IMPORTED FILL
VALIDATION REPORT
Proposed Residential Development
Herbert Road
Newport

Prepared for:
Keepmoat

September 2016

Report No. 12032/VR1

terrafirma

REPORT TITLE	:	**Imported Fill Validation Report : Herbert Road, Newport**
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Executive Summary

In order to comply with current Government directives and the Flood Consequence Assessment (FCA) approved by NRW the site is to be raised from its original level to an average formation level of 9.25m AOD.

Riversee Limited has to date completed partial fill of the site. This has been achieved by importation of soils from various sources.

All imported materials have been chemically screened and confirmed suitable use in accordance with Terra Firma Remediation Strategy, or in agreement with Newport City Council and National Resources Wales.

In-situ geotechnical testing has confirmed the effectiveness of the compaction process.

In-situ monitoring of settlement with in-situ piezometers and settlement pins is on-going. Assessment of the piezometer results in June 2016 confirmed that primary settlement was not complete since pore water pressure continued to fall and that dissipation of pore water pressure appears faster in the peat layers than in the clay. Piezometer 1 set within peat took roughly half the time for peak pore water pressure to dissipate to 40% than Piezometer 3 set within clay. Measured settlement to date (June 2016) recorded settlement of up to 28mm since the commencement of the earthworks.

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SECTION 1 Introduction

1.1 General

In order to comply with current Government directives and the Flood Consequence Assessment (FCA) approved by NRW the site is to be raised from its original level to an average formation level of 9.25m AOD.

Riversee Limited has to date completed partial fill of the site. This has been achieved by importation of soils from various sources.

The following sections provide a summary of the site, detail both chemical and geotechnical validation of the imported fill, and present the findings of settlement monitoring to date.

1.2 Limitations and Exceptions

The Imported Fill Validation Report has been prepared for Keepmoat. This report shall not be relied upon or transferred to any other parties without the express written authorisation of Terra Firma (Wales) Limited. If an unauthorised third party comes into possession of this report they rely on it at their peril and the authors owe them no duty of care and skill.

The report represents the findings and opinions of experienced geo-technical and geo-environmental consultants. Terra Firma (Wales) Limited does not provide legal advice and the advice of lawyers may also be required.

SECTION 2 Site Summary

2.1 Geotechnical and Geo-environmental Site Investigation

Investigation of the site was previously undertaken by Terra Firma (Wales) Limited. The details of the investigation were reported on in March 2013 (Geo-environmental and Geo-technical Report No. 12032). A copy of this report is provided in **Annex A**.

The site investigation was carried out between the 31st of October and the 8th of November 2012 comprising 19 trial pits and six cable percussive boreholes and three mini percussive boreholes.

In March 2014 additional testing of groundwater was performed.

2.1.1 Ground Conditions

The ground conditions encountered beneath the site can in general be summarised as made ground to between 0.2m ad 3.3m depth, underlain by soft grey and brown clay with bands of peat and intermittent sand and gravel deposits. Below 5.9m/10.3m depth firm becoming very soft red brown gravelly clay prevails, grading in to red mudstone between 10m to 12.7m depth depth.

2.1.2 Foundation Solution

Construction of shallow traditional foundations upon un-compacted made ground over soft clay bands beneath the site would lead to high total and differential settlements.

Precast concrete driven piles founded within the underlying very weak red brown and grey mudstone with a suspended floor slab were therefore recommended.

2.1.3 Contamination and Human Health Risk Assessment

During the intrusive investigation, small disturbed soil samples were collected for contamination screening. A number of contaminants of concern were identified. It was concluded that future site users, potentially at risk from contamination in site soils, will be protected by the thick layer of fill to be imported in order to raise the site. Upon development all garden and landscaped areas will be finished with a minimum of 600mm of clean imported subsoil and topsoil.

Comparison of in-situ gas monitoring results with CIRIA report C665 confirmed that gas protection measures will be required. It was concluded that gas protection to a 'gas characteristic 2' level may be adequate. However, further on-site gas monitoring from from flux boxes is to be undertaken during on completion of the earthworks to confirm that this level of protection will be suitable.

Basic radon protection measures should be incorporated into all new buildings on site. The radon/gas barrier should also be effective as a barrier to PCB vapours.

Prior to the placement of water supply pipes an assessment should be made, by the water provider, of soil along the route of the pipe with reference made to the material selection criteria quoted in UKWIR Report Ref No 10/WM/03/21 'Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites'.

2.1.4 Environmental Risk Assessment

Groundwater wells were installed and groundwater samples were also retrieved for testing. Samples from the drainage reen were taken and analysed in June 2013. Petroleum hydrocarbons, zinc and fluoranthene were found as contaminants in groundwater and the reen. Two rounds of groundwater testing in March 2014 identified only a single exceedence of zinc, in one location.

Monitoring of groundwater level in boreholes in January 2014 over a tidal cycle confirmed that there was no tidal influence on groundwater in the underlying sands and gravel and no hydraulic continuity between groundwater and the River Usk. The River Usk and hydrological environment are not therefore considered to be at risk.

2.2 Remediation Strategy

Following the Geotechnical and Geo-environmental Site Investigation a Remediation Strategy Report was prepared in December 2013. This has been updated several times, reflecting the proposed works for site.

A copy of the August 2015 Remediation Strategy Report is provided in **Annex B**.

In general, the following remedial measures proposed to ensure no risks to human health and the environment were:

1. Raising the site above the flood plain with imported engineered fill. All imported materials to date have been validated as suitable for use. All further imported fill will similarly be sampled, tested and validated as required.

2. Upon completion of the development placement of 600mm capping of clean soil (subsoil and topsoil) in garden and landscaped areas.

3. Installation as a minimum a 2000 gauge membrane suitable for protection against ground gas, radon gas and PCB vapours in all new buildings. Passive under-floor venting and taping and sealing of all joints will also be required. Dependant on further on-site flux box gas monitoring more robust gas protection measures may be required.

4. Sampling and analysis of groundwater prior to and following initial fill works.

5. New water supply pipes to be chosen in accordance with UKWIR Report Ref No 10/WM/03/21 'Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites'.

2.3 Earthworks

To date the site levels have been part-raised in accordance with the Remediation Strategy.

The following sections detail validation works completed on the imported engineered fill.

SECTION 3 Chemical Validation Imported Engineering Fill

A summary of the materials imported to date is provided in **Table 3.1** below.

Table 3.1 Summary of Imported Materials

Soil Source	Estimated Volume Imported (m^3)	Date Imported on to Site	Soil Validation Test Results
Upper Half of Riversee Limited Stockpile (Adjacent Herbert Road Site)	14,000	Small portion imported and placed in south of site prior to July 2015 Remainder July 2015	DETS test certificates 27313-1 & 27519-2 **Annex C**
Lower Half of Riversee Limited Stockpile (Adjacent Herbert Road Site)	9000	July 2015	DETS test certificates 40034-2 & 40314 **Annex D**
Taylor Wimpey Citivision Site	1000	August 2015	DETS test certificate 47308-1 **Annex E**
Taylor Wimpey Citivision Site	500	October 2015	DETS test certificate 46635 **Annex F**
Soils taken from area of site north of the drainage reen	500	October 2015	DETS test certificate 77110 **Annex G**

All soils were tested for a range of substances and compared to regulatory soil and leachate guidelines values in accordance with Terra Firma Remediation Strategy.

The soil test certificates are appended, as detailed in **Table 3.1**.

The Riversee Limited stockpile was sampled and tested in two halves. Each half was tested prior to import.

The other soil sources were sampled and tested once imported.

The soil and leachate test results are summarised in table format, please refer to **Annex E**.

On occasion some soil samples exhibited exceedences of chemicals above their respective soil or water threshold level were identified.

Newport City Council Environmental Protection officer and the NRW were contacted and acceptance of the soils sought in these instances.

Chemical Validation Imported Engineering Fill (Continued)

Table 3.2 below and **Annex h** detail correspondence between Terra Firma, the NRW and Newport Council during fill works.

Table 3.2 Summary of Correspondence

From	To	Format	Date	Subject	Annex F Ref
TFW	Riversee Limited	letter	22.06.2015	Chemical summary of soils from upper part of Riversee stockpile. Concludes soils should be acceptable provided appropriate bespoke permit granted from the NRW to allow asbestos	1
TFW	Newport Council Planning	Email	22.06.2015	Sent copy of letter on upper part of stockpile (as above) for approval	2
TFW	Riversee Ltd Copied to NRW and Newport Council Pollution Control	letter	06.08.2015	Summary of chemistry of lower part of Riversee stockpile and updated Remediation Strategy. **Riversee Limited stockpile material permitted for use on site. Remediation Strategy updated to include remedial measures required to protect against asbestos in fill material as requested by Newport Council Contaminated Land**	3a&b
NRW	Newport Council Planning	Letter	14.08.2015	Response to letter regarding leachate chemistry of lower part of Riversee stockpile	4
NRW	TFW	let20	19.08.2015	Response to NRW letter dated 14.08.2015. Stockpile chemical summary – suggestion place Riversee stockpiled soils at least 50m from reen	5
TFW	Newport Council Pollution Control	Email	13.10.2015	Query of high lead exceedence in Citivision (Aberbargoed – wrongly named) soils	6
Newport Council Pollution Control	TFW	Email	15.10.2015	Response to TF email 13.10.2015	7
TFW	NRW	Email	27.10.2015	Regarding Citivision soil and leachate results	8
NRW	TFW	Email	12.11.2015	Reply to TFW email 27.10.2015	9
TFW	Newport Council Pollution Control	Email	17.11.2015	Regarding asbestos and lead in Citivision soils	10
TFW	NRW	let 21	18.11.2015	Citivision source leachate results - TFW justification for acceptance	11
Newport Council Planning	TFW	Email	25.11.2015	Council/NRW inform that they are not recommending discharge of condition. Request info by 02.12.2015	12
TFW	NRW	Email	26.11.2015	Regarding above Newport Council correspondence 25.11.2015 and reference to Let20	13
NRW	NRW	Email	26.11.2015	**Confirmed received TFW let20 and agreed informally that proposal to place Lower Riversee Stockpile material 50m from reen was acceptable**	14
NRW	TFW and Newport Council Planning	Email with letter (SE-2015-119016-03-L02)	02.12.2015	NRW formal response to TFW let20 Partial discharge of condition 5 & 6 (remediation strategy) following receipt of TFW let20	15
NRW	TFW	Email	02.12.2015	Questioning how will know which part of the stockpile deposited where on site and placement of geotextile membrane	16
TFW	Newport Council Planning	Let 22	10.12.2016	Response to email 02.12.2015 (Annex Ref 14). Confirmation of fill placement and outline of intended remediation and validation proceedures	17
Newport Council Pollution Control	TFW	Email	22.01.2016	Response to TFW email 18.11.2015 regarding Citivision soils **Newport Council confirm Citivision soils are acceptable**	18

SECTION 4 Verification of Fill Compaction

The Riversee Limited stockpile was geotechnically tested prior to import to enable an Earthworks Compaction Specification Report to be provided.

The Compaction Specification Reports for the top half of this stockpile (Report No. 12032/CS1, dated July 2015) and bottom half (Report No. 12032/CS2, dated July 2015) are provided in **Annex I**.

A small portion of the top of the Riversee Limited stockpile was imported on to site prior to official commencement of the earthworks. This was placed across the southern end of the site. This fill was subject to plate testing and sand replacement density (SRD) tests on the 24th July 2015. A number of tests were also performed on the in-situ ground across the northern part of the site at this time.

'North' of the site refers to the area north of the track (see original topographic plan in Figure 2.1). 'South' is the area below the track.

Also prior to earthworks a small mound of imported soils (also from the top of the Riversee Limited stockpile) had been placed in the northwest of the site.

As the fill levels were raised further plate load and SRD tests were completed.

The testing completed is summarised in **Table 4.1** on the following page.

Recent sampling on behalf of Keepmoat confirmed the placed fill thickness to range between 0.6m and 1.3m.

Verification of Fill Compaction (Continued)

Table 4.1 Summary of In-situ Geotechnical Tests

Fill Location and Details	Source	Date Imported	Date Tested	Test Type
Pre earthworks fill placed in south of site and mound in northwest of site Max 600mm fill thickness	Top of Riversee Limited Stockpile	Pre July 2015	24.07.2015	Plate tests SRDs
400mm (2 layers) across north of site 200mm fill across southeast quadrant of site	Top of Riversee Limited Stockpile including previously imported bund	30.07.2015 – 04.08.2015	05.08.2015	Plate tests SRDs
Small mound placed along eastern half of southern site edge	Bottom of Riversee Limited Stockpile	05.08.2015		
Fill stockpiled then spread in southwest quadrant of site (400mm thick) Small mound in south spread over southeast quadrant (200mm thick)	Bottom of Riversee Limited Stockpile	07.08.2015		
Fill spread over north of site (200mm)	Bottom of Riversee Limited Stockpile	10.08.2015 – 11.08.2015		
Fill now 600mm in north and 400mm in south Eastern half of site tested following period of stipping / drying / replacing material previously tested and spread of mound in southeast quadrant 05.08.2015			18.08.2015 19.08.2015	Plate tests
Fill spread over eastern half of site	Bottom of Riversee Limited Stockpile	19.08.2015		
Fill stockpiled in northwest corner of site	First batch of Citivision soils	08.09.2015 – 10.09.2015		
Fill placed across the site, Northern area, the haul road and southern area.	- Fill from North/CV - Fill from S.pile - Fill from S.pile		11.09.2015	Plate tests
SRD 1 – Centre North SRD 2 – Southwest SRD 3 – South	- Fill from North - Fill from S.pile - Fill from S.pile		14.09.2015	SRDs
Placed in north of the site	Material taken from north of the reen	16.09.2015 – 18.09.2015	**Untested**	
Placed in central south of site	Bottom of Riversee Limited Stockpile	28.09.2015 & 02.10.2015	**Untested**	
Placed in south of the site	Second batch of Citi-vision soils	05.10.2015	**Untested**	

Test result certificates are provided in **Annex J.**

Where any unsatisfactory results were identified the fill was stripped or broken up to allow further drying before re-rolling and testing.

SECTION 5 Settlement Monitoring

During July 2015 six vibrating wire piezometers and eight settlement monitoring pins were installed across the site.

The location of these monitoring points is illustrated in **Figure 5.1** below.

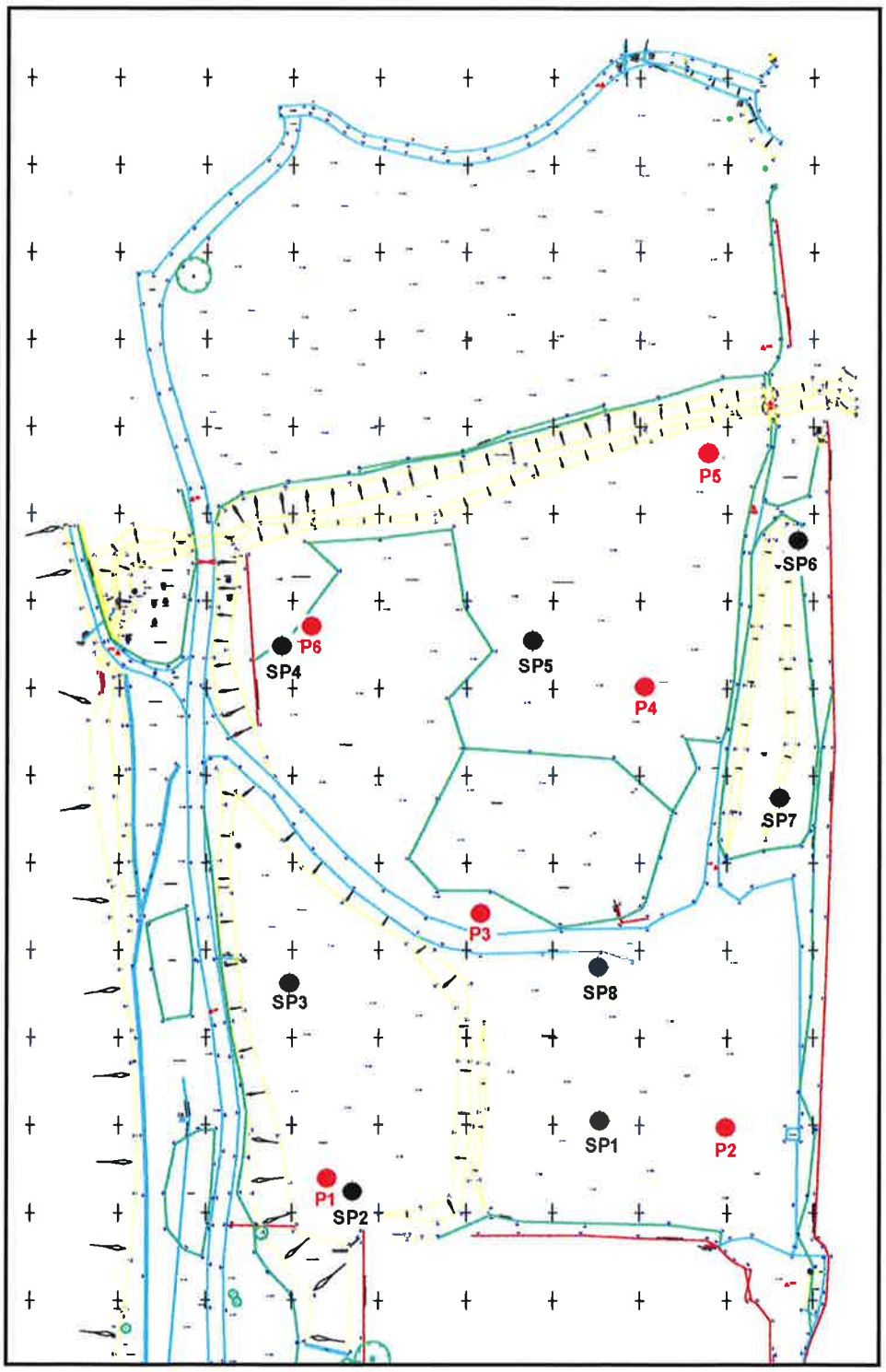


Figure 5.1: Piezometer (P1 – P6) and Settlement Pin (SP1 – SP8) Locations

Settlement Monitoring (Continued)

The piezometers and settlement pins were monitored and surveyed at regular intervals during the earthworks completed so far (July to October 2015), and intermittent monitoring was also completed in the period between October 2015 and May 2016.

With raising ground levels settlement is expected to occur on site in two phases, instantaneous and primary settlement and subsequent secondary settlement.

During instantaneous settlement the soil experiences only shear deformation resulting into change in shape without volumetric deformation. The loss of pore pressure in the soil is zero. Since this settlement is instantaneous it can only be monitored via monitoring pins as the pore pressure cannot be measured (zero).

During primary consolidation / settlement the soil is deformed by movement and compression of soil particles which overall results in volume change. Water held in pores of a saturated soil will migrate to pores of lower pressure (The process of consolidation). Primary settlement is time dependent on a logarithmic scale and stops when pore water pressure returns to baseline level.

Secondary consolidation / settlement occurs following the fall of pore water pressure. Secondary consolidation / settlement includes but is not limited to the following factors;

- Creep: With increasing pressure the grains may become so tightly packed that they will deform causing the soil mass to continue to reduce in volume
- Viscous behaviour of water between particles and pore water: During secondary compression the highly viscous water between the points of contact of soil particles is squeezed out.
- Compression and degradation of organic matter,

Consolidation is a process by which soils decrease in volume by decreasing water content within a saturated soil without replacement of water by air. Consolidation occurs when water is expelled under long term static loads. When a stress or surcharge is applied to a saturated soil the soil particles can compact, therefore reducing its bulk volume and excess water will be "squeezed out". As a soil consolidates excess pore water pressure will fall.

Vibrating wire piezometers were used to monitor pore water pressures (a pressure correlating to meters of water). Vibrating wire piezometers convert fluid pressures on a sensitive diaphragm into a frequency signal. The signals are capable of long transmission distances without degradation, tolerant of wet conditions and resistant to external electrical noise.

Settlement Monitoring (Continued)

To measure settlement baseline data is required.

Table 5.1 Installation details of Piezometers

Piezometer	Depth	Strata Description	Initial Reading		Possible Baseline Reading	
			mH2O	Date	mH2O	Date
P1	6.30mbgl	Peat	2.05	14/7/15	4.45	23/7/16
P2	2.60mbgl	Clay	0.017	15/7/15	2.20	24/7/16
P3	3.70mbgl	Clay	2.429	16/7/15	2.20	24/7/16
P4	4.95mbgl	Peat	0.358	16/7/15	4.10	22/7/16
P5*	2.90mbgl	Peat	0.324	17/7/15	1.95	29/7/16
P6	5.00mbgl	Clay	4.087	22/7/15	4.50	28/7/16
*P5 was last recorded on 4/1/16. The piezometer has been destroyed.						

The possible baseline readings are considered representative although project program would not permit prolonged monitoring to refine the baseline pressures further.

During the establishment of a baseline the piezometers were monitored for changes in pore pressure coinciding with changes in tide level. The tidal range of the River Usk in Newport can extend over 13m. Tide information from The United Kingdom Hydrographic Office for Newport, Wales was used to identify low tide and high tides. Despite the significant tidal range the effect on piezometers was slight / negligible.

As confirmation the piezometers were measured again from low tide to high tide, (a 10.3m tidal range) between 11:00 and 17:00 on 27/5/2016. The data is summarised below.

Table 5.2 Tidal Effect on Piezometers

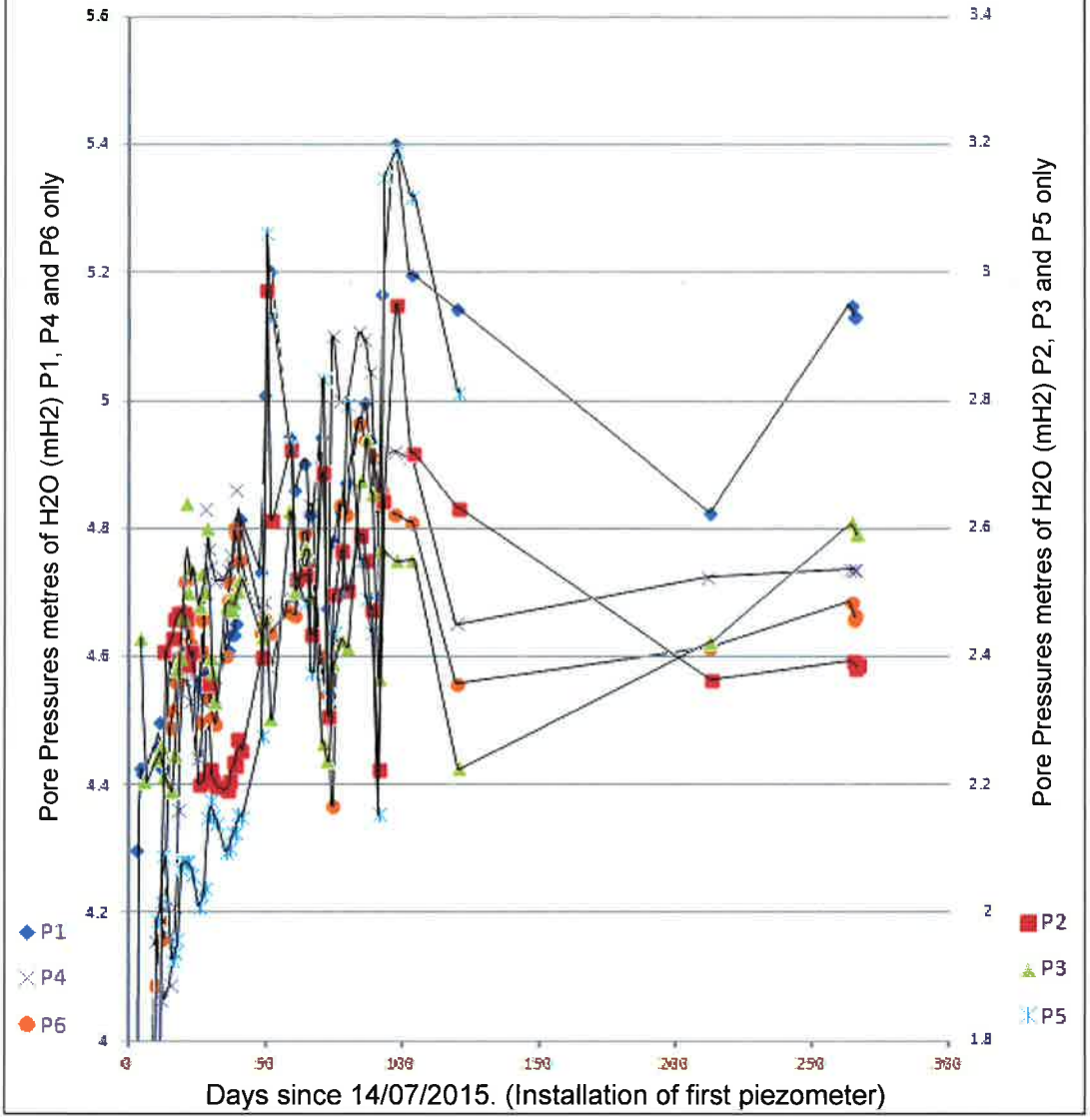
Time	11:00	14:00	17:00	Maximum measured Change in Pore Pressure
Tide Description	Low Tide	Rising Tide	High Tide	
P1	5.151573	5.13387	5.13387	-0.018mH2O
P2	2.3939187	2.3825055	2.3882121	-0.011mH2O
P3	2.6096248	2.5912062	2.5912062	-0.018mH2O
P4	4.7355286	4.7355286	4.7355286	0mH2O
P5	Destroyed			
P6	4.6853254	4.6593008	4.6646852	-0.026mH2O
Pore Pressures reported in mH2O.				

Pore water pressure would be anticipated to increase at high tide with rising water levels however this does not appear to be evident. The equivalent of under 30mm groundwater change was observed between low tide and high tide in this instance. It is considered that the groundwater beneath the site is unlikely to be significantly influenced by the high tidal range of the Usk.

Pore water pressure was monitored daily (or more) during the period of full time supervision. Full time supervision was between 14/7/2015 through to 20/8/2015. Budgetary constraints from 20/8/2015 meant that monitoring became less frequent.

Settlement Monitoring (Continued)

Graph 5.1 : Piezometer Monitoring Results

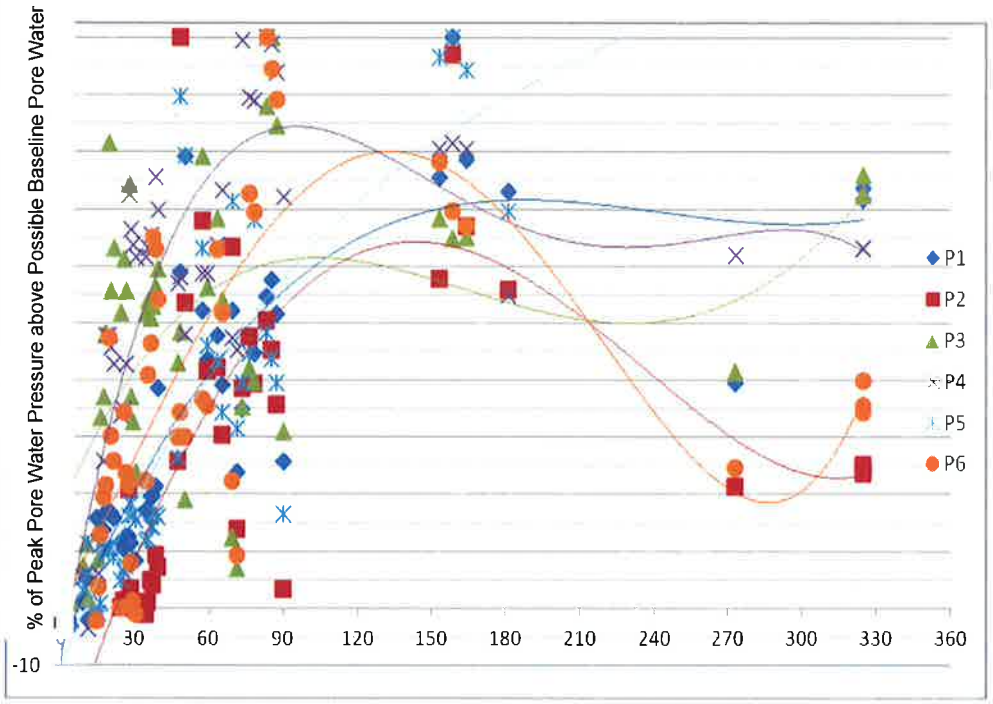


During full time supervision the increasing pore water pressures observed from the piezometers appeared to correlate with the placement of fill. As evidenced by jumps in pore water pressure over the day. Peak pore water pressure dissipated initially quickly but the rate of dissipation reduced resulting in jumps of pore water pressure.

Settlement Monitoring (Continued)

During settlement pore water pressure dissipates as water is squeezed out of consolidating material. The graph below shows the generation of peak pore water pressure generated by the placement of fill typically between 3 and 5 months after the commencement of the earthworks.

Graph 5.2 : Dissipation of Peak Pore Water Pressure



Pore water pressure has been observed to be dissipating, evidence of consolidation and settlement. However the monitoring of pore water pressure dissipation has been disrupted by unsupervised filling events subsequent to the termination of full time supervision.

Pore water pressure dissipation of a single filling event should produce a single curve. Unsupervised filling events are likely to explain for the polymodal lines of best fit of pore water dissipation suggesting that following the initial placement of the assessed stockpile further material has been placed on site. Gaps in monitoring at 4 months and 8 months after the commencement of the earthworks have lead to some uncertainty over likely pore water pressures beneath the site at those times.

A summary of pore water pressure dissipation 11 months after commencement of the earthworks is presented below;

Settlement Monitoring (Continued)

Table 5.3 Summary of Piezometer Monitoring to Date14/7/15 to 27/5/16		
Piezometer 1	Strata: Peat (6.30mbgl)	Location: South-western Corner of Site (Near River Usk Embankment)
Piezometer P1 dissipated to 40% of peak pore water pressure after 3 months but has recently increased to over 70% indicating the recent placement of fill. After a period of dispersion of water pressure there was a significant increase in pore water pressure at Piezometer P1 located beneath a recently placed plateaued stockpile.		
Piezometer 3	Strata: Clay (2.60mbgl)	Location: Southern Centre of Site
Piezometer P3 like Piezometer P1 also dissipated to 40% of peak water pressure taking ~6 months. Piezometer P3 like Piezometer P1 has also recently increased to over 70% of peak pore water pressure. After a period of dispersion of water pressure there was a significant increase in pore water pressure at Piezometer P3 both located adjacent to a recently placed plateaued stockpile to the south of the site.		
Piezometer 2	Strata: Clay (3.70mbgl)	Location: South-eastern Corner of Site (Near Rail Embankment)
Piezometer P2 dissipated initially but rose again to 95% of peak water pressure after 3 months. Pore water pressure dissipated again taking a further 3 months to dissipate to ~20% of peak pore water pressure however recently no dissipation has been recorded. After a period of dispersion of water pressure there was a slight increase in pore water pressure at Piezometer P2 located adjacent to a recently placed plateaued stockpile.		
Piezometer 4	Strata: Peat (4.95mbgl)	Location: North-Centre of Site
Piezometer P4 dissipated initially falling to 55% of peak pore water pressure after 3 months. Pore water pressure at Piezometer P4 has failed to dissipate in the last 4 months and currently in excess of 60% of peak pore water pressure. After a period of dispersion of water pressure there was a slight increase in pore water pressure at Piezometer P4 located near a recently placed plateaued stockpile.		
Piezometer 5	Strata: Peat (2.90mbgl)	Location: North-eastern corner of Site (Near Rail Embankment)
Before being destroyed Piezometer 5 was observing evidence of peak pore water pressure dissipation having dissipated to 70% of peak water pressure within a month.		
Piezometer 6	Strata: Clay (5.00mbgl)	Location: North-western corner of Site (Near River Usk Embankment)
After 6 months pore water pressure appears to have dissipated between to 20-40% of peak pore water pressure. The recent changes to pore water pressure only equate to an equivalent groundwater level change of ~100mm which is considered possible especially considering proximity to the River Usk and the sensitivity of the peat. After a period of dispersion of water pressure there was a slight increase in pore water pressure at Piezometer P6. There appears to be no obvious cause for this and may be a result of natural variation. Peat is known to be a more susceptible material to change than clay.		
Observations: Primary settlement is not complete since pore water pressure continues to fall. Dissipation of pore water pressure appears faster in the peat layers than in the clay. Piezometer 1 set within peat took roughly half the time for peak pore water pressure to dissipate to 40% than Piezometer 3 set within clay.		

Settlement Monitoring (Continued)

Settlement monitoring pins were installed targeting the following areas;

Monitoring Pin 1: South-eastern Corner of the site, near rail embankment,
Monitoring Pin 2: South-western Corner of the site, near River Usk Embankment,(Destroyed)
Monitoring Pin 3: Western Edge of the site, near River Usk Embankment,(Destroyed)
Monitoring Pin 4: North-western Corner of the site, near River Usk Embankment,(Destroyed)
Monitoring Pin 5: Northern edge of the site, near reen,
Monitoring Pin 6: North-eastern corner of the site, near rail embankment,(Destroyed)
Monitoring Pin 7: Eastern Edge of the site, near rail embankment,
Monitoring Pin 8: Centre of site

Unfortunately half of the original monitoring pins were disturbed during the earthworks causing the loss of corresponding baseline information for settlement monitoring. A summary of all survey data to date is presented in **Table 3.4** below.

Table 5.4 Summary of Survey Data

	Round1	Round2	Round3	Round4	Round5	Round6	Round7	Round8
Pin	17/7/15	24/7/15	7/8/15	17/8/15	24/8/15	2/10/15	29/12/15	17/3/16
P1	9.435	9.435	9.435	9.435	9.424	9.427	9.4187	9.418
P2	D	10.069	D	D	D	D	D	D
P2A	-	-	10.071	10.064	10.055	10.059	10.0464	10.0429
P3	9.136	9.136	9.137	D	D	D	D	D
P3A	-	-	-	9.195	D	D	D	D
P3B	-	-	-	-	-	9.708	9.6882	9.68
P4	8.772	8.773	8.771	D	D	D	D	D
P4A	-	-	-	-	9.009	9.013	8.9902	8.982
P5	9.195	9.195	9.198	9.195	9.186	9.178	9.1563	9.149
P6	9.22	D	D	D	D	D	D	D
P6A	-	9.268	9.267	9.271	9.264	9.274	9.2721	9.263
P7	8.954	8.954	8.955	8.955	8.945	8.935	8.9125	8.91
P8	9.209	9.209	9.207	9.208	9.199	9.202	9.1563	9.185

- = not present
D = Destroyed,
Green filled cells indicate pins with a mostly complete set of monitoring data

During earthworks half of the monitoring points were lost or damaged resulting in the loss of data comparable to baseline conditions. Monitoring Pins 2, 3, 4 and 6 were lost. Monitoring Pins 1, 5, 7 and 8 remain intact.

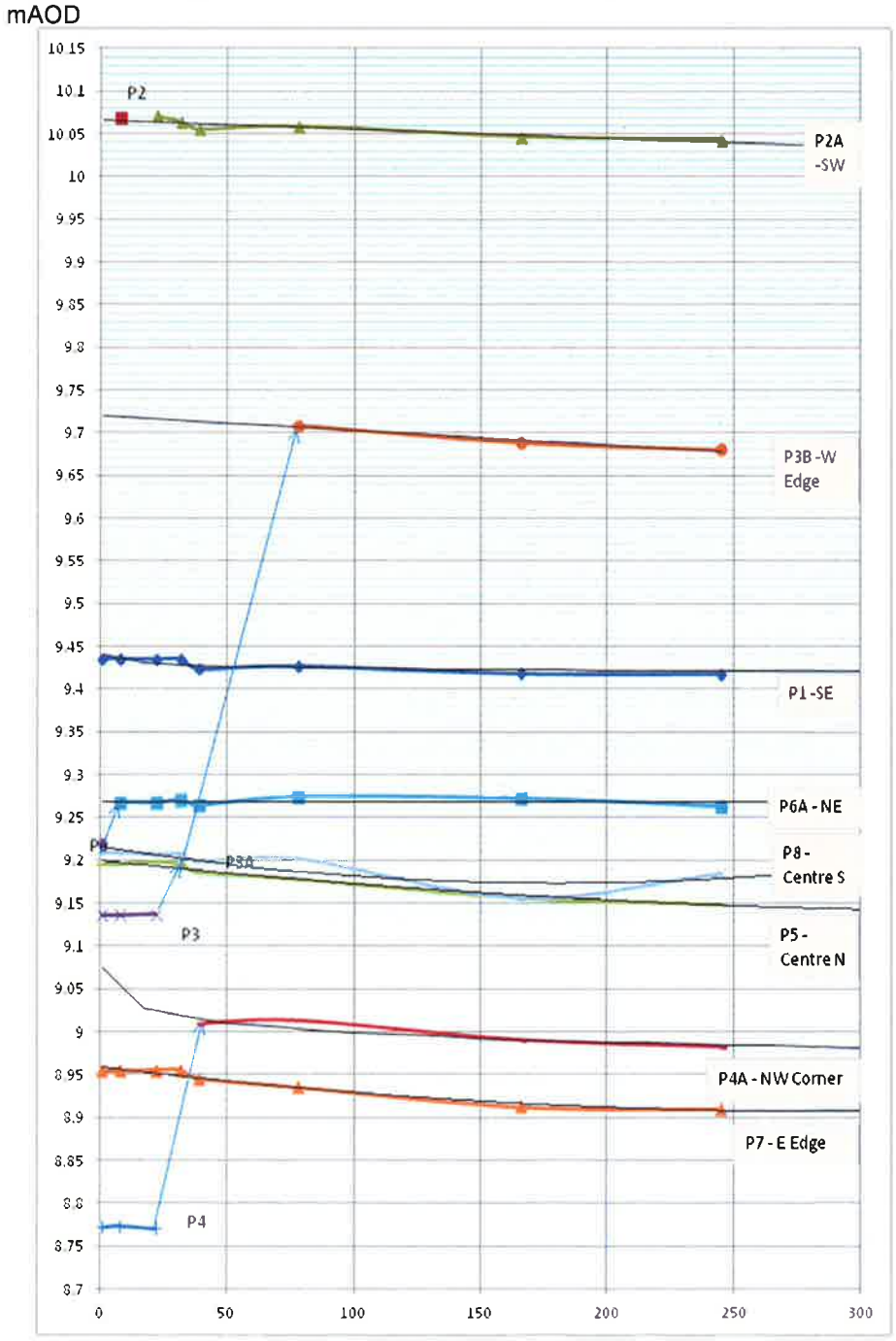
Justification of Survey Rounds;

Round 1, 17/7/15.	Initial Survey (P2 damaged - not surveyed)
Round 2, 24/7/15.	Initial Survey of P2 and P6A
Round 3, 7/8/15,	Initial Survey of P2A
Round 4, 17/8/15,	Initial Survey of P3A and survey of damaged P2A
Round 5, 24/8/15,	Initial Survey (P3A damaged - not surveyed)
Round 6, 2/10/15	Initial Survey of P3A
Round 7, 29/12/15	Follow up survey
Round 8, 17/3/15	Follow up survey

Settlement Monitoring (Continued)

The graph below shows all of the surveyed monitoring pins on an arithmetic time scale. When a monitoring pin was damaged or destroyed an effort was made to replace the pin. When a monitoring pin was damaged / destroyed it was given a sequential alphabetical designation.

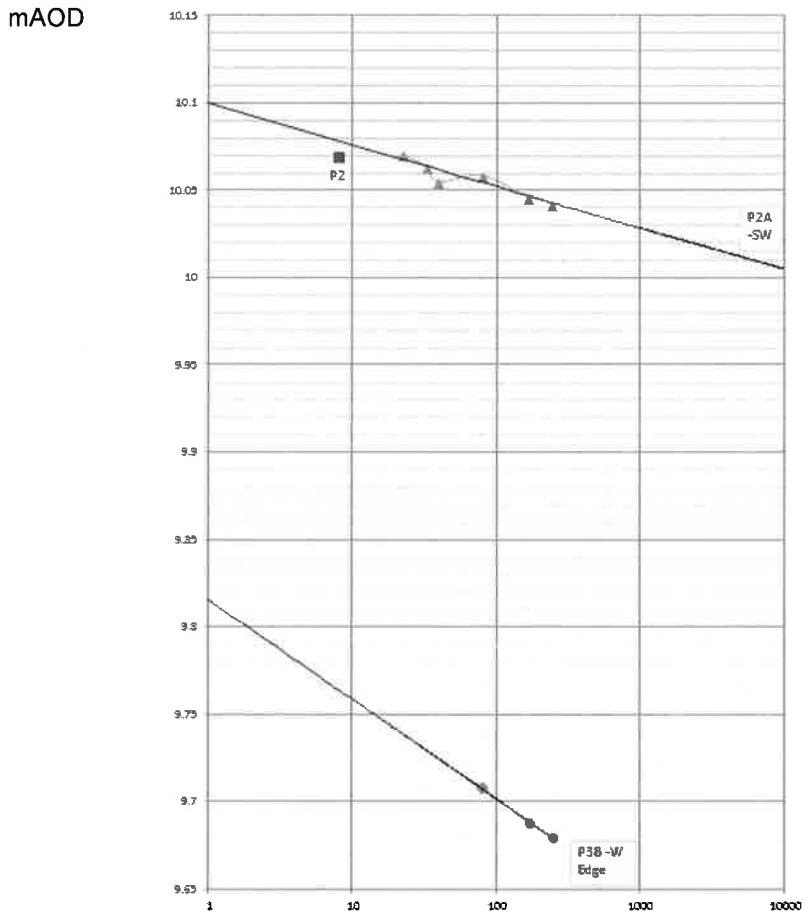
Graph 5.3 : Settlement Monitoring Pin Results



Settlement Monitoring (Continued)

In principle secondary settlement is infinite with settlement rates dropping on a logarithmic scale. However in practice the increase in settlement after 10^4 days (~30years) appears to be generally "complete".

Graph 5.4 Settlement at Monitoring Pins P2A and P3B
(South-western Corner and Western Edge only)



Days since 17/07/2015. (First survey of Settlement Pins) – Log base 10
* Note Original Pins of P2, P3 and P3A were lost or damaged.

Monitoring Pin 2

Unfortunately baseline conditions for Monitoring Pin 2 (located within the south-western corner of the site) were lost as the pin was destroyed following the placement of fill. Monitoring Pin 2A however recorded ~28mm of settlement over 7 months. Whilst the initial readings may be lost it may be possible to conjecture future settlement from the data obtained.

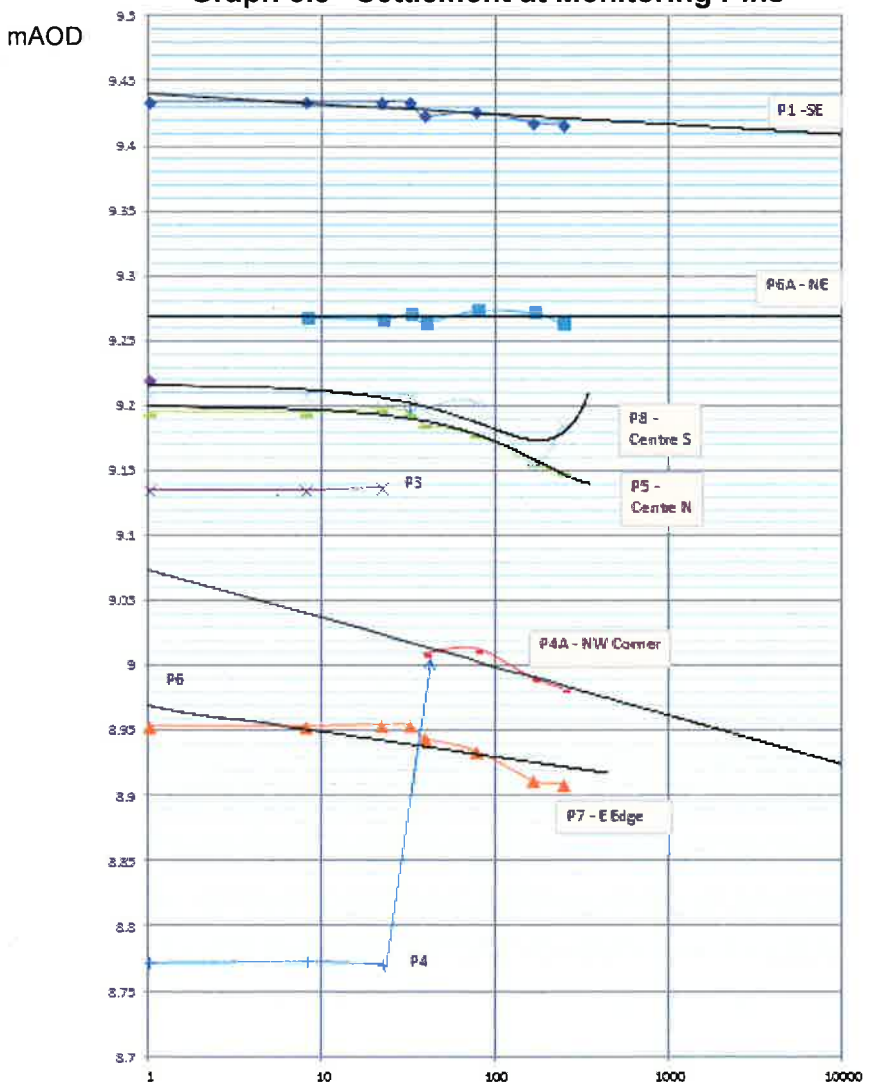
Following the current trend of settlement the above graph indicates at that levels may settle to 10.005mAOD after 10^4 days (~30years or 2045). With the last survey indicating levels of 10.043m a further 0.035m (35mm) should be anticipated under the current surcharge by 2045.

Settlement Monitoring (Continued)

Monitoring Pin 3

Unfortunately baseline conditions for Monitoring Pin 3 (located on the western edge of the site) were lost as the pin was destroyed following the placement of fill. Monitoring Pin 3A was similarly lost. It is considered that any attempt to assess future settlement from Monitoring Pin 3B would be open to too much error and inaccuracy to predict. It is however noted that having measured ~30mm settlement in 5 months that future settlement at this location may be greater than at Monitoring Pin 2A.

Graph 5.5 Settlement at Monitoring Pins



Days since 17/07/2015. (First survey of Settlement Pins) – Log base 10

* Note Original Pins of P4 and P6 were lost or damaged.

Monitoring Pin 1

Data for Monitoring Pin 1 (located near the South-eastern Corner of the site) is complete and to date indicates settlement of ~10mm over 8 months. Conjecturing future settlement from the data obtained indicates that levels may settle to 9.41mAOD after 10^4 days (~30years or 2045). With the last survey indicating levels of 9.42m a further 0.010m (10mm) should be anticipated under the current surcharge by 2045.

Settlement Monitoring (Continued)

Monitoring Pin 6

Unfortunately baseline conditions for Monitoring Pin 6 (located within the North-eastern corner of the site) were lost as the pin was destroyed. Monitoring Pin 6A has however recorded ~5mm of settlement over 7 months. Whilst the initial readings may be lost it may be possible to conjecture future settlement from the data obtained.

Following the current trend of settlement the above graph indicates at that levels may have settled at 9.27mAOD after 10^4 days (~30years or 2045). With the survey indicating fluctuating levels of 9.263m no further settlement is anticipated under the current surcharge by 2045.

Monitoring Pin 4

Unfortunately baseline conditions for Monitoring Pin 4 (located within the North-western corner of the site) were lost as the pin was destroyed. Monitoring Pin 4 recorded 1mm of settlement within a month before it was destroyed.

Like Monitoring Pin 3B it is considered that any attempt to assess future settlement from only 4 survey points at Monitoring Pin 4A would be open to too much error and inaccuracy to predict. It is however noted that following the current trend of settlement the graph indicates at that levels may settle to 8.920mAOD after 10^4 days (~30years or 2045). With the most recent survey indicating levels of 8.982mAOD a further 62mm settlement is anticipated under the current surcharge by 2045. However, this statement is based upon fewer readings.

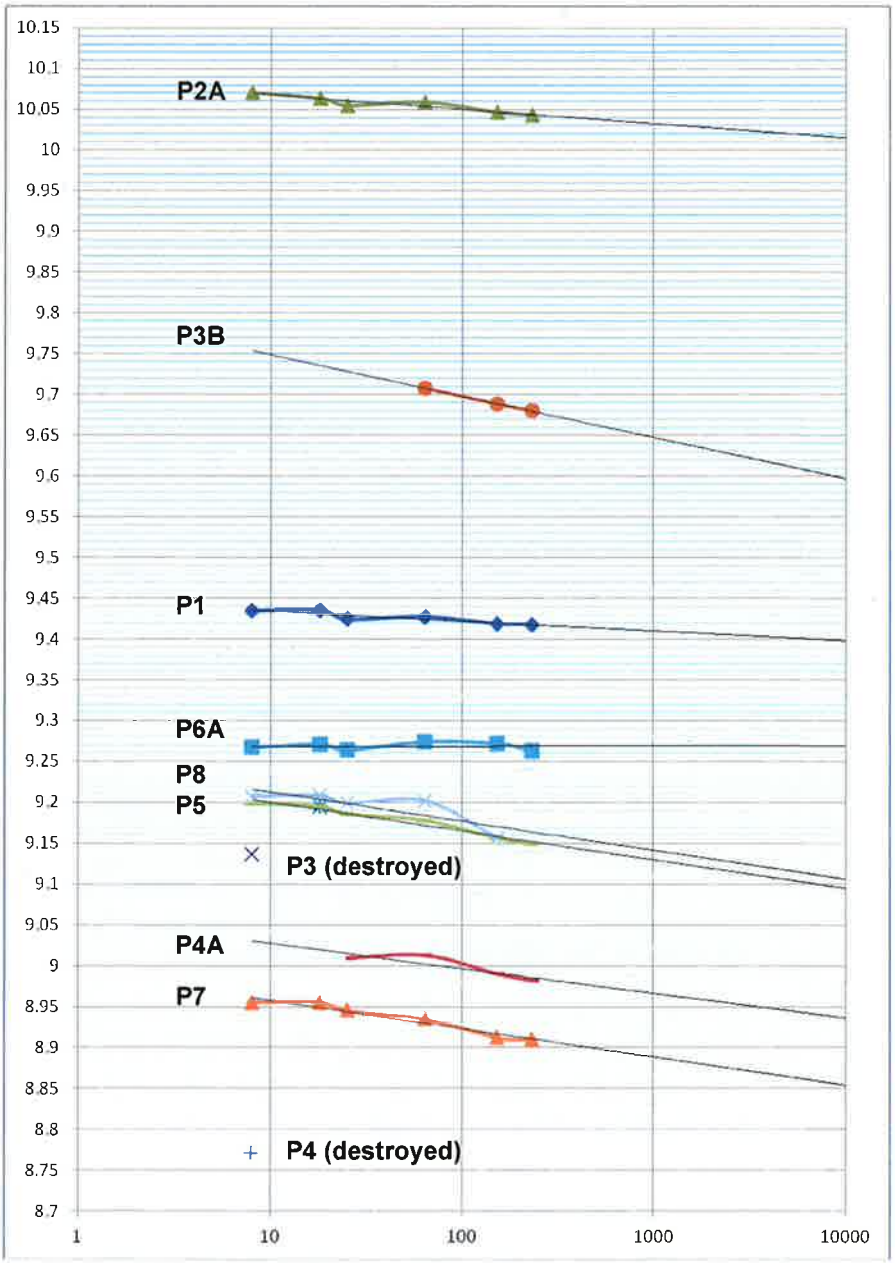
Monitoring Pin 5, Monitoring Pin 7 and Monitoring Pin 8

Data for Monitoring Pins 5, 7 and 8 do not appear to fit a logarithmic settlement curve suggesting that the start date may be out. No settlement was observed within the first two weeks. This could be a result of the earthworks taking longer than anticipated and the placement of fill in these areas being delayed. It has therefore been considered to discount the first two weeks of placement of the settlement pins since the correlation with a logarithmic settlement curve is closer.

Settlement Monitoring (Continued)

Data for Monitoring Pins 5, 7 and 8 do not appear to fit a logarithmic settlement curve as no settlement was observed within the first two weeks. This suggests that the start date may be out. Therefore Graph 3.6 shows settlement on a logarithmic scale starting on 31/7/2015, two weeks after the commencement of the earthworks. Settlement at Monitoring Pins 5 and 7 appear to be a closer fit as a result.

Graph 5.6 2 Week Adjusted fit of Logarithmic Settlement Curve due to Earthworks Delay



Days since 31/07/2015. (2 wks after first survey of Settlement Pins) – Log base 10

Settlement Monitoring (Continued)

Monitoring Pin 5,

Monitoring Pin 5 from the northern centre of the site follows a logarithmic settlement curve fairly closely. In an effort to predict settlement the existing trend, which may be inaccurate, indicate a possible settlement to ~9.1mAOD, a further ~50mm settlement from recent level.

Monitoring Pin 7

Monitoring Pin 7 from the eastern edge of the site follows a logarithmic settlement curve fairly closely. In an effort to predict settlement the existing trend, which may be inaccurate, indicate a possible settlement from ~8.91mAOD to ~8.85mAOD, a further ~60mm settlement from recent level.

Monitoring Pin 8

Monitoring Pin 8 from the southern centre of the site continues to deviate from a logarithmic settlement curve. It may be that the pin was damaged or that multiple phases of earthworks over an extended period mean that settlement cannot be traced from a single event. The most recent survey result indicates an increase in level, which suggests that the pin may be damaged and has been discounted from the estimate below.

In an effort to predict settlement the existing trend, which may be inaccurate, indicate a possible settlement to ~9.1mAOD, a further ~50mm settlement from recent level. It is noted however that the settlement prediction is comparable to Monitoring Pin 5 which is expected to be similar.

Settlement Monitoring (Continued)

Table 5.5 Summary of Predicted Settlements

Monitoring Pin	Initial Survey mAOD	Measured Settlement	Predicted Settlement after 10^4 days (2045)*		Predicted Settlement Remaining (2045)*
Monitoring Pin 1 (SE Corner)	9.435	-18mm (7 months)	- 25mm (approx)	9.410 mAOD	- 6mm (approx)
Monitoring Pin 2 (SW Corner)	10.069	Not Achieved	N/A		N/A
Monitoring Pin 2A (SW Corner)	10.071	-28mm (7 months)	-66mm (approx)	10.005 mAOD	- 38mm (approx)
Monitoring Pin 3 (W Edge)	N/A	+1mm (1 month)	N/A		N/A
Monitoring Pin 3A (W Edge)	9.195	Not Achieved	N/A		N/A
Monitoring Pin 3B (W Edge)	9.708	-28mm (5 months)	N/A		N/A
Monitoring Pin 4 (NW Corner)	8.772	-1mm (1 month)	N/A		N/A
Monitoring Pin 4A (NW Corner)	9.009	-27mm (7 months)	-89mm (v.approx)	8.920 mAOD	- 62mm (v. approx)
Monitoring Pin 5** (N Edge)	9.195	46mm (7 months)	-100mm (approx)	9.095 mAOD	- 54mm (approx)
Monitoring Pin 6 (NE Corner)	9.220	Not Achieved	N/A		N/A
Monitoring Pin 6A (NE Corner)	9.268	-5mm (7 months)	0mm (approx)	9.27 mAOD	0mm (approx)
Monitoring Pin 7** (E Edge)	8.954	44mm (7 months)	104mm (approx)	8.85 mAOD	- 60mm (approx)
Monitoring Pin 8** (Centre)	9.209	53mm (7 months)	99mm (v.approx)	9.11 mAOD	- 46mm (v.approx)

Assumptions:
Earthworks are instantiations with settlement beginning on Day 1.
Settlement is logarithmic

Known Inaccuracies:
Earthworks was not instantaneous and in reality took longer than anticipated
Earthworks has not occurred equally across the site, notably:

- Some areas have more fill placed than others.
- Additional fill has been placed during the settlement process sometimes months later through intermittent earthworks post supervision.

Notes:
Established base line levels filled green
* Assuming no further fill is placed
** Monitoring Pins 5, 7 and 8 do not conform with a logarithmic settlement curve. A better fit is achieved when the start date is set back 14 days. Estimates for Monitoring Pins therefore discount any settlement during the first two survey rounds.
N/A = Not achievable, insufficient baseline information.

SECTION 6 Groundwater and Reen Monitoring

Sampling and testing of the deep groundwater and reen water was scheduled to be carried out prior to earthworks, and two rounds following completion of the intended Riversee Limited fill works or no later than 6 months of earthworks commencement.

Six water monitoring wells were installed, BH1 to BH6, as illustrated in **Figure 6.1** below.

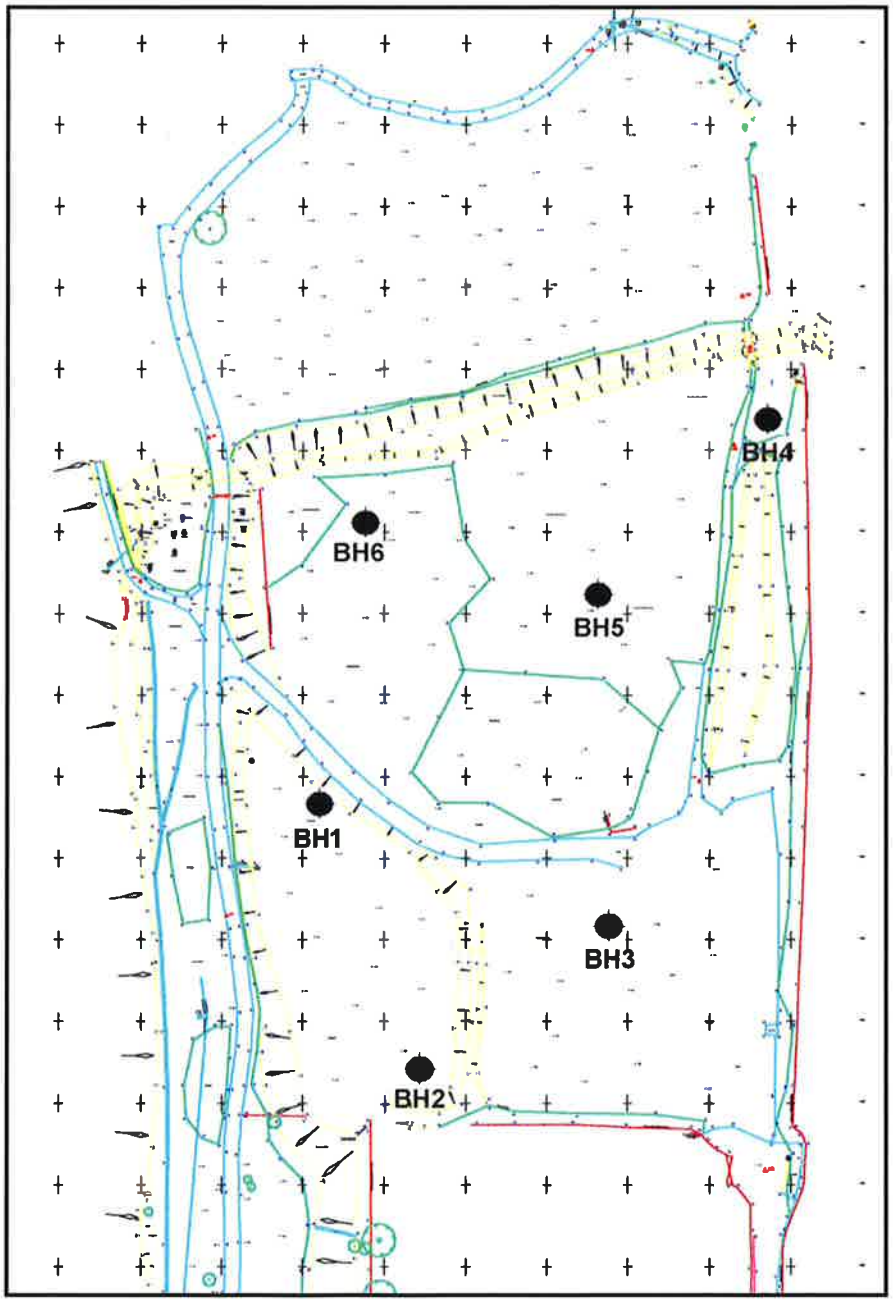


Figure 6.1: Water Monitoring Well Locations

Groundwater and Reen Monitoring (Continued)

The pre-earthworks monitoring round was carried out in July 2015.

The second monitoring round was undertaken in January 2016, and the third followed in February 2016.

All water results were acceptable, displaying no notable variation to the previously established water quality.

The results were presented to the NRW in Letter 25, dated 30th August 2016. A copy of this letter is presented in **Annex K**.

This letter proposed that no further groundwater monitoring was required.

The NRW subsequently agreed that this would be acceptable in an email dated 1st September 2016. A copy of this email may be found in **Annex L**.

SECTION 7 Engineering Recommendations

7.1 Foundation and Floor Slab Solution

Due to the presence of soft clay bands beneath the site traditional shallow foundations are not recommended. Such foundations are likely to lead to high total and differential settlements.

A piled foundation is advised for the proposed residential properties. Precast concrete driven piles founded within the underlying very weak red brown and grey mudstone are recommended. For a 275mm square precast concrete pile driven to an appropriate set within the underlying gravels a safe working load of typically 500kN should be achieved. Based upon the site investigation data, pile lengths should vary between 12m and 15m beneath original ground levels. Following placement of the fill piles lengths will be increase to approximately 14 and 17m below original ground levels.

The estimated working loads, pile type and lengths should be confirmed by a specialist piling contractor. It may be prudent to test drive piles at select locations. For the quoted pile size, founded within the competent gravels, total settlements should not exceed 10mm with differential movements between adjacent piles being less than half this value. Allowances should be made for re-driving piles should buried obstructions be encountered.

A trunk sewer passes beneath the site and the use of precast concrete piles is prohibited along its route. Due to these restrictions all new dwellings to be built along the sewer route are to be founded upon bored piles. The sewer lies at around 25m depth below ground level, within the underlying mudstone. These piles should be bored and installed as specified by the piling contractor.

Floor slabs should be designed as suspended.

Measurements should be kept on pile vibrations during driving. Measures should also be taken to dampen such vibrations. If, however, vibrations exceed permissible values then consideration should be given to using a contiguous flight auger (cfa)/bored pile solution.

Network Rail may also require a bored pile solution close to the railway.

7.2 Protection of Buried Concrete

Laboratory soil chemical analysis undertaken for the Geotechnical and Geo-environmental Report identified concentrations of total sulphate of between 200 and 2500 mg/kg and pH of between 8.2 and 11.8 pH units. Due to an elevated level of total sulphate in TP12 at 0.40m below ground level, sulphate aqueous extract was undertaken. A value of 160 mg/l was recorded.

Sulphate levels in the imported fill range between 400mg/kg and 4100mg/kg., at a pH of between 7.6 and 11.7. Leachate sulphate results ranged between 2mg/l and 51mg/l at a pH of between 6.5 and 10.7.

Based upon the above results we recommend that all buried concrete should conform to Design Class DS-1, ACEC Class AC-1, of BRE Digest 1:2005.

7.3 Compaction of Imported Fill

Fill materials should be placed at or close to, i.e. 95%, of their optimum moisture content/maximum dry density and compacted in layers as per the requirements of the the Department of Transport 'Specification for Highway Works, Series 600'.

Where combinations of different types or categories of plant are used, the depth of the layer should be for the type of plant requiring the least depth of layer, and the number of passes should be that for the type of plant requiring the greatest number of passes.

Earthmoving plants are not recommended for use as compaction plant, nor are lighter categories of plants used to provide preliminary compaction to assist the use of heavier plant.

Any deleterious material, such as timber and plastic, should be removed.

Any roots and tree roots should be excavated and removed.

The stability of excavations or fills should not be compromised by the location of stock piled materials or use of plant or location of temporary buildings/structures.

All earthworks must be kept free of water including arranging for the rapid removal of water, water shed onto the earthworks and water entering the earthworks from any source.

Fill materials especially cohesive (silt and clay) fill should not be deposited and compacted during wet weather, where an increase in moisture content will increase the liquid limit of the soil.

All exposed fill surfaces must be adequately weather proofed during inclement weather or at the end of the working day/compaction process. Any exposed cohesive fill that becomes wet and slurrified due to water ingress or weather erosion must be stripped off, spread into thin layers and aerated. The fill should then be re-compacted.

Plant movement across compaction layers should be restricted to that plant necessary for its deposition, spreading and compaction.

Fill areas should be constructed evenly over their full width and their fullest possible extent and the contractor should control and direct constructional plant and other traffic uniformly over them. Damage by construction plant should be made good with material having the same characteristics and strength as the material had before it was damaged.

Embankments and other areas of unsupported fills should not be constructed with steeper side slopes than the materials effective shear strength, with exception to allowing the adequate compaction at the edges before trimming back, within the minimum period necessary for the safety of the works.

Where fill is to be placed against a natural slope, or sloping earthworks face including embankments, cuttings and other fills and excavations, such faces should be appropriately benched immediately before placing the subsequent fill.

7.3 Compaction of Imported Fill (Continued)

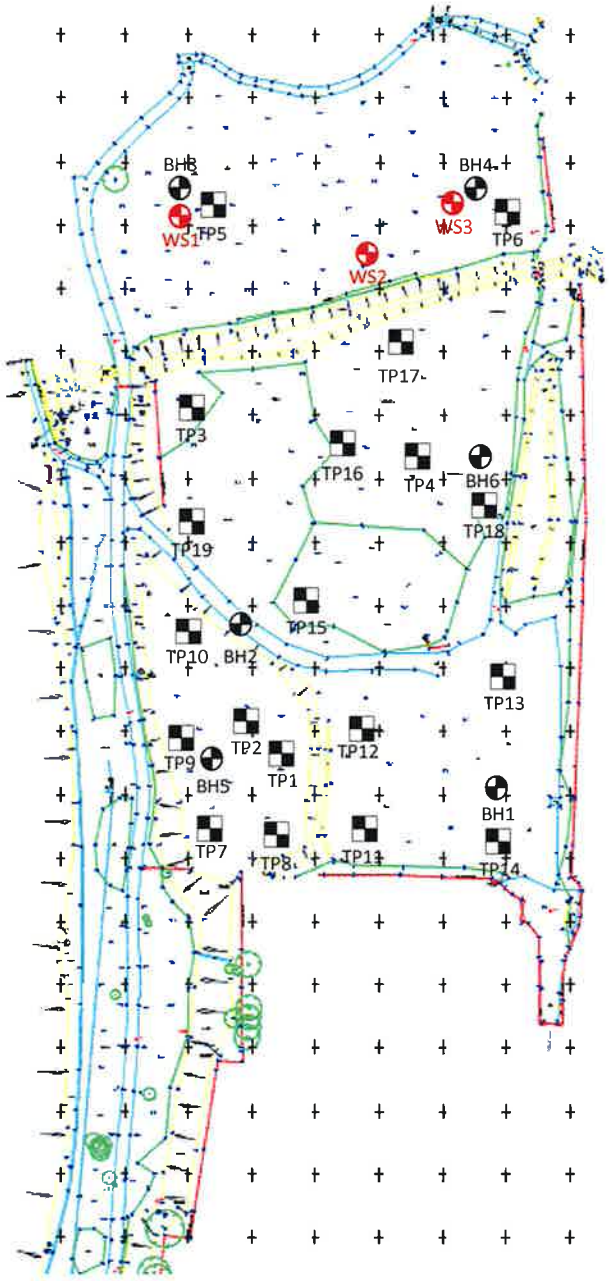
In-situ plate bearing tests and/or density tests (sand replacement method) should be undertaken to ensure the compaction process is performing satisfactory during the enabling works. In-situ testing should be undertaken at an appropriate spacing to reflect the adequacy of the compaction process beneath the entire development area.

The earthworks should be supervised by a suitable engineer.

The tests should be conducted in accordance with BS 1377: Part 9: 1990 under the supervision of a qualified geotechnical engineer.

Should the in-situ testing indicated that the compaction process has been inadequate, the deposited material must be excavated out and re-laid.

Allowances should be made for the removal of soft spots and their replacement with imported suitable selected inert granular materials or suitable inert site won materials.

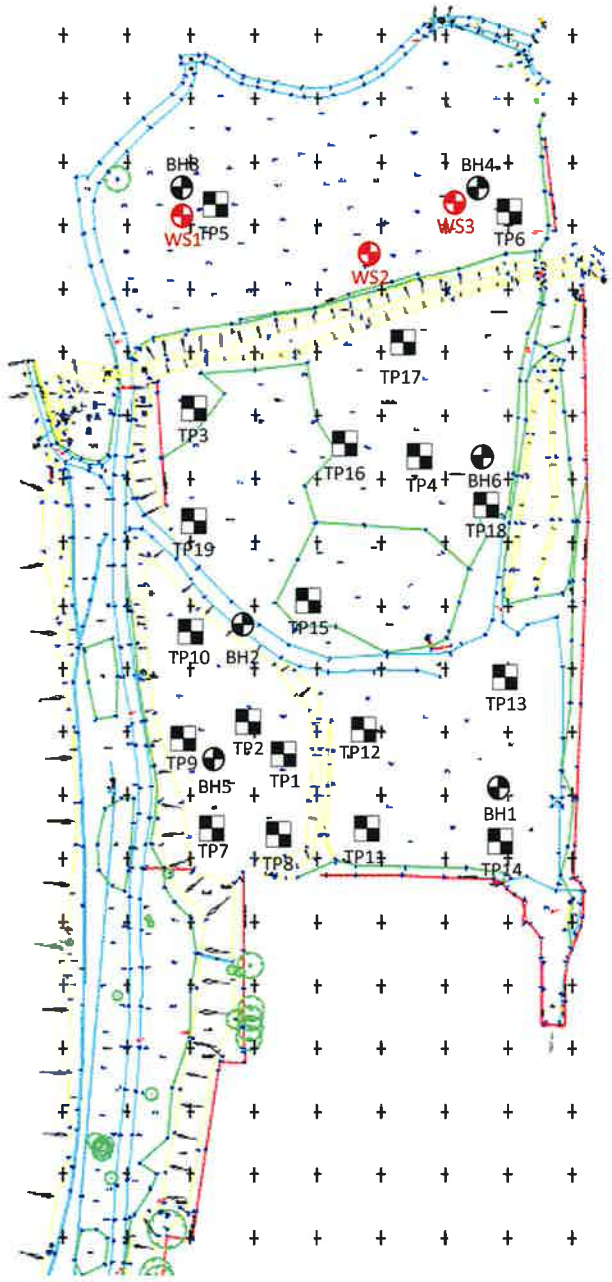


terrafirma

Job Number:	12032
Job Title:	Land off Herbert Road, Newport
Drawing Title:	Current Site Layout
Drawing Number:	02
Scale:	Not To Scale

Legend:

- Trial Pit Location
- Cable Percussive Borehole
- Windowless Sample Borehole



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