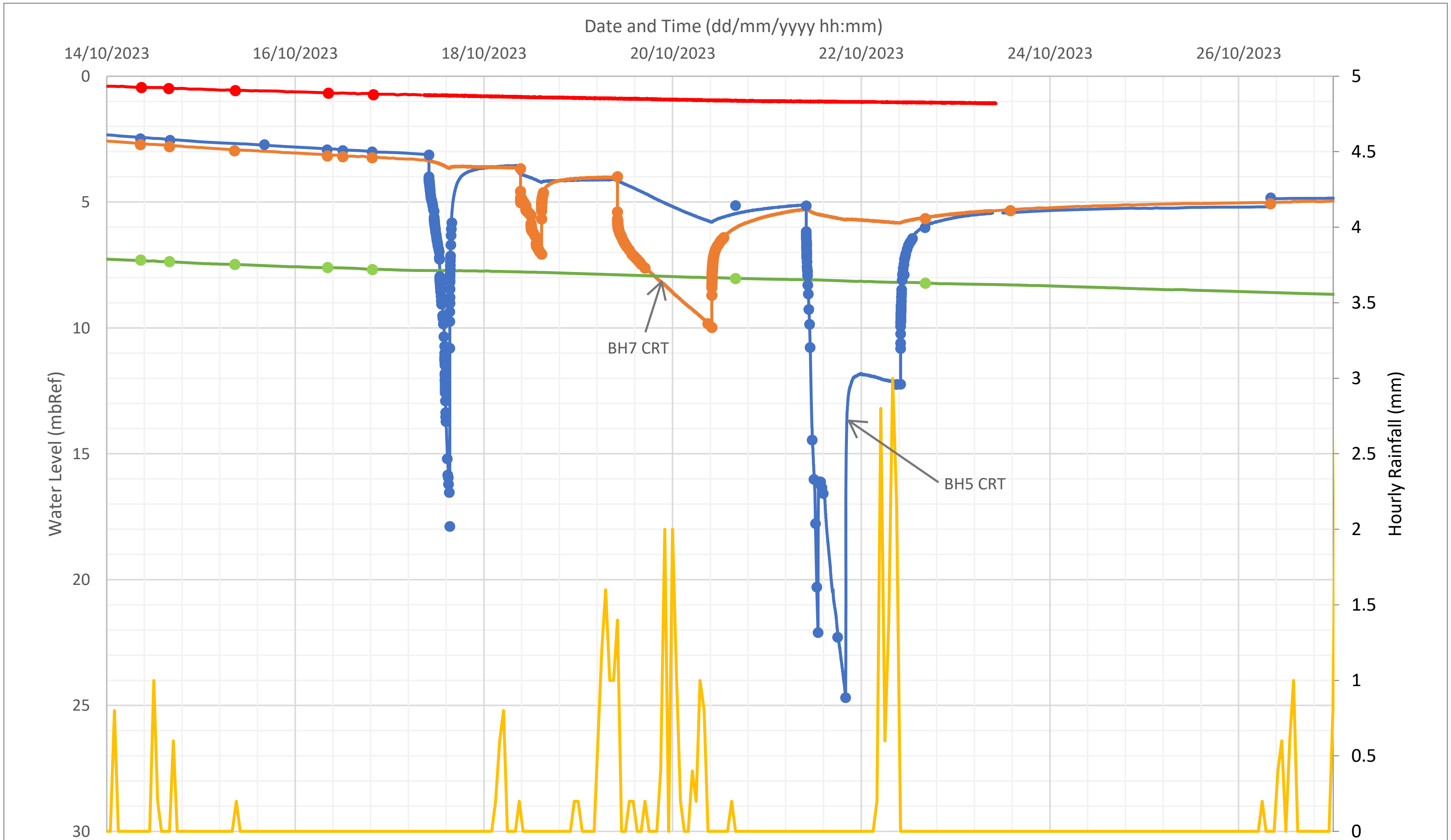


Figure 7: Water Level in all Boreholes during monitored period	Date: 9/11/23	Prep By: [redacted]
	Project: HW004	Report No: HW004
	BH No: 5,6,7 & 8	

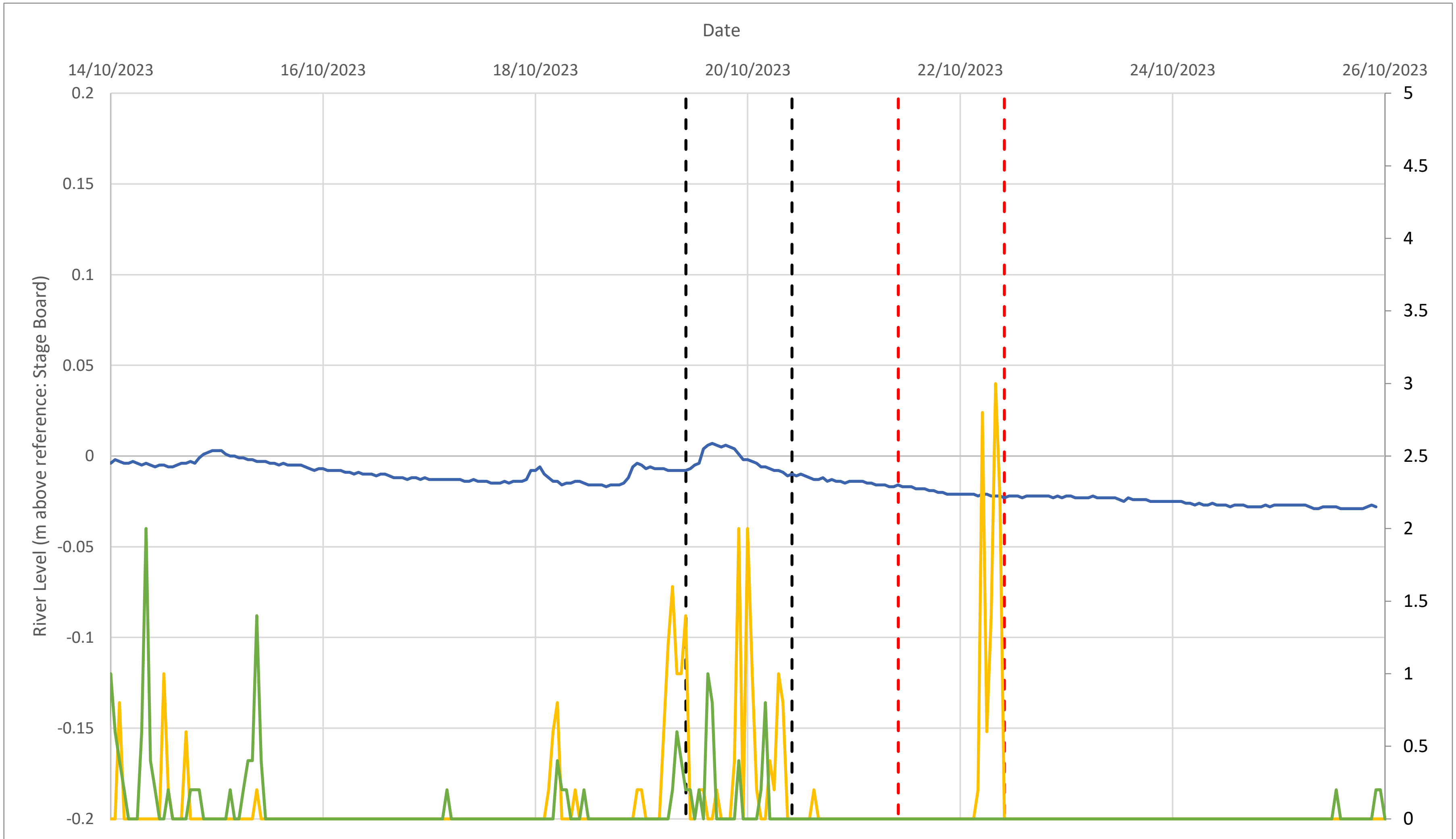


Figure 8: Water Level in Sruthan na Cille Burn	Date: 9/11/23	Prep By [redacted]
	Project: HW004	Report No: HW004

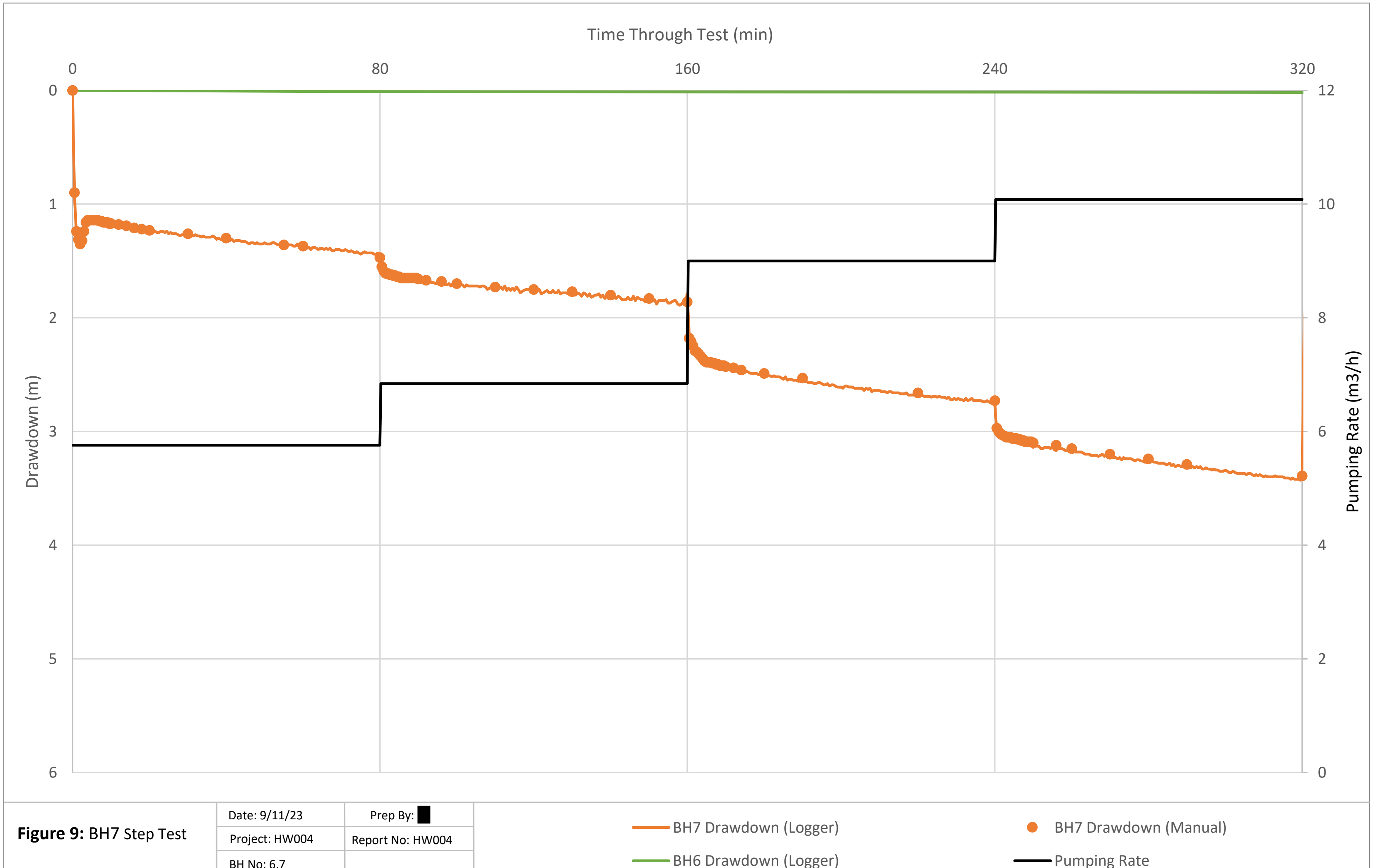


Figure 9: BH7 Step Test

Date: 9/11/23	Prep By: [redacted]
Project: HW004	Report No: HW004
BH No: 6,7	

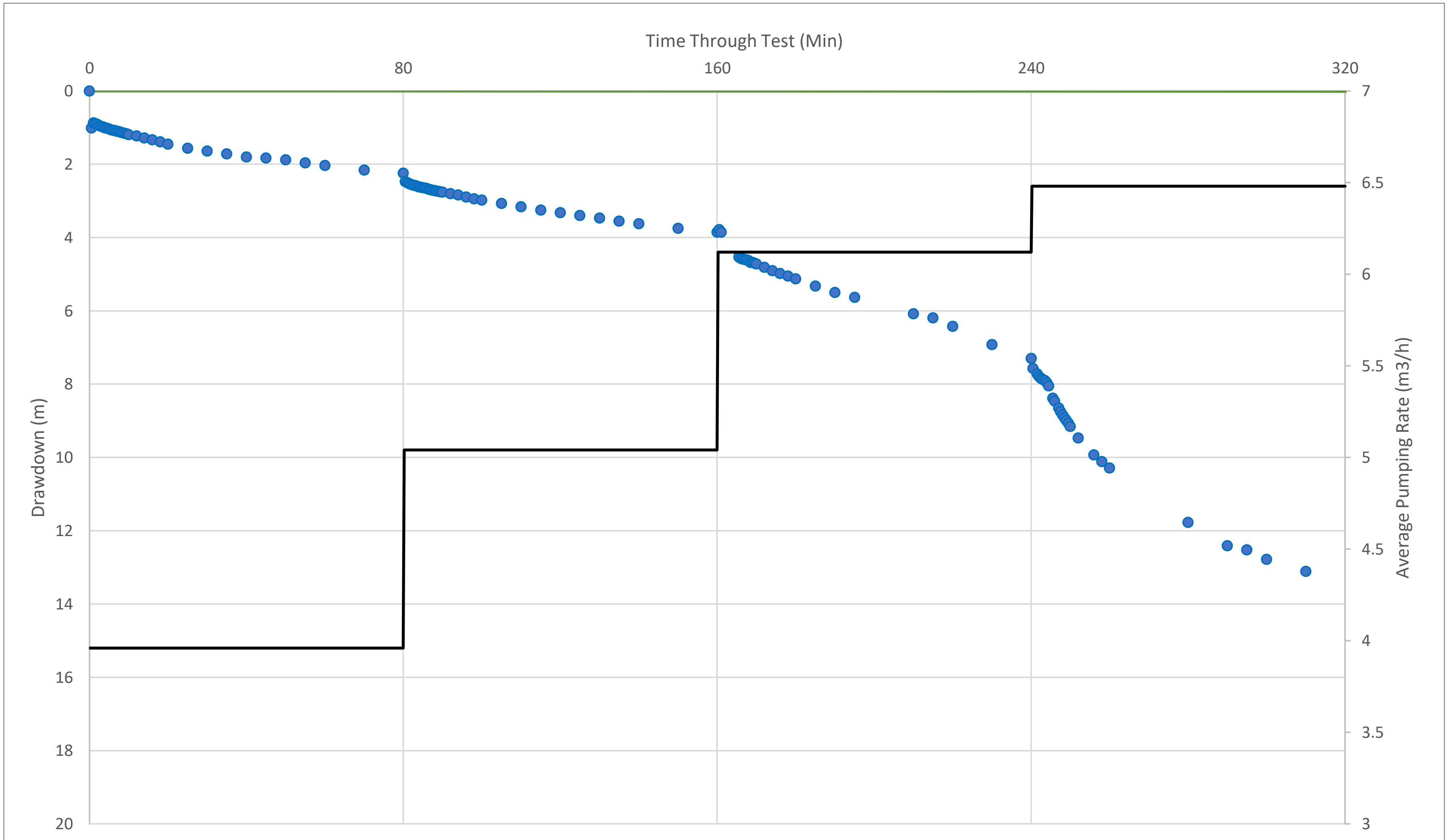


Figure 10: BH5 Step Test

Date: 9/11/23	Prep By: [redacted]
Project: HW004	Report No: HW004
BH No: 5, 6	

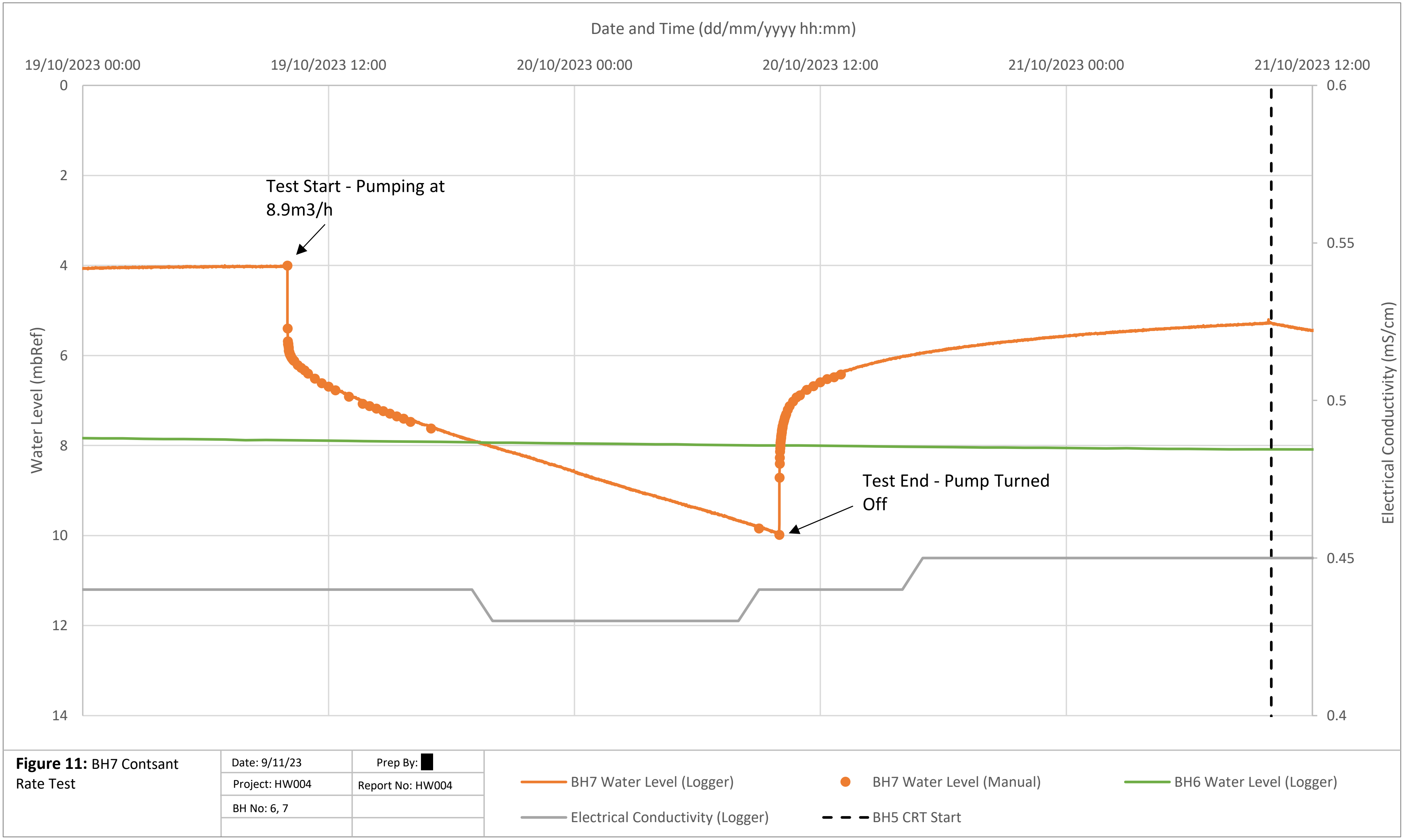


Figure 11: BH7 Contsant Rate Test	Date: 9/11/23	Prep By: [redacted]
	Project: HW004	Report No: HW004
	BH No: 6, 7	

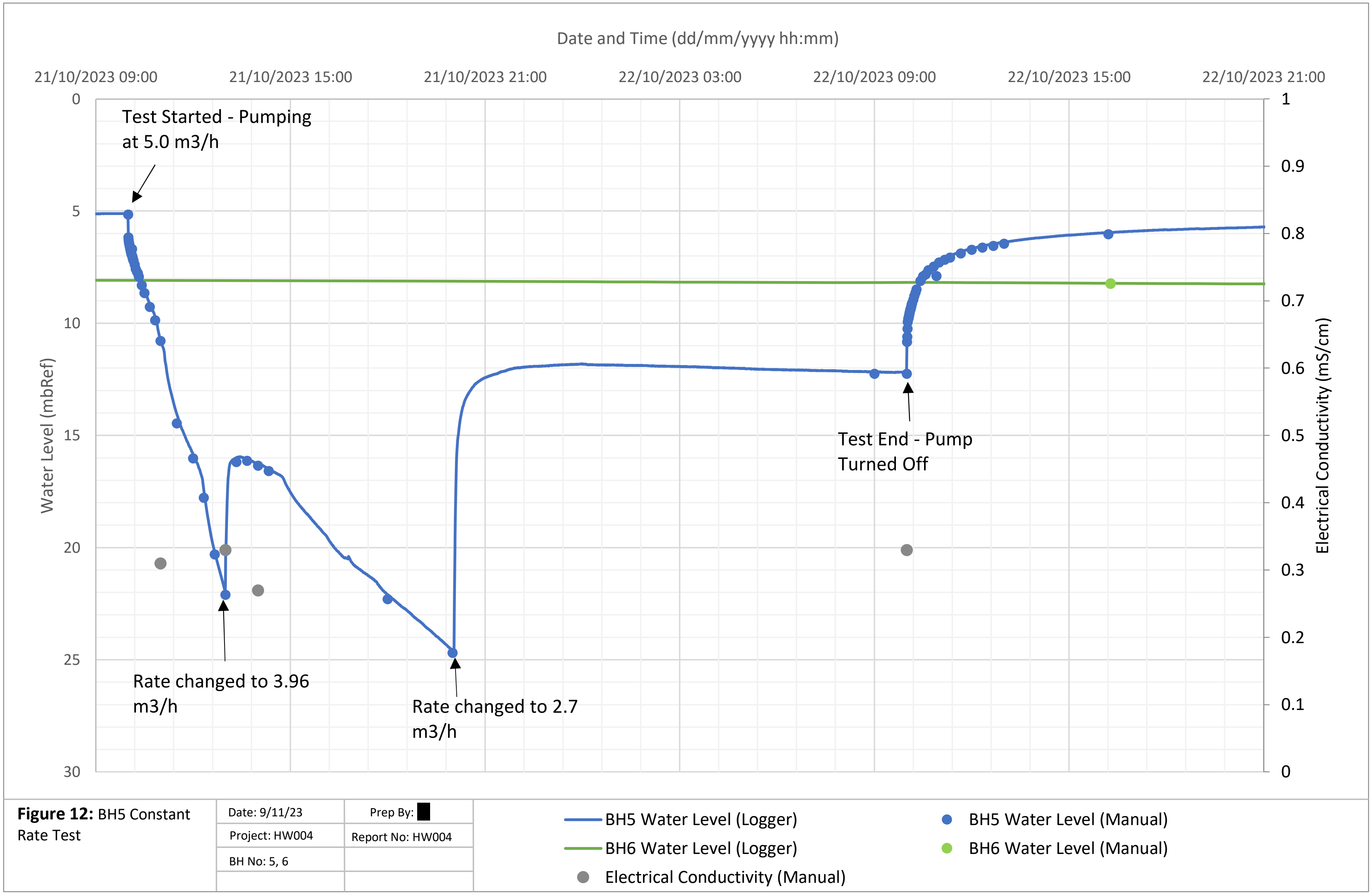


Figure 12: BH5 Constant Rate Test	Date: 9/11/23	Prep By: [redacted]
	Project: HW004	Report No: HW004
	BH No: 5, 6	

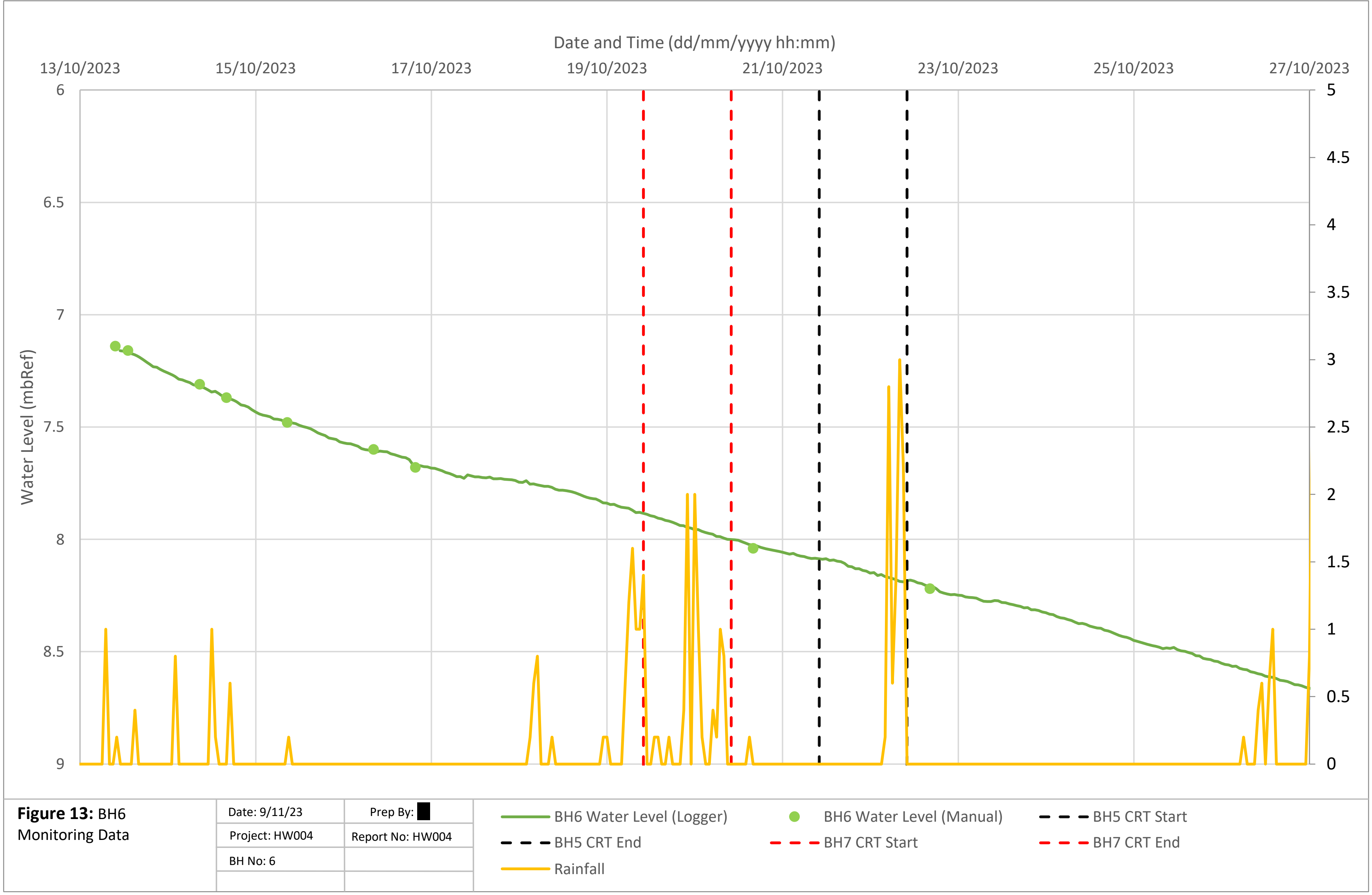


Figure 13: BH6 Monitoring Data

Date: 9/11/23	Prep By: [redacted]
Project: HW004	Report No: HW004
BH No: 6	

8 Appendices

Appendix 1: Pumping Test Data Records

Appendix 2: Laboratory Water Quality Sample Results

Appendix 3: Radius of Influence (ROI) Calculation using Sichardt Equation

Appendices are provided in electronic format attached to report submission