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Horizon Jersey

Groundwater Monitoring Data and Recommendations

Date: 2nd August 2018

Client Name: States of Jersey Development Company Ltd

Document Reference: WIE13175-101-3-2-3 TN

This document has been prepared and checked in accordance with
Waterman Group's IMS (BS EN ISO 9001: 2015, BS EN ISO 14001: 2015 and BS OHSAS 18001:2007)

Issue	Prepared by	Checked & Approved by
A01	[redacted] Senior Geotechnical Engineer	[redacted] Director
A02	[redacted] Senior Geotechnical Engineer	[redacted] Director
A03	[redacted] Senior Geotechnical Engineer	

1. Introduction

Waterman Infrastructure & Environment Ltd (Waterman) was instructed by States of Jersey Development Company to undertake a Geotechnical Ground Investigation at a reclaimed land site located at Castle Quay, St Helier, Jersey.

The proposed development is to comprise the construction of three up to 8 storeys tower blocks. Typically, the blocks will have ground floors of retail and office space, with the remaining floors allocated for residential apartments.

Although the Site has no watercourses located within its boundary, it is located immediately adjacent to the Elizabeth Marina and English Channel. It is understood that the water level within the marina is maintained at a level of 5.7m AOD by a sill gate. It is likely tides will have an impact on the level of the groundwater within the Made Ground (reclaimed land), Beach Deposits (natural superficial geology) and bedrock.

The site footprint covers an area of approximately 5700m^2 and is located in the north-east of Elizabeth Marina in St Helier, as depicted in Figure 1.

Figure 1: Proposed development location (marked in red) with respect to Elizabeth Marina

The ground surface at the site of the proposed development is found to be at an average elevation of 10m AOD. The proposed development comprises a single basement level (*Basement 1* - structural slab level assumed at 5.0m AOD) in the western part of the site and a 2-level basement (*Basement 2* - structural slab level assumed at 2.2m A OD) in the eastern part. The proposed basement arrangement is indicatively presented in Figure 2 and Figure 3.

Figure 2: Proposed basement arrangement

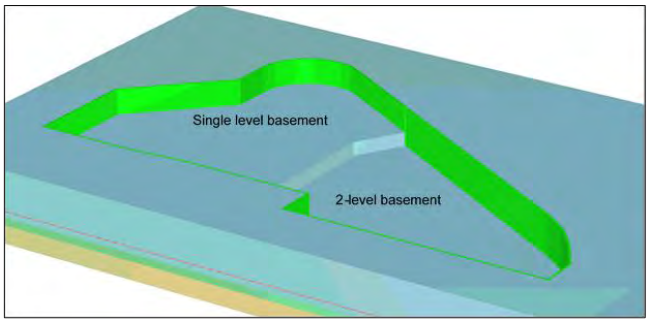


Figure 3: View of the proposed basement

The Ground Investigation was undertaken by Geotechnical Engineering Ltd (GEL) to Waterman's specification. The initial site works comprising of 14No. boreholes and 34No. trial pits/trenches was completed between the 13th November to 15th December 2017 with an additional two boreholes and in-situ testing being undertaken in February 2018. The ground conditions proven by the ground investigation are summarised in Table 1. Positions of the exploratory holes are given in Drawing WIE- SA-80-0100-F01 *Exploratory Hole Plan* in Appendix A.

Table 1: Ground Summary

Stratum	Depth of Top of Stratum (m bgl)	Thickness (m)	Description
Made Ground (Topsoil)	0.00	0.10 to 0.55	Made Ground (Topsoil) was described as grassed soft brown and dark brown slightly gravelly sandy clayey silt.
Made Ground (Tarmacadam)	0.00	0.10 to 0.20	Made Ground (Tarmacadam) was typically described as: dark and light grey and was located on the ground surface and also between 1.70m bgl and 1.55m bgl in BH2/09.
Made Ground	0.00 - 0.55	9.20 – 13.30	Interbedded layers of granular and cohesive stratum of sand, gravel, cobbles, clay and silt.
Alluvial Deposits	10.10 - 11.90	0.65 – 3.40	Interbedded horizons of tidal deposits comprising sands, clays and silts.
Bedrock	11.60 – 17.25	Unproven	Weathered DIORITE and weathered GRANITE

2. Groundwater and Standpipes

Groundwater strikes recorded during the ground investigation indicated a minimum depth of 0.7m bgl in TP2/21A with the post ground investigation monitoring recording a minimum depth of 3.26m bgl (6.49m AOD) in BH2/11.

The groundwater levels in BH2/11 (6.49m AOD) were recorded on 18th December 2017, with subsequent elevations recorded between 9th January and 20th March 2018, noted up to 5.38m AOD. The levels recorded in December may be in response to the ongoing drilling and bad weather (drillers logs noted '*lashing down with rain'*) on the first day of drilling (7th December 2018).

A summary of groundwater monitoring levels is given in Table 2 and in Table 3.

Table 2: Groundwater Monitoring (m bgl)

BH	Installation depth (m bgl)	Groundwater Level (m bgl)							
		18/12	09/01	10/01	24/01	25/01	06/02	06/03	20/03
BH2/01	17.0	-	7.27	7.56	7.15	7.37	7.36	7.23	6.97
BH2/03	17.0	6.46	6.33	6.37	6.31	6.27	6.31	5.54	5.88
BH2/04	17.0	8.24	7.71	8.34	7.67	7.98	8.21	7.11	7.91
BH2/06	17.0	8.60	6.93	7.43	6.87	7.53	6.67	5.19	6.46
BH2/07	17.0	6.79	7.08	7.22	5.82	5.97	5.89	6.27	6.68
BH2/10	9.2	8.76	5.69	6.51	5.31	7.09	4.95	5.57	8.65
BH2/11	17.0	**3.26**	4.41	4.42	4.40	4.41	4.37	4.57	4.91

Table 3: Groundwater Monitoring (m AOD)

BH	Installation depth (m AOD)	Groundwater Elevation (m AOD)							
		18/12	09/01	10/01	24/01	25/01	06/02	06/03	20/03
BH2/01	-7.15	-	2.58	2.29	2.70	2.48	2.49	2.62	2.88
BH2/03	-7.10	3.44	3.57	3.53	3.59	3.63	3.59	4.36	4.02
BH2/04	-7.10	1.66	2.19	1.56	2.23	1.92	1.69	2.79	1.99
BH2/06	-7.35	1.05	2.72	2.22	2.78	2.12	2.98	4.46	3.19
BH2/07	-7.50	2.71	2.42	2.28	3.68	3.53	3.61	3.23	2.82
BH2/10	-0.80	-0.36	2.71	1.89	3.09	1.31	3.45	2.83	-0.25
BH2/11	-7.25	**6.49**	5.34	5.33	5.35	5.34	5.38	5.18	4.84

3. Vibrating Wire Piezometers

Vibrating wire piezometers (VWP) were installed in six boreholes (BH2/02, BH2/05, BH2/08, BH2/09, BH2/15 and BH2/16) and from the data obtained (Figure 4 to Figure 15); it can be seen that there is a tidal influence on the groundwater levels below the Site, which generally ranges from approximately -0.50m AOD to 4.55m AOD.

BH2/05 shows an occasional spike up to 11m AOD, these spikes are inconsistent with the remaining BH2/05 data and are considered erroneous.

BH2/16 records groundwater levels generally to a maximum elevation of 6.83m AOD with occasional elevated readings recorded up to 51.68m AOD. This data also appears to be inconsistent with the data obtained for BH2/02, BH2/05, BH2/08, BH2/09 and BH2/15, and is therefore, considered erroneous and should not be viewed as accurate.

The VWP data appears to indicate that the flow of groundwater below the site, groundwater levels are at their highest, close to the Marina wall (BH2/08) with flow moving NE towards BH2/02. This appears to correspond to the known tidal streams for Jersey (approximately East – West). These

locations are the only areas where groundwater appears above the structural slab level of the deep basement.

Proposed basement levels have been added to these figures to demonstrate proximity of the variable groundwater level to the basements.

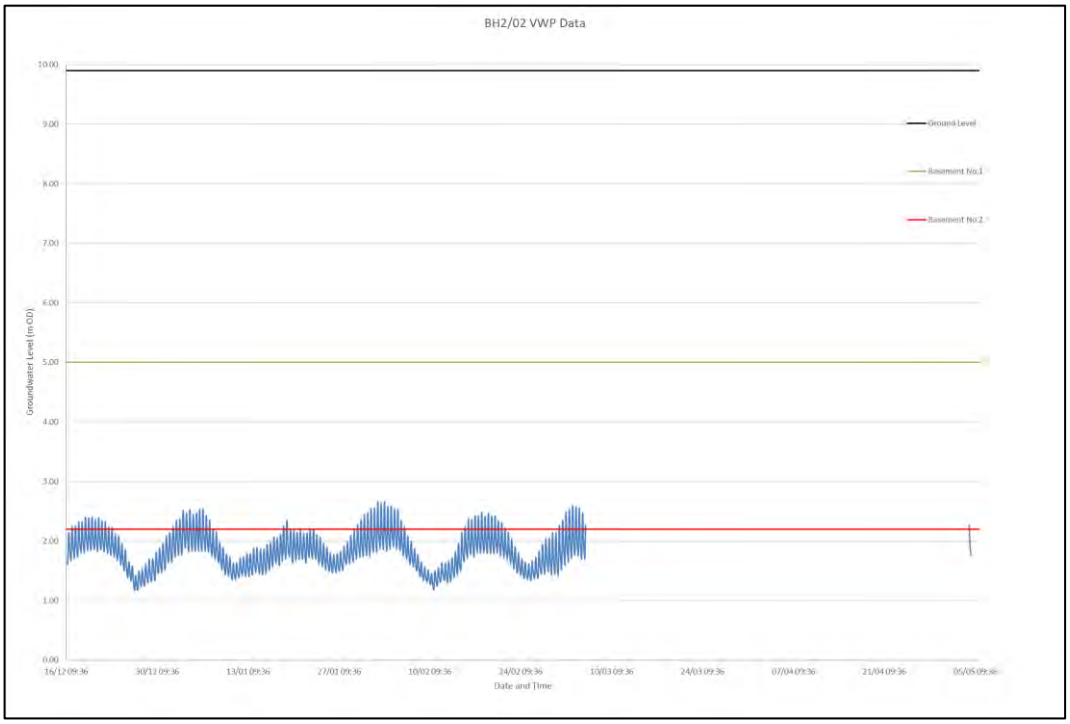


Figure 4: Borehole BH2/02 Vibrating Wire Piezometer Data – Groundwater Level

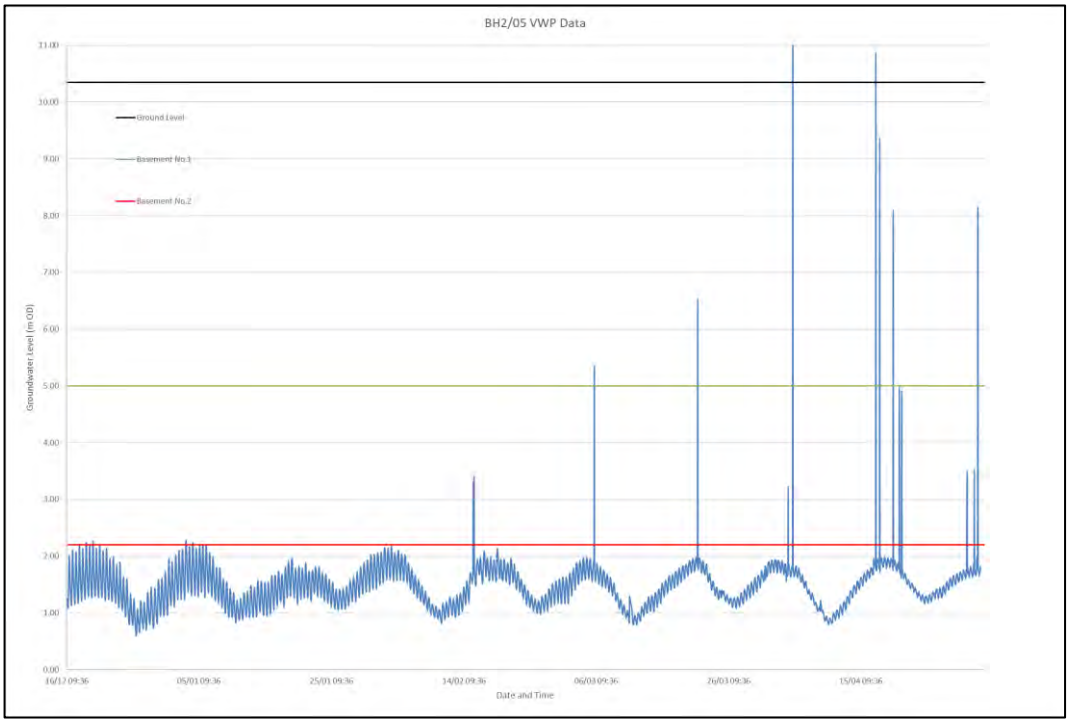


Figure 5: Borehole BH2/05 Vibrating Wire Piezometer Data– Groundwater Level

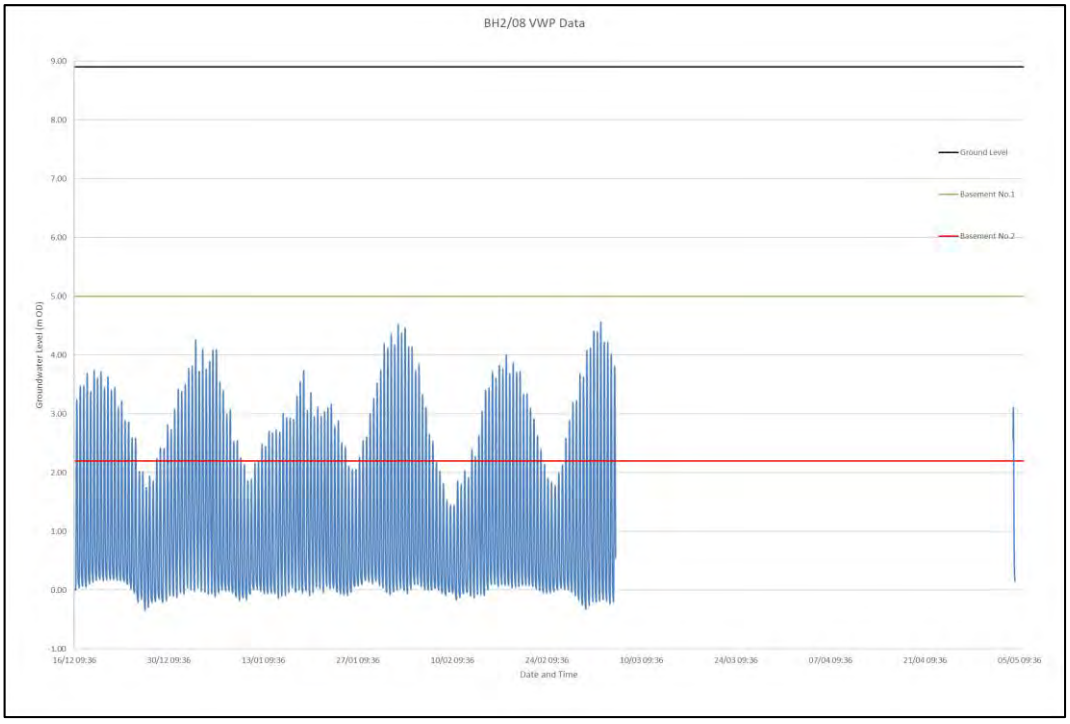


Figure 6: Borehole BH2/08 Vibrating Wire Piezometer Data– Groundwater Level

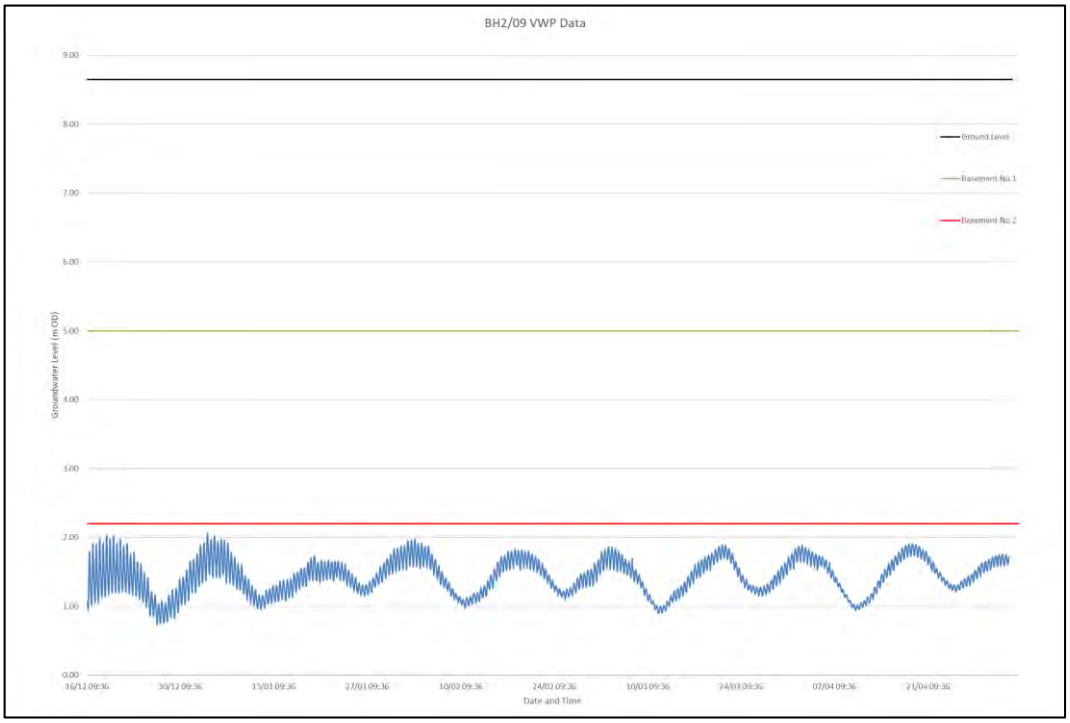


Figure 7: Borehole BH2/09 Vibrating Wire Piezometer Data– Groundwater Level

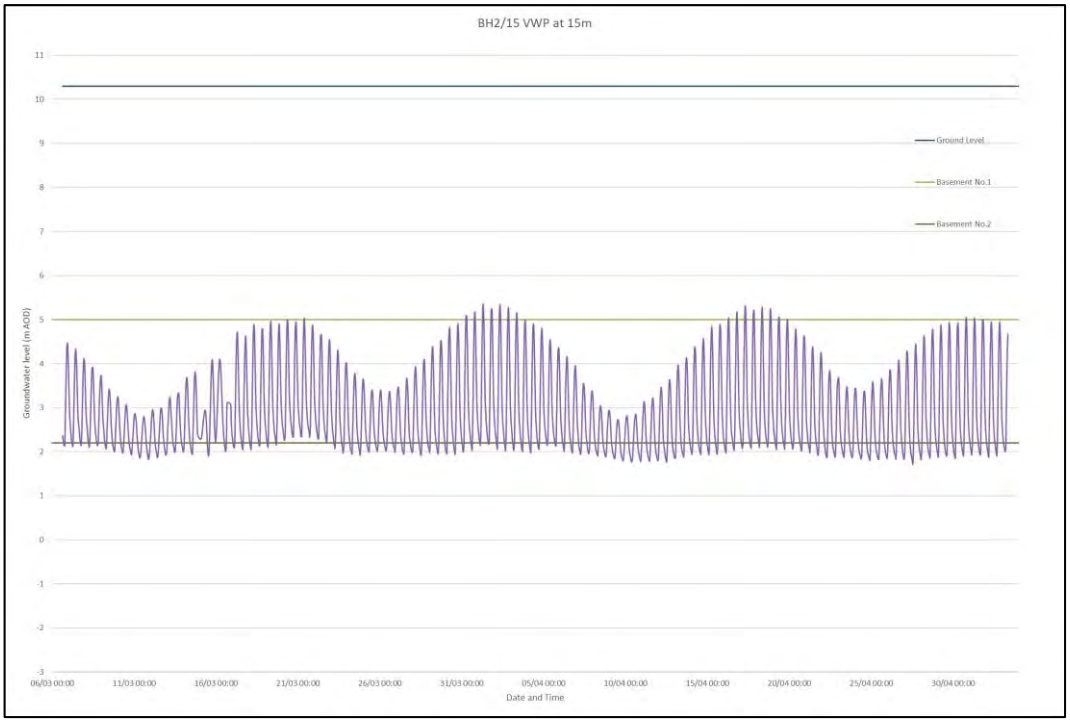


Figure 8: Borehole BH2/15 Vibrating Wire Piezometer Data (15m bgl) – Groundwater Level

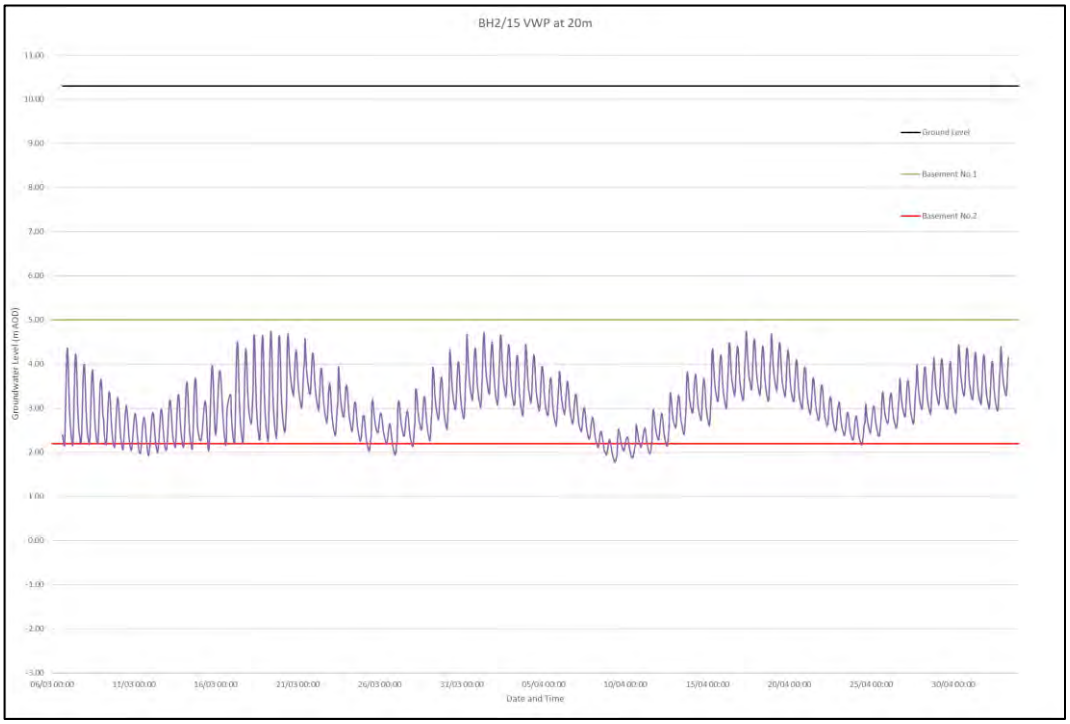


Figure 9: Borehole BH2/15 Vibrating Wire Piezometer Data (20m bgl) – Groundwater Level

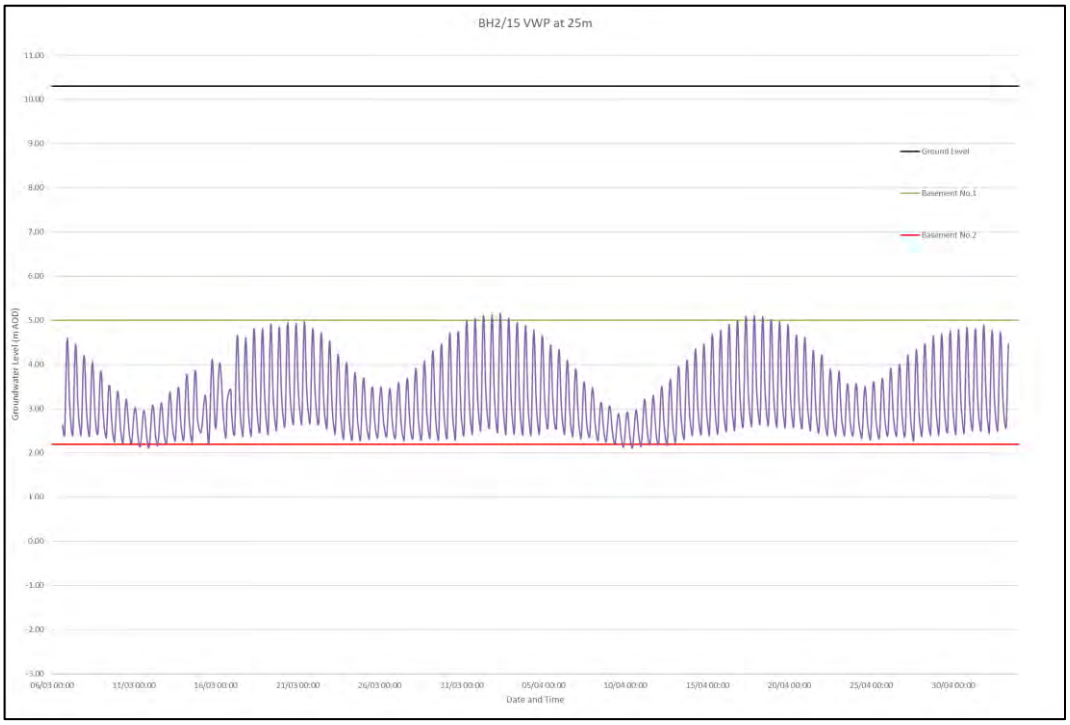


Figure 10: Borehole BH2/15 Vibrating Wire Piezometer Data (25m bgl) – Groundwater Level

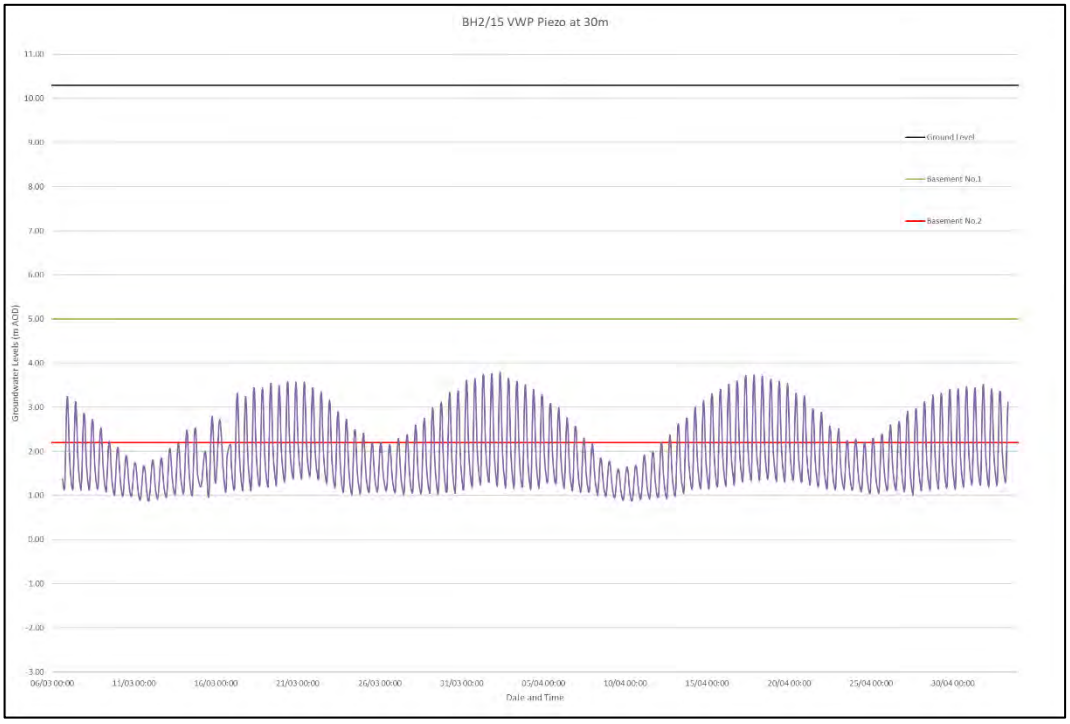


Figure 11: Borehole BH2/15 Vibrating Wire Piezometer Data (30m bgl) – Groundwater Level

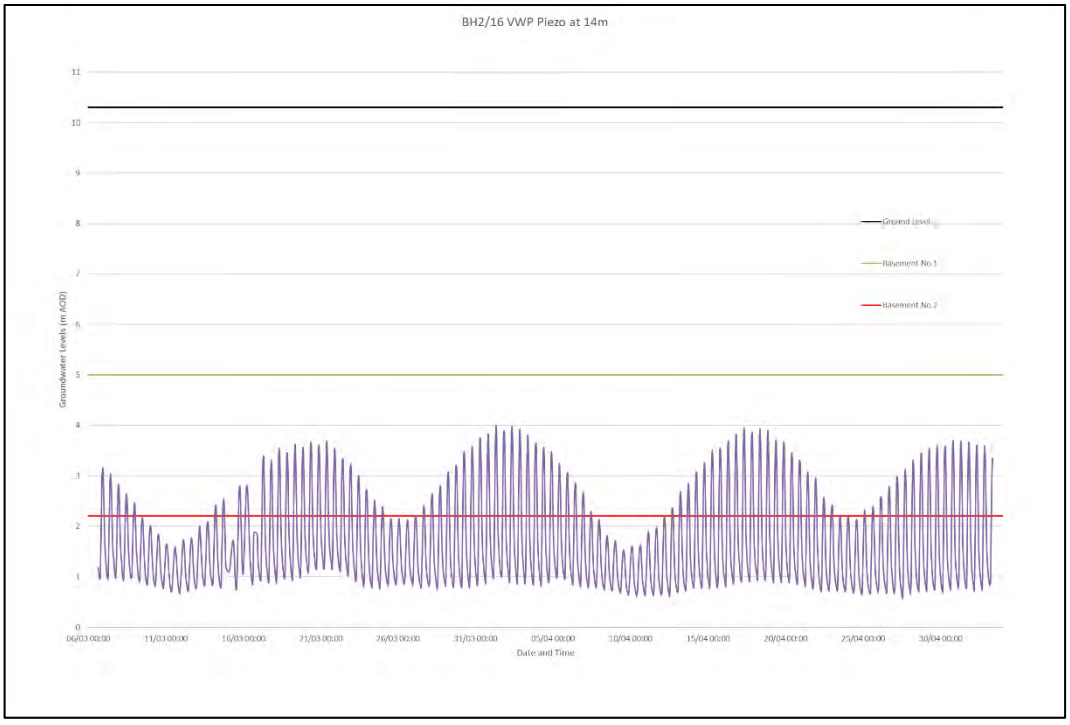


Figure 12: Borehole BH2/16 Vibrating Wire Piezometer Data (14m bgl) – Groundwater Level

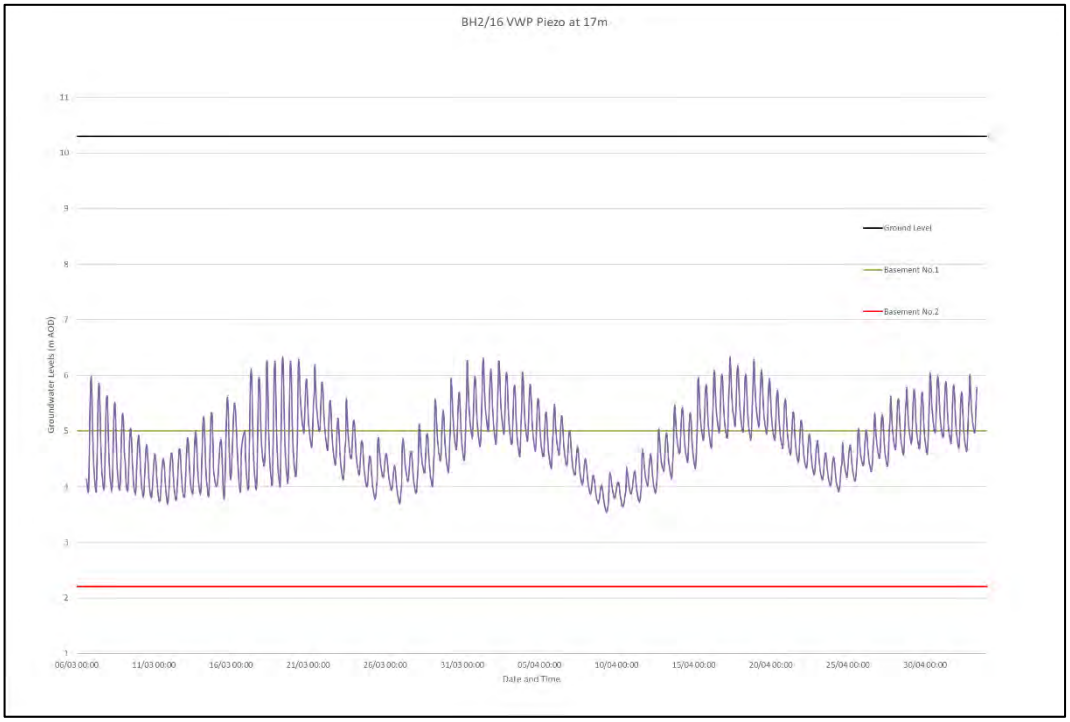


Figure 13: Borehole BH2/16 Vibrating Wire Piezometer Data (17m bgl) – Groundwater Level

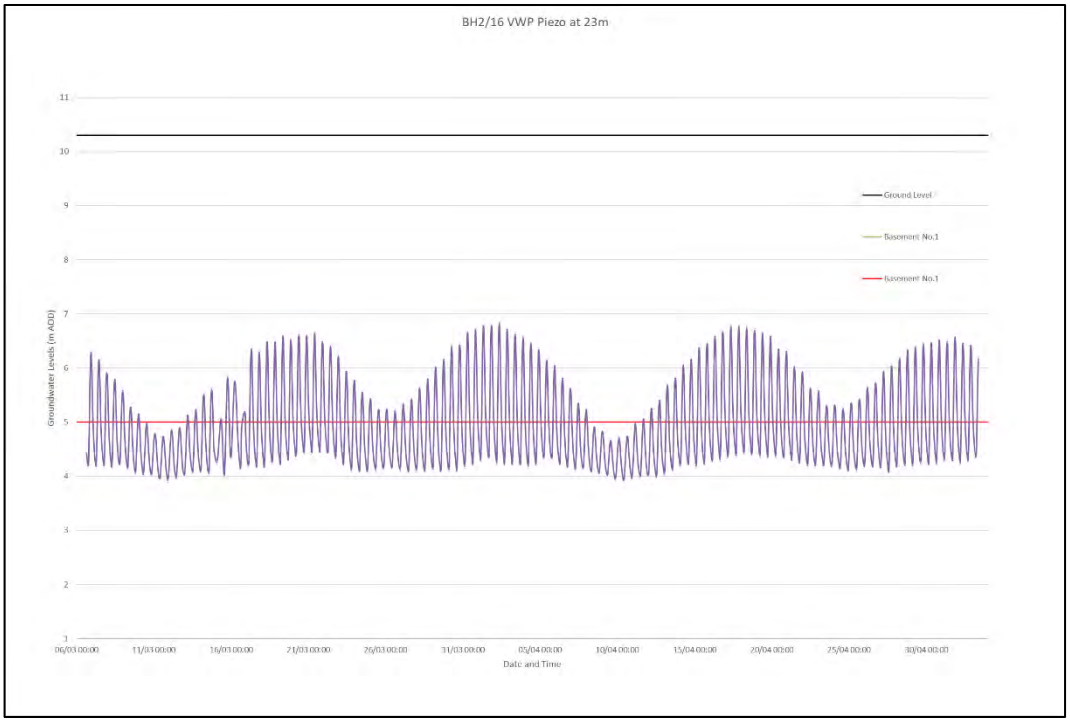


Figure 14: Borehole BH2/16 Vibrating Wire Piezometer Data (23m bgl) – Groundwater Level

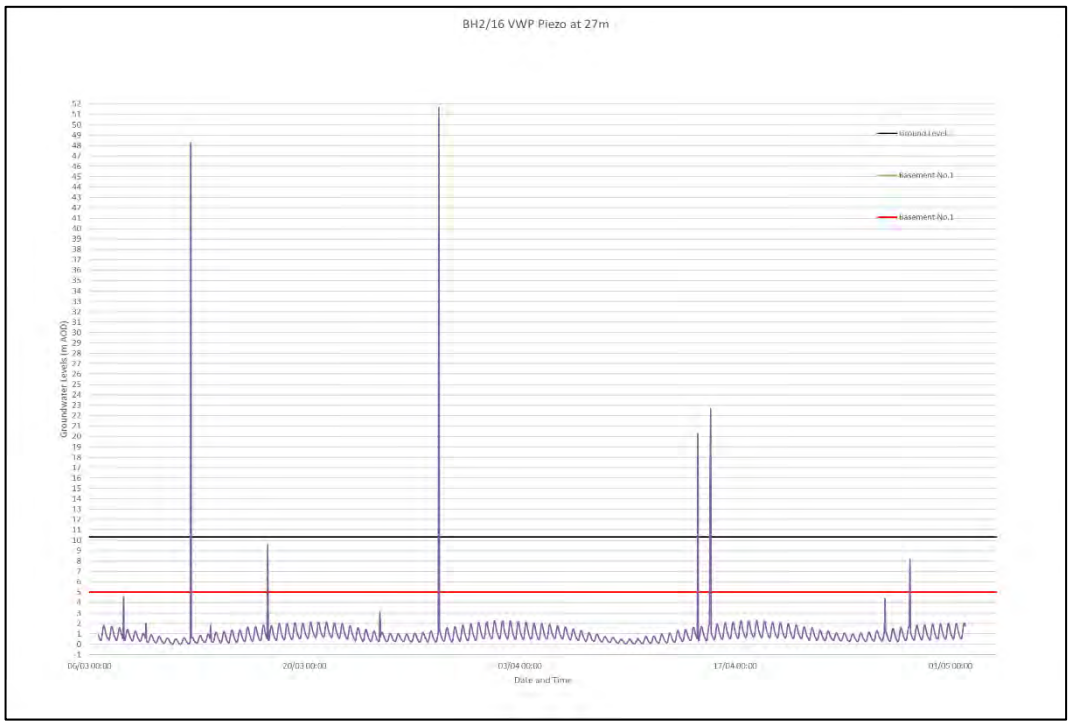


Figure 15: Borehole BH2/16 Vibrating Wire Piezometer Data (27m bgl) – Groundwater Level

3.1 Groundwater Pore Pressure

Vibrating wire piezometers were installed in BH2/15 and BH2/16 at varying depths between 14m bgl and 30m bgl, the data recorded indicates that the groundwater pore pressures at depths below the Site range from 27kN/m^2 to 638kN/m^2. Figure 16 displays the range of pore pressure with elevation.

It should be noted that BH2/16 piezo at 27m recorded a groundwater levels of up to 51.68m AOD, reviewing tide information for this period, it appears that these water levels do not coincide with any tides and are therefore considered erroneous. From Figure 16, it can be seen that pore pressure increases with depth across the Site.

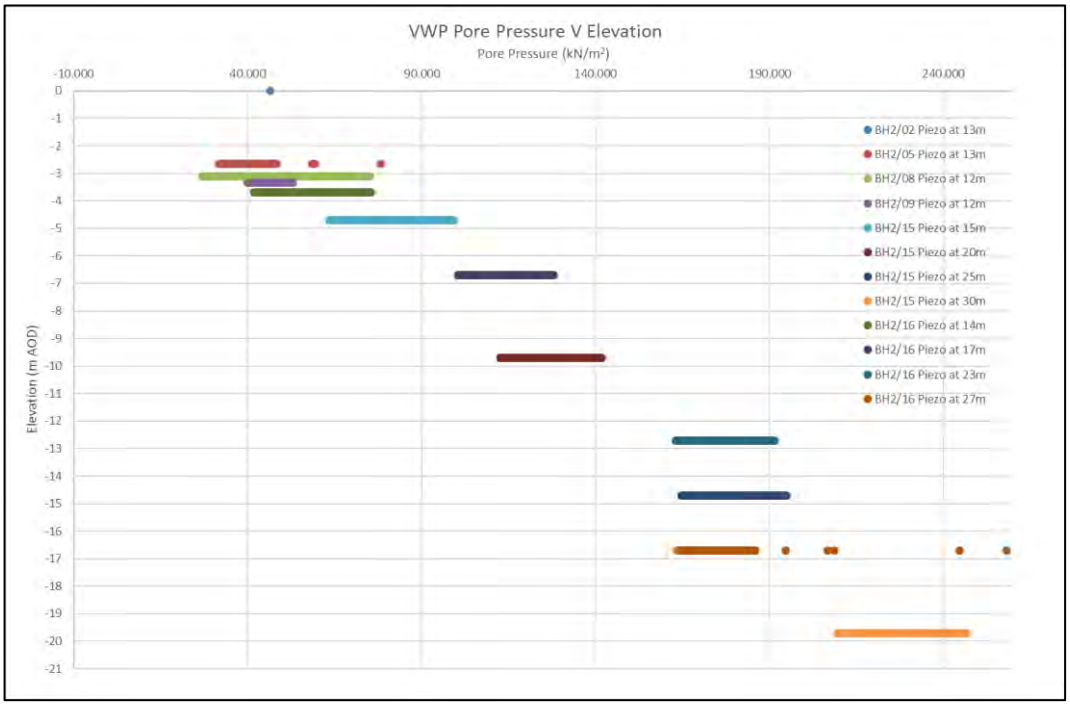


Figure 16: Vibrating Wire Piezometer Results - Pore Pressure v Elevation

3.2 In-situ Permeability Tests

8No. packer tests and 6No. variable head tests (falling/rising head tests) were carried out, at depths ranging from 13.3m bgl to 28.8m bgl and 13.2m bgl to 25.0m bgl respectively, in order to provide an indication of the Granite/Diorite rock mass permeability.

The testing results indicate permeability values ranging between 8.1 x 10^{-6} and 2.1 x 10^{-4}m/s from the falling head tests and between 7.7 x 10^{-8} and 7.6 x 10^{-6}m/s from the packer tests. As no permeability testing results are available for the superficial Made Ground and Alluvium strata, assumptions have been made based on the materials description. The permeability values assumed undertaken are presented in Table 4 which were ascertained within the WIE Ground Modelling Study Report [1].

Table 4: Ground Model and Assumed Soil/Rock Permeability

Stratum	Top of stratum [m AOD]	Thickness [m]	Permeability [m/s]
Made Ground	+9.5	11	1 x 10^{-5} to 1 x10^{-4}
Alluvium	-1.5	1.8	1 x 10^{-7} to 1 x 10^{-6}
Weathered Granite/Diorite	-3.3	4.2[1]	2 x 10^{-5} to 5 x 10^{-5}

[1] Model base assumed at 7.5 m AOD

3.3 Predicted Tides and Groundwater Monitoring Data

The 2018 predicted tidal data for St Helier was obtained from the Hydrographic Office (https://www.gov.uk/government/organisations/uk-hydrographic-office) and has been plotted below

[1] Waterman Infrastructure and Environment, Horizon Jersey, Groundwater Modelling Study, Ref. WIE13175-104-1-1-3.GMS dated 11/04/18)

in Figure 17, with the groundwater standpipe data obtained between December 2017 and March 2018.

From Figure 18, it can be seen that the sea level beyond the Elizabeth Marina at St. Helier ranges from 0.5m AOD to 11.7m AOD depending on the time of year and tides. The marina level is maintained at 5.7m AOD, which is just under the mid-level of the tidal range at St. Helier.

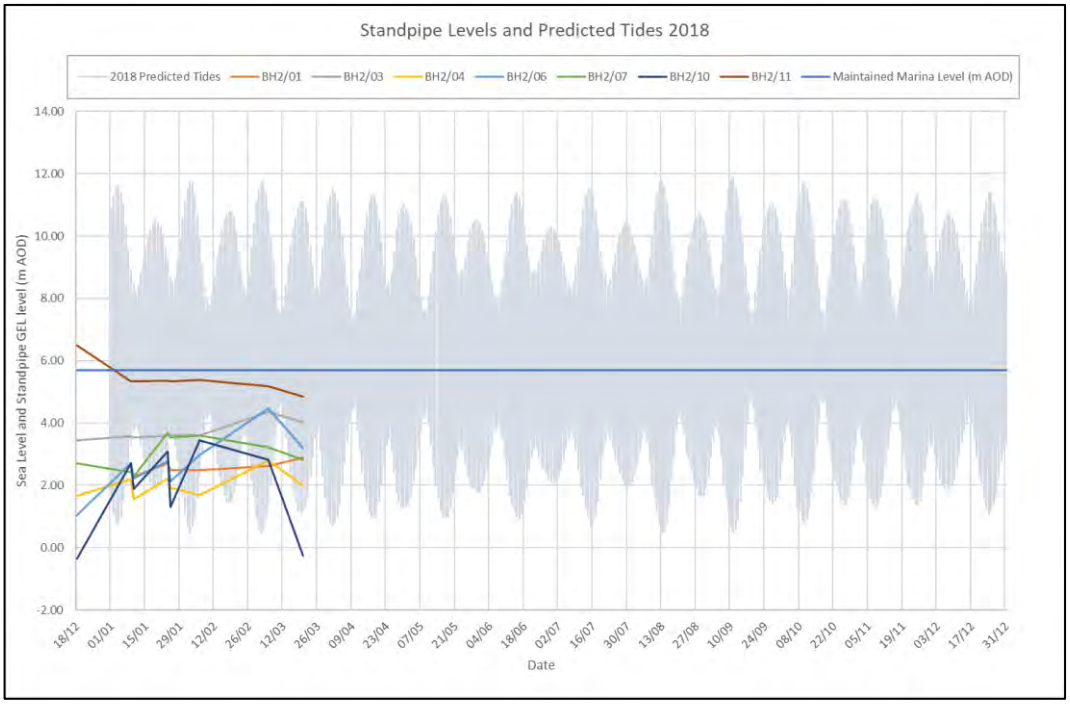


Figure 17: Predicted Sea Level (Tidal) Data with Standpipe and Marina Levels

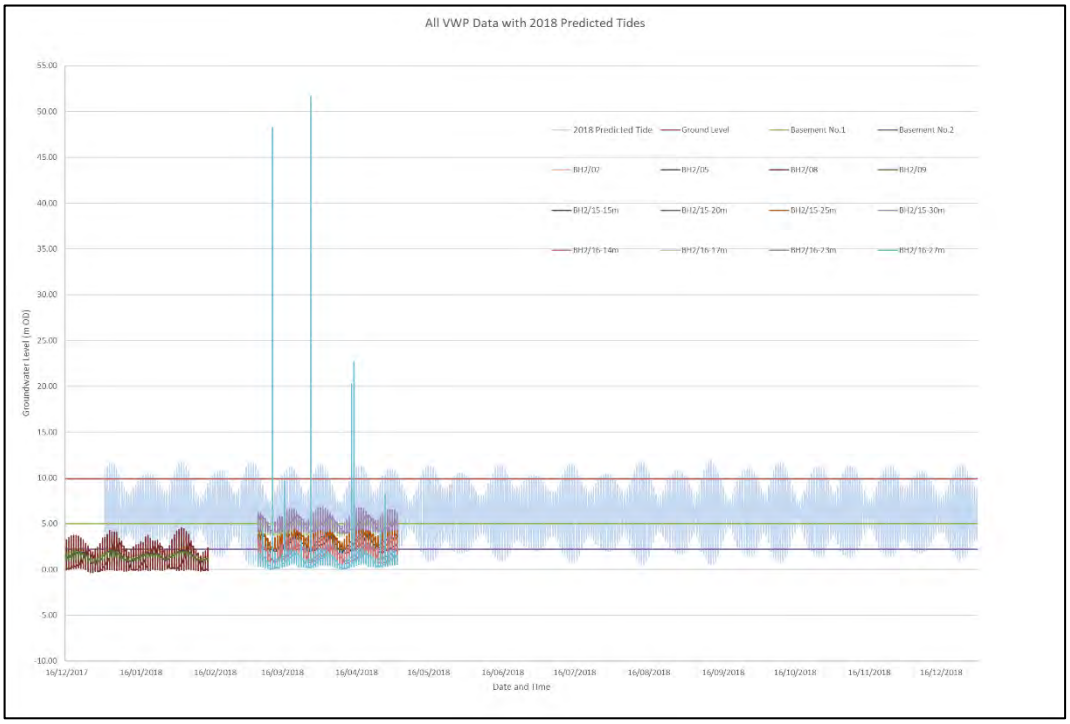


Figure 18: Predicted Sea Level (Tidal) Data with VWP data

3.4 Conclusions and Recommendations

Groundwater monitoring data from the standpipes indicate that recorded levels below the Elizabeth Marina (5.7m AOD) are at a maximum level of 5.38m AOD. This is also confirmed by the VWP data obtained from BH2/02, BH2/05, BH2/08, BH2/09 and BH2/15 which recorded a range up to 4.55m AOD (BH2/08) (Figure 18).

Therefore, the groundwater level, for foundation design purposes, should be assumed to be approximately at an average of **5m AOD**, although levels will depend on weather conditions. It can be seen from Figure 18 that groundwater influenced by the tides is at a maximum elevation of approximately of 4.55m AOD (4.35m bgl) and any groundwater encountered above 5.0m AOD, may be considered as perched water.

The VWP data appears to indicate that the flow of groundwater below the site, groundwater levels are at their highest, close to the Marina wall (BH2/08) with flow moving NE towards BH2/02. This appears to correspond to the known tidal streams for Jersey (approximately East – West). These locations are the only areas where groundwater appears above the structural slab level of the deep basement.

Considering the variation of groundwater across the site, the effect of Tidal behaviour, proximity to Marina and presence of perched water table across the site, appropriate retention system for excavation and suitable mitigation measures should be in-placed. Such measures can further be supported through appropriate analytical and modelling approach to quantify the pumping rates and effect of basement construction on the groundwater regime in the area.

Construction of the basements will involve the excavation of a single basement level below Building A and two basement levels beneath Buildings B and C (Appendix B). Basement excavations will extend to 5.0 m AOD (SSL) for Building A and 2.2m AOD (SSL) for Buildings B and C, with basement invert level within the Made Ground. This will involve the removal of material to approximately 5.0m below ground level in the northwest of the site, and to approximately 7.8m below ground level in the south of the site. It is understood the basements will be formed by means of retaining walls, formed of a contiguous pile for Building A and a combination of secant and contiguous pile wall for Buildings B and C.

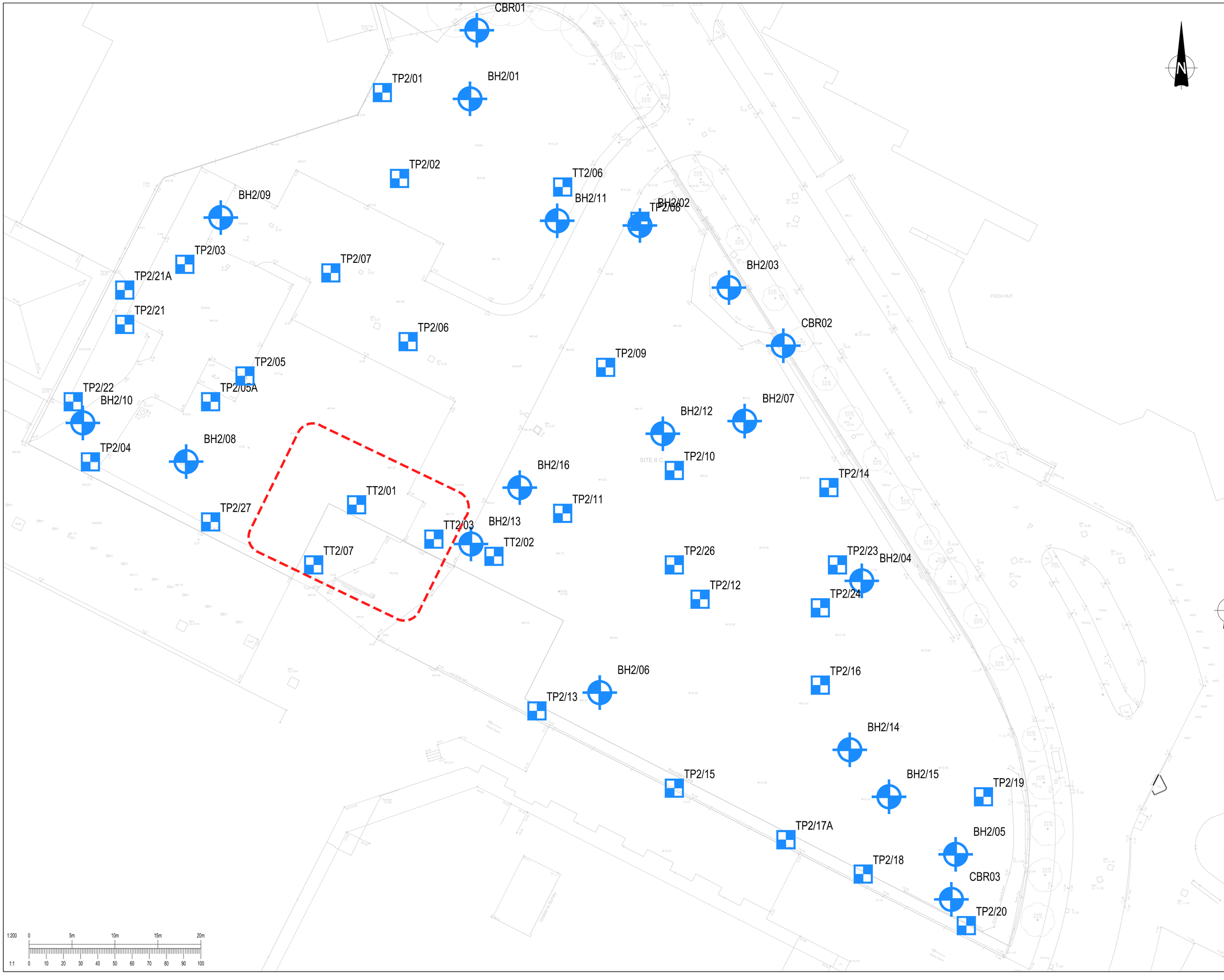
Limited de-watering of the perched water within 4.3m of the ground surface and groundwater control within the Made Ground would be required during construction of the basement to introduce dry and stable environment. Excavations will be required to extend through the Made Ground which, dependant on the groundwater conditions, may be prone to 'running sand' conditions.

For the construction of the basement structures with structural slab levels of 2.2m AOD and 5.0m AOD and taking into account predicted high tide levels; as per BS:8102 (2009), the groundwater is considered to be 'High' for Buildings B and C and 'Variable' for Building A.

The presence of water-bearing strata within or immediately below the deep excavation requires dewatering both to allow excavation in the dry (should this be a requirement of the construction methodology) and to control pore pressures to prevent base heave, therefore foundations should be designed for uplift and short-term tide conditions. Construction sequence will have to be designed round the tides, which will likely have an impact on the construction timetable as well as costs.

Some of these measures are exclusion techniques which include: permeation grouting, ground freezing, and compressed air and, the provision of a cut-off or cofferdam. Appropriate dewatering measures employed should be in accordance with relevant guidance such as CIRIA Report C750, Groundwater control: design and practice, second edition (2016).

Appendix A WIE- SA-80-0100-F01 Exploratory Hole Plan



This drawing should not be scaled. Dimensions to be verified on site.
Any discrepancies should be referred to the Engineer prior to work being put in hand.

Pickfords Wharf, Clink Street, London SE1 9DG t 020 7928 7888 f 020 7902 0992

GENERAL NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL ENGINEER'S, ARCHITECT'S OR OTHER RELEVANT DRAWINGS AND SPECIFICATIONS.
2. ALL DIMENSIONS AND LEVELS ARE TO BE CHECKED ON SITE BY THE CONTRACTOR PRIOR TO PREPARING ANY WORKING DRAWINGS OR COMMENCING ON SITE.
3. THE CONTRACTOR MUST ENSURE AND WILL BE HELD RESPONSIBLE FOR THE OVERALL STABILITY OF THE BUILDING/STRUCTURE/EXCAVATION AT ALL STAGES OF THE WORK.
4. ALL WORK BY THE CONTRACTOR MUST BE CARRIED OUT IN SUCH A WAY THAT ALL REQUIREMENTS UNDER THE HEALTH AND SAFETY AT WORK ACT ARE SATISFIED.
5. ALL WORK IS TO BE CARRIED OUT IN COMPLIANCE WITH THE REQUIREMENTS OF THE RELEVANT STATUTORY AUTHORITIES AND REGULATIONS.
6. ALL COORDINATES BASED ON TOPOGRAPHIC SURVEY SUPPLIED BY 'PRECISION SURVEYS'. SURVEY GRID NOTED AS 'JERSEY MERCATOR GRID'- REFER TO TOPOGRAPHIC SURVEY DRAWING(S) FOR DETAILS.

LEGEND:

- SITE BOUNDARY
- BH2/07 — BOREHOLE LOCATION
- TP2/12 — TRIAL PIT LOCATION
- TT2/02 — TRIAL TRENCH LOCATION

Rev	Date	Description	By
F01	22.05.18	AS DUG LOCATIONS	MC
E01	31.10.17	ISSUED FOR CONSTRUCTION	DC
A02	17.10.17	UPDATE BOUNDARY	DC
A01	26.07.17	ISSUED FOR INFORMATION/DISCUSSION	MC

Amendments

Project: CASTLE QUAY 2

Title: EXPLORATORY HOLE LOCATIONS

Client: CQ2JV

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Drawing Status: AS BUILT

Designed by	MF	Checked by	MF	Project No: WIE13175
Drawn by	MC	Date	17.10.17	
Scales @ A1 work to figured dimensions only	1:200			Computer File No: WIE-13175-SA-80-0100.dwg

Publisher	Zone	Category	Number	Revision
WIE	SA	80	0100	F01

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A1-Wat-S, WIE-13175-SA-NS-P_GI_-L_-, WIE-13175-SA-NS-SU_2D-L_

Appendix B Proposed Development Layout