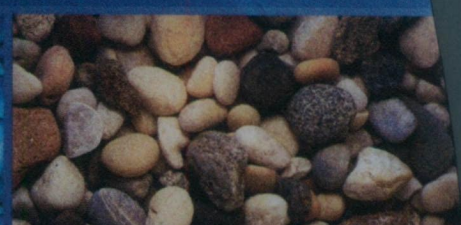




Tonkin & Taylor

ENVIRONMENTAL AND ENGINEERING CONSULTANTS



REPORT 7535

Watercare Services Ltd

**Huia Water Treatment Plant Rebuild
Geotechnical Investigation and
Assessment**

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1 Introduction

Tonkin & Taylor Ltd (T&T) were engaged by Watercare Services Ltd (Watercare) to carry out a geotechnical investigation to support the proposed rebuild of the Huia Water Treatment Plant in Waima, West Auckland.

We understand that Watercare are planning a significant upgrade of the Huia Water Treatment Plant, with the majority of the infrastructure replacement to take place over the next five years (upgrade options presented in Appendix A). Given that this plant provides a significant percentage of the Auckland Regions water supply, the risk of ground deformation due to settlement or slope instability needs to be assessed.

T&T have previously presented a preliminary assessment of the expected ground conditions and geotechnical design considerations in a previous report titled *Huia Water Treatment Plant Rebuild - Preliminary Geotechnical Assessment* [Ref 2]. This assessment was based on an archive search by Tower Foundations Ltd [Ref 1], which collects all the pre-existing geotechnical investigation data since it's the sites construction beginning in the 1920's. Our preliminary assessment highlighted the need for further investigation to better understand potential for ground movements and to detail the groundwater model.

Our present scope of work, as outlined in our proposal dated 26 March 2010, addresses these needs and includes:

- Ground investigation comprising
 - Engineering geological mapping focussing on geomorphic evidence of slope instability of the site and near surrounds.
 - 4 machine drilled boreholes to a maximum depth of 25 m positioned within the perimeter of the existing plant.
 - 3-4 machine drilled boreholes to a maximum depth of 25 m located in the bushland north of Woodlands Park Road.
 - One day of CPT probing with pore pressure dissipation testing.
 - Standpipe piezometer installation in each borehole.
 - Installation of 3-4 groundwater pressure transducers (divers) to automate daily ground water monitoring.
 - Sampling for laboratory testing.
- Laboratory testing comprising
 - 6 soil triaxial tests for strength data on colluvium and weathered Cornwallis Formation
 - 6 consolidation tests to assess settlement parameters for design
- Update the existing geological model
- Assess the geotechnical material strengths and parameters for design
- Re-assess slope stability utilising update models and design parameters
- Provide options for suitable foundations systems and foundation design parameters
- Provide a geotechnical report addressing all of the above

2 T&T April - May 2010 Site Investigation

2.1 General

The Huia Water Treatment Plant has been subject to a range of different sub-surface site investigation with the oldest available data stretching back to the mid 1980's.

Tower Foundations Ltd collected all available site investigation historical data and presented them in their report titled *Huia Water Treatment Plant – Review of Historical Geotechnical Information* [Ref 1].

T&T reviewed this information in our previous preliminary report [Ref 2] and highlighted the need for further site investigation in order to address uncertainties regarding the local groundwater regime, potential for the presence of a continuous low angle shear surface and consolidation settlements.

2.2 Site Investigation Details

On 14 April 2010 T&T began the site investigation works at the Huia Water Treatment Plant and completed it on 7 May 2010.

The site investigation consisted of

- 8 machine drilled boreholes with core sampling and push tubes for laboratory testing
- Installation of standpipe piezometers and borehole groundwater pressure transducers (Divers) which automate recording of groundwater pressures
- Laboratory testing (completed on 31 May 2010)
- 4 hand augured boreholes with hand Shear Vane testing along the south-western bank of the lagoons. The Client requested these boreholes outside the scope of the this report
- Walk over survey to map exposed geology
- Aerial photo interpretation of historical aerial photos

CPT testing was not carried out because we perceived that the risk of damaging underground services was too high and access was limited.

2.2.1 Machine Drilled Boreholes

Five boreholes were drilled within the treatment plant and three in the bush area north of Woodlands Park Road. The following Table 1 provides details of the boreholes and their locations are shown in Drawing 27064.001-01. Borehole logs and core photos are attached in Appendix B.

Table 1 – Summary of machine drilled boreholes

Borehole	Location	Final Depth	Installation	Sampling
BH 1	Garden shed	24.75 m	Nested piezometers	2 push tubes
BH 2	Sludge thickener tank	21.00 m	Nested piezometers	1 push tube
BH 3	Washwater thickener	24.85 m	Nested piezometers	No sampling ¹
BH 4	Lagoon	24.00 m	Single piezometer	3 push tubes 1 core sample
BH 4A	In front of BH 4 opposite service road	0.9 m	Hole abandoned because underground services were encountered	
BH 5	Water tank	18.85 m	Nested piezometers	1 push tube
BH 6	Spillway	22.50 m	Nested piezometers	4 push tubes 1 push tube for fill 2 core samples for fill 3 core samples
BH 7	Bush – side of creek	15.00 m	Nested piezometers	No sampling ²
BH 8	North of raw water aqueduct	22.50 m	Nested piezometers	1 push tube

¹ Frequent and sharp variation in ground strength prevented obtaining suitable samples

² Unexpected limited thickness of Colluvium and absence of CW-HW Cornwallis Formation prevented obtaining suitable samples

Fill was found in the southern area of the site, overlying Colluvium deposits. The Cornwallis Formation is present underneath the Colluvium or at surface towards the east, ranging from completely weathered to moderately/slightly weathered at depth. Coarse sandstone interbedded with conglomerate layers was found across the whole site. Table 2 below summarises the geological units encountered during drilling and these are described further in Section 3.

Table 2 – Summary of geological units encountered during 2010 T&T drilling campaign

Unit	Depth of top-bottom of Geological Units (m b.g.l.)							
	BH 1	BH 2	BH 3	BH 4-4A	BH 5	BH 6	BH 7	BH 8
Fill	0.0-4.5			0.0-1.0	0.0-1.5	0.0-2.0		
Colluvium	4.5-8.0	0.0-3.8		1.0-5.0	1.5-4.5	2.0-3.8	0.0-3.0	0.0-6.6
CW-HW Cornwallis	8.0-14.3	3.8-18.0	0.0-1.0	5.0-16.0		3.8-12.0		6.6-18.5
MW (softened) Cornwallis	14.3-20.5	18.0-EoB	1.0-19.0	16.0-18.0	4.5-15.8	12.0-EoB	3.0-10.0	18.5-20.5
MW-SW Cornwallis	20.5-EoB		19.0-EoB	18.0-EoB	15.8-EoB		10.0-EoB	20.5-EoB

We note that apparent asbestos containing material was identified in the fill in BH 4A. The presence of this hazardous substance should be taken into account when planning and undertaking earthworks in that area and the extent of this material may need to be confirmed by a geo-environmental investigation if this area is to be disturbed during the re-build.

2.2.2 Groundwater Monitoring

Standpipe piezometers were installed in each machine drilled borehole. Three divers were also installed for continuous hourly recording of groundwater levels and these are scheduled to remain in place for 12 Months to give an indication of the seasonal variation in groundwater levels. Summary of piezometers installations are presented in Appendix C.

Groundwater levels were measured during drilling and are reported in the borehole logs. Table 4 below summarises the groundwater levels measured with a dipmeter on 02 June 2010. On the same day data from 3 divers were downloaded and the data are presented in Appendix C.

It should be noted that during drilling a thick (1.5m-2m) bed of jointed conglomerate was encountered in boreholes BH5, BH7 and BH8. When encountered at depth (typically below 11m) the drillers immediately reported 100% loss of their drilling fluid, which, when the drilling rig was idling, could be observed rapidly dropping down the borehole.

Table 3 – Summary of groundwater readings

Borehole	Piezometer	Material	Groundwater depth from ground level	Approx Groundwater Elevation (m RL)	Pressure head (m above piezo tip)
BH 1	Piezometer 1	CW-HW Cornwallis	7.56 m	101.64 m	3.44m
	Piezometer 2	MW-SW Cornwallis	8.64 m	100.56 m	16.36m
BH 2	Piezometer 1	CW-HW Cornwallis	5.85 m	109.15 m	3.65m
	Piezometer 2	MW-SW Cornwallis	11.10 m	103.90 m	9.9m
BH 3	Piezometer 1	Softened Cornwallis	4.37 m	104.91 m	3.63m
	Piezometer 2	MW-SW Cornwallis	5.12 m	104.16 m	19.73m
BH 4	Piezometer 1	CW-HW Cornwallis	4.30 m	104.04 m	6.7m
BH 5	Piezometer 1	CW-HW Cornwallis	6.60 m	114.40 m	1.4m
	Piezometer 2	MW-SW Cornwallis	11.10 m	109.90 m	7.75m
BH 6	Piezometer 1	CW-HW Cornwallis	8.28 m	98.47 m	4.72m
	Piezometer 2	Softened Cornwallis	9.12 m	97.63 m	13.32m
BH 7	Piezometer 1	Softened Cornwallis	9.55 m	110.95 m	0.95m
	Piezometer 2	MW-SW Cornwallis	9.55 m	110.95 m	5.45m
BH 8	Piezometer 1	Colluvium	Dry	Dry	0.0m
	Piezometer 2	Softened Cornwallis	15.10 m	108.90 m	5.4m

2.2.3 Sampling and Laboratory Testing

Undisturbed push tube samples and partly undisturbed core samples from triple tube barrel were collected during drilling. A total of 19 samples (13 push tubes and 6 core samples) were collected. The following Table 4 summarised the sample campaign and laboratory testing scheduling.

Table 4 – Summary of sampling and laboratory testing

Borehole	Sample	Depth	Type	Material	Test scheduled
BH 1	PT 1	6.0-6.5 m	Push tube	CW-HW Cornwallis Frm	Triaxial CUP
BH 1	PT 2	9.0-9.5 m	Push tube	CW-HW Cornwallis Frm	Triaxial CUP
BH 2	PT 1	3.0-3.5 m	Push tube	Colluvium	Consolidation
BH 4	PT 1	2.0-3.0 m	Push tube	Colluvium	Triaxial CUP
BH 4	PT 2	4.5-5.0 m	Push tube	Colluvium	Consolidation
BH 4	DS 1	6.85-7.10 m	Core sample	CW-HW Cornwallis Frm	Not scheduled ⁽¹⁾
BH 4	PT 3	7.5-8.0 m	Push tube	CW-HW Cornwallis Frm	Consolidation
BH 5	PT 1	2.5-3.0 m	Push tube	Colluvium	Consolidation
BH 6	S 1	0.75-0.85 m	Core sample	Fill	Not scheduled ⁽²⁾
BH 6	PT 1	0.85-1.35 m	Push tube	Fill	Not scheduled ⁽²⁾
BH 6	S 2	1.60-1.70 m	Core sample	Fill	Not scheduled ⁽²⁾
BH 6	PT 2	2.25-2.75 m	Push tube	Colluvium	Consolidation
BH 6	PT 3	3.0-3.5 m	Push tube	Colluvium	Triaxial CUP
BH 6	PT 4	4.5-5.0 m	Push tube	CW-HW Cornwallis Frm	Triaxial CUP
BH 6	SS 1	5.40-5.55 m	Core sample	Shear surface	Not scheduled ⁽³⁾
BH 6	PT 5	6.5-7.0 m	Push tube	CW-HW Cornwallis Frm	Consolidation
BH 6	SS 2	3.95-3.05 m	Core sample	Shear surface	Triaxial CUP
BH 6	SS 3	8.40-8.55 m	Core sample	Shear surface	Triaxial CUP
BH 8	PT 1	2.0-2.3 m	Push tube	Colluvium	Triaxial CUP

1. Sample unsuitable for testing

2. Requested by Watercare Ltd. for possible future testing beyond the scope of this report

3. Sample damaged, unsuitable for testing

Multistage Consolidated Undrained Triaxial Compression Tests have been undertaken according to BS1377:1990-Part 8. One-dimensional consolidation tests were carried out according to NZS4402:1986. Laboratory test results are presented in Appendix D.

2.2.4 Walk Over Survey

On 6 May 2010 a T&T engineering geologist carried out a walk over survey at two locations in the area surrounding the treatment plant

- Along the creek at Armstrong Gully where the Cornwallis Formation outcrops.
- Along Exhibition Drive (an unsealed Watercare access road) to the north of Woodlands Park Road where the Nihotupu Formation outcrops.

The walk over survey focused on identifying and measuring the bedding and defects within the rock mass and evidence of slope instability.

2.2.4.1 Rock Outcrop in Armstrong Gulley

Highly weathered Cornwallis Formation outcrops along the bed of creek. This comprises grey silty fine grained SANDSTONE extremely weak, bedded, weathering to orange brown.

The bedding is variable from 18°/280° (dip/dip direction) close to the road to 10°/300° towards the waterfall. This unit appears to be locally thinly bedded, with layer thickness varying from 20-50 mm to 300 mm.

Two sets of sub-vertical defects were identified dipping towards 200° and 120°. These appear to be stress relief defects and were observed to terminate on bedding partings.

2.2.4.2 Rock Outcrop on Exhibition Drive

Exposures of Nihotupu Formation are clearly visible along the up-slope cuttings. The Nihotupu Formation consists of reddish to dark brown, medium grained, very weak, volcanoclastic SANDSTONE.

The bedding appears to be relatively constant dipping at 10°/010°, which accounts for the overall performance of this material in the near vertical cut slopes on the North side of Exhibition Drive. The thickness of the layers is variable from a few centimetres to more than 1 m.

Two main sets of defects are present dipping approximately 88°/200° and 70°/270°, the former being highly persistent and controlling the localised toppling instability observed in places along the road cuttings.

2.2.5 Hand Augured Boreholes

In order to assess the shear strength of the fill at the south-western side of the lagoon, 4 hand-augured boreholes with hand held Shear Vanes were undertaken on 5 May 2010. The hand augured were push to either refusal or to a maximum depth of 2 m bgl, which is the typical thickness of the fill identified in BH 6. Shear Vane testing was carried as the auger holes were advanced at 0.5 m intervals.

The following Table 6 summarises the data of the hand augured boreholes and their location is shown in Drawing 27064-001.01.

Table 5 – Summary of hand augured boreholes

Borehole	Depth	Hand Held Shear Vane Strength (kPa, peak/residual)			
		0.5 m bgl	1.0 m bgl	1.5 m bgl	2.0 m bgl
HA 1	2.0 m	108/46	77/18	65/28	83/55
HA 2	2.0 m	123/31	77/28	62/31	83/62
HA 3*	1.0 m	UTP	UTP		
HA 4	2.0 m	UTP	114/40	123/65	95/28

* Ended at 0.4 m bgl on gravel layer. Further attempts aborted on same gravel layer

2.2.6 Aerial Photo Interpretation

As part of our assessment of geotechnical slope stability of the site an aerial photo interpretation was carried out on a pair of stereo photographs dated November 1961 at an average scale of 1:16,000.

From the aerial photo interpretation it appears that the treatment plant is located in the northern part of a wider depression defined by ridges and a large escarpment. Secondary ridges are present within the depression with a sub-parallel trend, defining the catchment into four main steeply incised gullies (one of these is Armstrong Gulley). These gullies are sub-parallel each other and show sharp changes of direction which we consider is likely to be indicative of structural control (faulting). The geomorphology of the area suggests that the depression is probably tectonic generated.

The aerial photographic interpretation indicates no evidence of deep seated or shallow instability in the area, beyond the escarpment that encompasses the entirety of the Waima catchment. This is discussed further in Section 3.4 below.

3 Ground Conditions

3.1 Geotechnical Units

Our previous geological model [Ref 2] has been updated to include a zone of softened (or moderately weathered) Cornwallis Formation sandstone as well as incorporating new strength testing data and revised unit thicknesses. In summary the site is underlain by the following geotechnical units.

3.1.1 Fill

Fill material was encountered in the south of the site (BH 1, BH 4, BH 5 and BH 6) and forms the bank of the lagoon with a thickness of up to 4.5 m to the west of the site and 2.0 m at the lagoon. It comprises reworked site-won materials, mainly yellow brown to grey brown clayey or sandy silts with some coarse sand. The base of the unit becomes organic rich and fibrous indicating stripping of the original ground surface prior to placement was of poor quality or not carried out at all.

From historical data, the fill is firm to stiff in strength with SPT testing ranging between 0 to 10 blows/300 mm and undrained shear strengths ranging from 29/15 kPa to 130/41 kPa (peak/residual) [Ref 1 & 2].

It is apparent from the testing data that some of the historical consolidated undrained triaxial tests have been conducted in fill material, while in some cases it is not apparent whether the test results are within fill or colluvial soils. For the purposes of the stability analyses that follow these two units have been modelled as one.

3.1.2 Colluvium

Apart from BH 3, all boreholes encountered a layer of colluvial deposits of thickness varying from 2.0 m to 6.6 m, with the maximum thickness encountered to the north and west of the site.

The colluvium comprises sandy silts and sands (fine to coarse) reworked from the underlying Cornwallis Formation to the south of Woodlands Park Road and possibly from the Nihotupu Formation at the north of Woodlands Park Road. The colluvium is typically light grey brown orange mottled with rare carbonaceous inclusions.

From historical data the SPT N values vary from 3 to 11 blows for 300 mm [Ref 1 & 2]. Analysis of Triaxial test results from this study and from historical data (P-Q plot in Appendix D) indicates Mohr-Coulomb parameters of $c' = 2$ kPa and $\phi' = 30^\circ$ for the colluvium material.

3.1.3 Completely/Highly Weathered Cornwallis Formation

This material is similar to the colluvium but with a more structured appearance with relict defects and bedding planes visible. This unit consists of fine to coarse sand and silt with fine to medium grained rounded gravel in discrete beds. Typically it is dark orange to brown. The thickness of this unit is variable across the site.

From historical data the SPT N values vary from 15 to 30 blows for 300 mm but values above 50 were recorded [Ref 1 & 2]. Triaxial test results from this study and from historical data (P-Q plot in Appendix D) indicate Mohr-Coulomb parameters of $c' = 8$ kPa and $\phi' = 28^\circ$ would be appropriate for the CH-HW Cornwallis Formation.

3.1.4 Moderately Weathered Softened Cornwallis Formation

All boreholes encountered this unit which has a thickness that varies from 2 m to 18 m with an average of 10 m. It consists of greenish grey and pink speckled fine to medium (locally coarse) grained silty sand and fine to medium sub-rounded gravel. It is characterised by alternating poorly cemented and well cemented beds.

From historical data the SPT N values vary from 25 to 45 blows for 300 mm [Ref 1 & 2]. Mohr Coulomb parameters for this material have been assessed at $c' = 5$ kPa and $\phi' = 35^\circ$ on the basis of the available SPT data and our field observations.

3.1.5 Slightly Weathered Cornwallis Formation

The rock mass comprises fine to medium grained sandstone with layers of medium grained conglomerate and thin laminations of siltstone. The colour is typically greenish grey with pink and white speckling. The rock is typically very weak to weak, with the conglomerate often closer to the upper end of this range.

The SPT N values typically exceed 50 blows/300 mm [Ref 1 & 2]. For the purposes of our stability modelling this unit has been modelled as bedrock.

3.2 Geological structure

Our walk over mapping showed that the general trend of the Cornwallis Formation is for bedding to dip at 5-10° towards the north-west (based on rock outcrops in Armstrong Gully and Exhibition Drive). The dip magnitude is also evident in borehole core where bedding is apparent in the weathered and unweathered rock mass (although dip direction can not be ascertained from vertical boreholes).

In the rock mass jointing is typically very steeply inclined to sub-vertical, with variable spacing, as confirmed from the outcrops in Armstrong Gully. The joint surfaces are typically clean within the unweathered material or with a silt/clay coating in the weathered material.

Some defects which exhibit evidence of shearing (polished and slickensided surfaces) were encountered at different locations within the borehole core. Some of the defects were bedding, being inclined at 5° to 15°, while other joints of 30° and 45° were also observed.

Brown, soft, plastic clay seams were identified in boreholes BH 6 and BH8 and in historical Beca boreholes BBH 4 and BBH 6. These seams were encountered within the colluvium and completely weathered Cornwallis Formation.

Some gravel-conglomerate layers were identified during drilling. By comparing depths of interception in borehole core and utilising structural contouring based on local bedding orientation it has been possible to correlate these conglomerate beds in the sub-surface profile. This correlation is not possible in the eastern part of the site adjacent to the sludge lagoons and the old gully alignment through this area. These conglomerate beds can be traced into the completely weathered Cornwallis Formation indicating little significant movement at depth has occurred at the site.

3.3 Groundwater

Casagrande type piezometers were installed during the 2010 site investigation and have been read manually. In three boreholes groundwater pressure transducers (divers) with data loggers have been lowered down the Casagrande piezometer to automatically monitor groundwater pressure. Groundwater levels are shown in Table 3 above and plots from diver data are presented in Appendix C. The gravel/conglomerate layers present a high primary and secondary permeability

and are expected to underdrain parts of the site where they are found at moderate depths (10-15m).

The groundwater data from shallow piezometers indicates groundwater levels of around 110m RL in the upper slopes (North), reducing to around 98-100m RL on the lower slopes (South).

We note that the groundwater levels within the underlying SW Cornwallis Formation are only 1m to 1.5m lower than those recorded in the shallow piezometers. This translates to a significant groundwater pressure in these deeper piezometers (10-15m of pressure head) although this is predominantly the case only in those boreholes within the Treatment Plant compound.

For boreholes BH2, BH5, BH7 and BH8, significantly reduced piezometric heads are recorded in the deeper piezometers (5.5m to 10m head). This is broadly consistent with the location of a jointed conglomerate bed which occurs in all four boreholes and appears to provide some underdrainage in these areas.

For the purposes of the slope stability modelling we have taken the conservative case of a single piezometric surface coincident with the groundwater levels observed in the shallow boreholes and applied this to the entirety of the site.

3.4 Interpreted Geological Model

Our updated geological model for the site is illustrated in cross sections 27064.001-02 to 04. In summary the site is covered by an upper layer of colluvium, 3m to 7 m thick, overlain by up to 4.5 m of fill in places, being thickest in the southern part of the site.

The completely to highly (CW-HW) Cornwallis Formation underlies the colluvial deposits and is about 10 m thick. Its thickness appears to increase northwards.

Up to 18 m of softened moderately weathered (MW) Cornwallis Formation is found underneath the CW-HW layer. The average thickness is about 8-10 m. This unit is characterised by alternated poorly cemented sand and cemented sandstone.

The lowermost unit consists of moderately weathered to slightly weathered Cornwallis Formation sandstone.

The shear surfaces identified in borehole core have either been on jointing, which is intersecting core at 30-45° or along bedding which is known (from surface outcrop) to dip into the slope at 10-15°. These shear surfaces are apparent in some boreholes and not in others and can neither be traced along bedding with any continuity nor along the contact between the soil materials (colluvium and Cornwallis Formation) and the underlying rock mass.

Additionally, the conglomerate layers that can be correlated between boreholes (as discussed in Section 3.2 above) can also be traced into the highly weathered zone, and indicate significant continuity of lithology in the sub-surface (i.e. no historical slope instability extending into the Cornwallis Formation).

The escarpment that encircles the upper part of the Little Muddy Creek catchment has been identified historically as potentially being a head scarp of large scale catchment wide slope instability [refer Ref 2]. This has been challenged by recent work carried out in reference 3. We consider that the offset of the escarpment is not matched by the depth to Cornwallis Formation rock beneath the site, and we would not expect to find in-situ, Cornwallis Formation Sandstone that has not been deformed in Armstrong Gully. Alternative interpretations for this feature may include fault control, or a large scale erosional feature also been proposed [Ref 3], but we consider that it is not indicative of large scale, catchment wide slope instability.

4 Geotechnical Design Considerations

4.1 Slope Stability

Recommendations and opinions contained in this report are based on data from borehole and geological mapping from our 2010 site investigation, and on historical data collected by others. The nature and continuity of subsoil away from the investigations locations are inferred but it must be appreciated that actual conditions could vary from the assumed model.

4.1.1 General

Over the past 40 years the site has been significantly modified with considerable earthworks and re-levelling of the original topography. Any geomorphic evidence of historical slope instability is expected to have been removed. A discussion of the wider geomorphic regional setting is summarised above and has discounted a catchment wide landslide [Ref 3]. Continuity in bedding and intact rock observed in outcrop near the site support this.

We note that BBH2 drilled by Beca in 2005 was instrumented with an inclinometer to a depth of 39 m to monitor potential deep seated ground movements. Monitoring data are not available for this inclinometer beyond the baseline data reading made soon after installation. Arrangements have been made for further monitoring of this inclinometer, but this data is not presently available.

For design purposes, Watercare has categorised the treatment plant as an importance level 4 structure in accordance with AS/NZS 1170:0 2002. This indicates a seismic event with 1:2,500 annual probability of exceedence. For design, in accordance with AS/NZS 1170:5 2004 a peak ground acceleration of 0.31 g have been calculated and adopted for slope stability design.

4.1.2 Material Strength Parameters

Preliminary material strength parameters provided in our previous report dated January 2010 have been revised in the light of T&T laboratory testing. The material parameters for the geotechnical units described in Section 3.3 are outlined in the following Table 7.

Table 6 – Material strength parameters

Geotechnical Unit	Bulk Density (kN/m ³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
Colluvium/Fill ⁽¹⁾	16.0	2	30
CW-HW Cornwallis Formation ⁽¹⁾	17.5	8	28
Shear Surface ⁽¹⁾⁽⁴⁾	17.5	0	16
MW Softened Cornwallis Formation ⁽²⁾	18.0	5	35
SW Cornwallis Formation ⁽³⁾	20.0	30	38

1. From T&T 2010 Triaxial tests

2. From historical SPT tests

3. Modelled as impenetrable bedrock

4. Not continuous across the site and not included in the SlopeW models

4.1.3 Design Criteria

The following table summarises the design criteria adopted for the site. The criteria were developed from various legislation, codes and guidelines that govern how development on land is to be undertaken.

Crawford and Millar [Ref 4] make reference to an FOS of 1.5 for design conditions and 1.2 for more extreme conditions and these have generally been adopted by Territorial Authorities in New Zealand. However, we note that the recommendations for a FOS of 1.2 under seismic load is considered overly onerous and not generally accepted practice where level of slope movement is generally more relevant than FOS.

Table 7 – Recommended Design Criteria: Slope Stability

Design Groundwater Conditions	Elevated Groundwater Conditions	Seismic Stability
Groundwater conditions expected within design life	Groundwater conditions associated with low probability high intensity rainfall event	0.65 PGA (1:2,500 AEP)
FOS > 1.5	FOS > 1.2	FOS > 1.0#
# = any movement will be negligible (within tolerance of structures)		

The seismic criteria recommended here are based on a very low risk of large scale slope movement following an earthquake. Current practice using semi-empirical methods to estimate ground movements indicate limited or insignificant movements provided the FoS under the selected pseudo-static loading is not less than 1.0 with a seismic load of 0.65 of the design PGA. These criteria should not be applied to slopes that may become mobile due to position at cliff tops or ground at risk to liquefaction. Our assessment of the slopes at the Huia Water treatment plant is that the seismic response is most likely to result in insignificant or limited displacement.

4.1.4 Results of Slope Modelling

Modelling has been undertaken using limit equilibrium methods by means of Geostudio SlopeW 2007 software. Analyses have been carried out according to the geological model described in Section 3 and shown in Drawing 27064.001-02 to 04. Geotechnical parameters have been applied as per Table 6 above.

No continuous shear surface has been introduced in the model as the results of this ground investigation have disproven this analysis case.

We focused our analyses along the eastern slopes (see Drawing 27064.001-04) as they are the steepest and thus are considered to best represent the worst case geometry with respect to slope instability (if occurring). Result outputs from SlopeW are presented in Appendix E.

We have considered three possible analysis cases:

- Case A: Current slope conditions in static and seismic conditions.
- Case B: Current slope conditions varying the groundwater levels (sensitivity analysis) in static conditions.
- Case C: Development Option 1 in static and seismic conditions.

Proposed development Option 2 has not been analysed at this stage. In order to build the flocculation tanks the small hill just north of Woodlands Park Road would need to be excavated to RL 125.5 m. This would require the excavation of about 6 m of ground to be replaced by a concrete structure filled with a maximum of 3 m of water. This is expected to result in a significant

unloading of the slope with a consequent improvement in slope stability expected. However, if Development Option 2 should be preferred, detailed analyses would be required.

Our analyses indicate that generally acceptable levels of stability are expected for the slope in static conditions (FoS > 2). For seismic conditions a minimum factor of safety (FoS) of 1.05 was calculated within the site and 0.97 in the slope below the site (beyond the property boundary). In all seismic assessments FoS values for slip circles that intersect the Huia WTP property boundary were >1.0.

Sensitivity analysis on groundwater levels (Case B) shows acceptable level of stability even in high groundwater conditions. We did not undertake sensitivity analysis on groundwater levels for Development Option 1 because the slope geometry modifications and applied loading have proven to be beneficial for stability when comparing Case A and Case C.

We note that the analysed slip circles are typically localised in nature and confined to steeper portions of the overall slope or within historical fill materials. Given the extent of excavations that may be required for individual structures for either development plan, consideration should be given to assessing temporary excavation stability during the design process.

4.2 Foundations

4.2.1 General

The existing infrastructure has been built in stages from 1926 to 1970's. It is our understanding that the existing structures are on shallow spread foundations. These have performed adequately to date, although discussions with site staff suggest that there is hairline cracking of many of the concrete tanks, including the clarifiers and some ongoing leakage results.

According to records and settlement monitoring carried out at the clarifier [Ref 1], post construction in 1973 the maximum settlement recorded was 39 mm with a maximum differential settlement of 30 mm. These values are within typically accepted design tolerances, however, it is not known when settlement monitoring was initiated in relation to construction and it is possible that a significant magnitude of settlement may have been missed prior to monitoring starting. Additionally, much of the clarifier footprint has been developed within cut (0-1m at SE corner, up to 5-7m of cut in SW corner) and the net loads applied are likely to have been reduced considerably due to the weight of soil removed.

4.2.2 Shallow Foundations

On the basis of historical settlement monitoring and taking into account the general condition of existing structures we expect that structures of similar foundation pressures to those existing should perform adequately with respect to bearing capacity and settlements if constructed on shallow foundations.

For shallow foundations, Ultimate Bearing Capacity, Ultimate Limit State (ULS) and Working Load Design are summarised in the following Table 8 for Colluvium and CW-HW Cornwallis Formation.

Table 8 – Summary of bearing capacity for shallow foundations

Material	Geotechnical Ultimate Bearing Capacity	Ultimate Limit State	Working Load Design
Colluvium	350 kPa	175 kPa	115 kPa
CW-HW Cornwallis Formation	800 kPa	400 kPa	265 kPa

For the same geological units short term bearing capacities (during construction) have also been calculated. Assuming an average undrained shear strength of 100 kPa for both materials [Ref 1 & 2], the geotechnical ultimate short term bearing capacity is 500 kPa and the short term working bearing capacity is 170kPa.

For initial guidance, a preliminary estimate of expected settlements has been made for new structures considering that only the Colluvium deposits and the CW-HW Cornwallis Formation are compressible. The following assumptions have been made:

- 1 m cutting to prepare foundation and even out grade.
- 1 compressible soil unit of 10 m thickness (average thickness of compressible material for the area).
- 1 compressible soil unit of 16 m thickness (maximum thickness of compressible material for the site as identified in BH 1).
- 100 kPa maximum structure surcharge (chlorine contact tanks).
- Surcharge pressure calculated at centre of compressible layer.
- Average $m_v=0.2 \text{ m}^2/\text{MN}$ (no significant difference in m_v for Colluvium and CW Cornwallis formation)

On the basis of these assumptions, the maximum expected settlements are of 100 mm for a 10 m thick compressible unit and 110 mm for a 16 m thick compressible unit. We note that the formula used to estimate the settlements are conservative when compared with actual measured settlements and in many cases only 75% of the predicted settlements actually occurs.

We stress that the settlement figures quoted above are for initial guidance only. If shallow foundation options are favoured, then detailed analyses should be undertaken for each structure at detailed design stage.

It is important to note that pre-consolidation of the soils is expected beneath the footprint of existing structures and this may result in reduced settlements magnitude for those parts of new structures that overlap these areas. However, higher differential settlements would then be expected for new structures built across both the footprint of pre-existing structures and ground that has not been previously loaded. This potential for significant differential settlements will need to be addressed in detailed design, but should be considered in site layout and preliminary design.

We expect that the differential and total settlements may be able to be mitigated using either pre-load or ground improvement techniques for moderately sensitive structures.

We note further that in many cases a flat foundation platform for new structures will need to be developed either by earthworks cut or earthworks fill. In either case the changes in slope geometry need to be taken into account when calculating net loading.

4.2.3 Piled Foundations

Pile foundations allow transferring the load of the structures to stronger and deeper material. This type of foundation may be appropriate if:

- High foundation pressures are expected.
- Structures are to be constructed above very soft soils (parts of the old backfilled sludge lagoons?).
- Differential settlements may compromise the new structures.

For single driven piles founded on top of the Softened MW Cornwallis Formation with minimum embedment of 3 times the pile diameter a geotechnical ultimate end-bearing capacity of 2 MPa can be assumed. Ultimate Limit State Design and Working Load Design end bearing capacities are 1 MPa and 670 kPa respectively. A skin friction of 20 kPa can also be assumed.

5 Conclusions

Tonkin & Taylor was engaged by Watercare Services Ltd to carry out a site investigation and assessment of the geotechnical conditions at the Huia Water Treatment Plant. The plant is due for a significant upgrade in the next 2 to 5 years.

We have carried out a site investigation consisting of 8 machine drilled boreholes with sampling, laboratory testing and groundwater monitoring. We have interpreted and assessed the results of this site investigation campaign and re-assessed all available historical information [Ref 1 & 2]. Our conclusions are as follows:

- The geological model shown in Drawings 27064-02 to 04 has been developed on the basis of all current and historical data. The revised model comprises 4 to 5m of fill mainly in the south part of the site overlying Colluvial deposits up to 7.0 m thick. This in turn overlies up to 12 m of CW-HW Cornwallis Formation. Softened MW Cornwallis Formation is present beneath the CW-HW Cornwallis Formation to a maximum depth of 20.5 m, overlying the SW Cornwallis Formation.
- Continuity of conglomerate beds between boreholes indicates that and historical slope instability is expected to be confined to the uppermost Colluvium unit.
- Some slickensided clay seams and polished surfaces were encountered within the Colluvium and CW-HW Cornwallis Formation. However, these are not traceable between boreholes either at the soil/rock contact or along bedding planes. We have concluded that they do not define a continuous shear surface beneath the site.
- The groundwater data from shallow piezometers indicates groundwater levels of around 110m RL in the upper slopes (North), reducing to around 98-100m RL on the lower slopes (South). Across the Treatment Plant site the water levels recorded within the SW Cornwallis Formation at depth are on average only 1-1.5 m lower than those recorded in the Colluvium. Noticeably, groundwater levels in the SW Cornwallis to the North of Woodlands Park Road are underdrained by a jointed conglomerate bed and considerably reduced groundwater levels are recorded in these areas. For the purpose of design we have considered a (conservative) single piezometric surface coincident with the shallow piezometers water levels.
- Slope stability analyses undertaken on the basis of the defined ground and groundwater model have returned acceptable levels of stability for static (FoS > 1.5), elevated groundwater (FoS > 1.2) and a 1:2,500 AEP seismic event (FoS > 1.0).
- Slope stability analyses were undertaken to identify possible reductions in stability for the proposed development options. For the purposes of this reporting Development Option 1 was analysed and found to improve the factor of safety for the analysed section. Development Option 2 has not been analysed to date, but the geometry of the proposed earthworks suggests that it should be beneficial or at least neutral with respect to impacts on the existing level of slope stability.
- Shallow foundations are considered suitable for the site.
 - Settlements of 75-100mm may need to be designed for depending on the extent of slope cut required to develop a foundation platform. Differential settlements need to be considered based on extent of proposed cut and extent of pre-consolidated ground associated with previously developed parts of the site.
 - Alternative options to address settlements may include pre-loading of those parts of the site that have not previously been subject to structure loadings. This may or may not be feasible within the construction staging whilst still maintaining operations.

- Depending on the depth of earthworks cut required to develop foundation platforms, the effect on net loading may be such that settlements can be minimised. However, where the building platform cut varies in depth, differential settlements should be expected.
- Driven Pile foundations are expected to be suitable for the site, end bearing in the MW Cornwallis Formation Sandstone present at approx 15m below ground surface to the west and south of the site (BH1, BH2, BH4, BH6, BH8) and as shallow as 5m in the north and west of the site (BH3, BH5 and BH7).

6 Applicability

This report has been prepared for the benefit of Watercare Services Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Part of the information used in this report has been collated by others and has been used in good faith. While every attempt has been made to verify the data, we cannot guarantee the accuracy of data supplied by other parties.

During excavation and construction the site should be examined by an engineer or engineering geologist competent to judge whether the exposed subsoils are compatible with the inferred conditions on which this report has been based. We would be pleased to provide this service to you and believe your project would benefit from such continuity. However, it is important that we be contacted if there is any variation in subsoil conditions from those described in the report.

Tonkin & Taylor Ltd


Environmental and Engineering Consultants

Report prepared by:

Authorised for Tonkin & Taylor by:



.....
Cameron Lines
Senior Engineering Geologist



.....
Chris Bauld
Project Director

With assistance from S. Mosconi

CJL

4-001stmm20101001FINAL.rpt.doc

7 References

- i. Tower Foundations Ltd, *Huia Water Treatment Plant – Review of Historical Geotechnical Information*, Ref JN004/08 Report 5330 and 5331, October 2008
- ii. Tonkin & Taylor, *Huia Water Treatment Plant Rebuild Preliminary Geotechnical Assessment*, Ref 27064, January 2010
- iii. Tower Foundations Ltd – *Titirangi No. 3 Reservoir Geotechnical Report*, Ref JN005/08 Report 5336, October 2008.
- iv. Crawford, S. A., and Millar, P.J., 1999; *The design of permanent slopes for residential development*, Proceedings 8th Australia New Zealand Conference on Geomechanics, Hobart.

Drawings

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- NOTES :
1. All dimensions are in metres unless noted otherwise.
 2. Existing contours from WSL survey. Drawings E3X144 dated 10.10.05, E3X122 dated 08.04.04, E3X123 dated 04.05.04, E3X130 date 15.06.04 and E3X132 dated 23.06.04.
 3. Borehole positions from GHD report No. 2585 dated september 2002, BECA - Fig 1 dated 17.11.05 and Tonkin & Taylor Ltd report dated October 2005.

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DRAWN :	LJD	Jun. 10
DESIGN CHECKED :		
DRAFTING CHECKED :		

REFERENCE :

CADFILE : \\27064.001-01.dwg

APPROVED :

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

HUIA WATER TREATMENT PLANT INVESTIGATION PROPOSED INFRASTRUCTURE UPGRADE T&T 2010 Site Investigation Location Plan

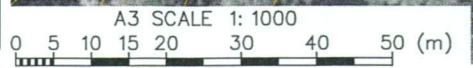
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AS SHOWN

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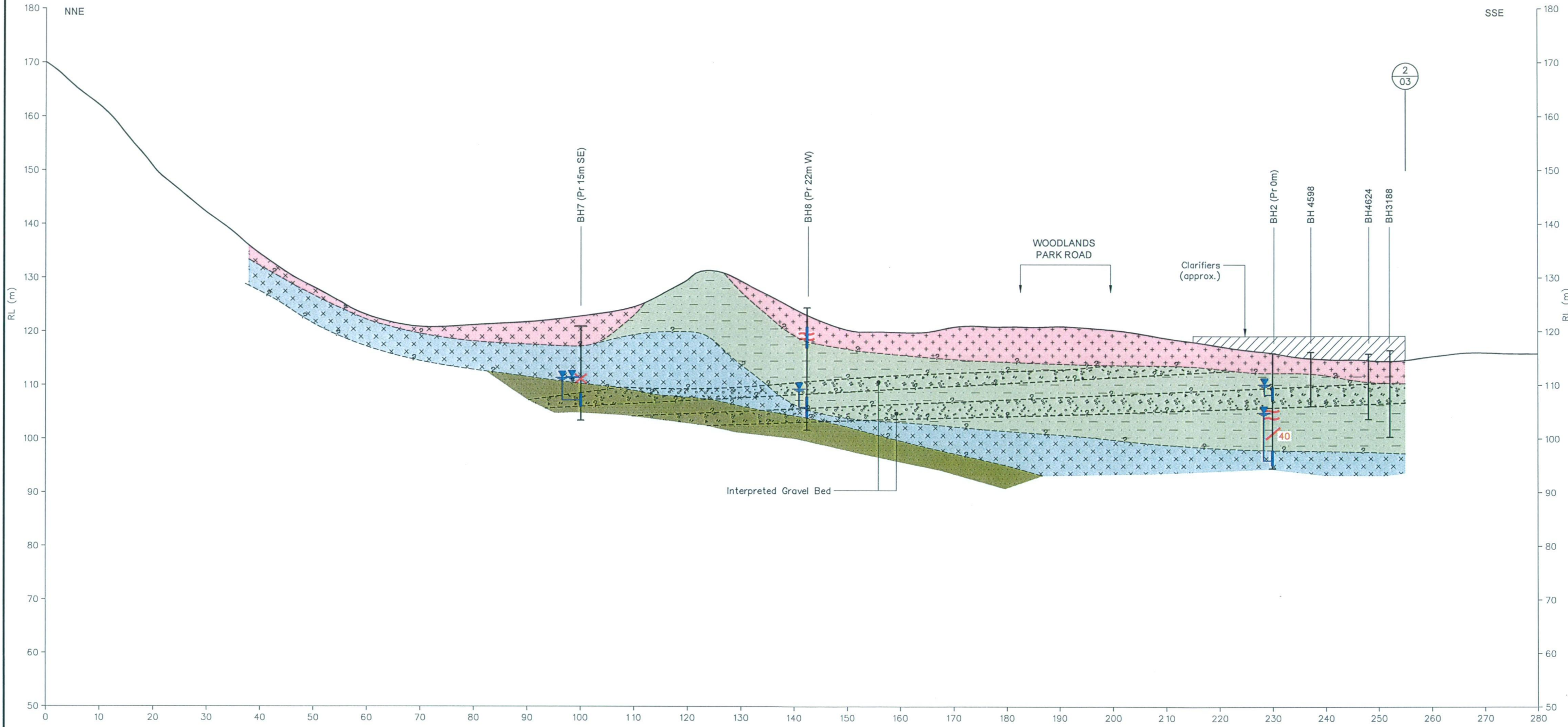
REV. 0

LEGEND

-  BH 1 Tankin & Taylor Ltd Borehole & Handauger Locations (2010)
-  ARA Circa 1984-1988
-  Tonkin & Taylor (2005)
-  Beca
-  Tower Foundations 2008
-  Harrison Grierson 2008



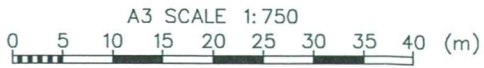
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	Colluvium		Polished surface not following bedding (inclination from horizontal shown)
	CW - HW Cornwallis Formation		Polished surface unknown orientation
	HW Cornwallis Formation		Piezometer
	SW Cornwallis Formation		

SECTION 1
SCALE 1:750



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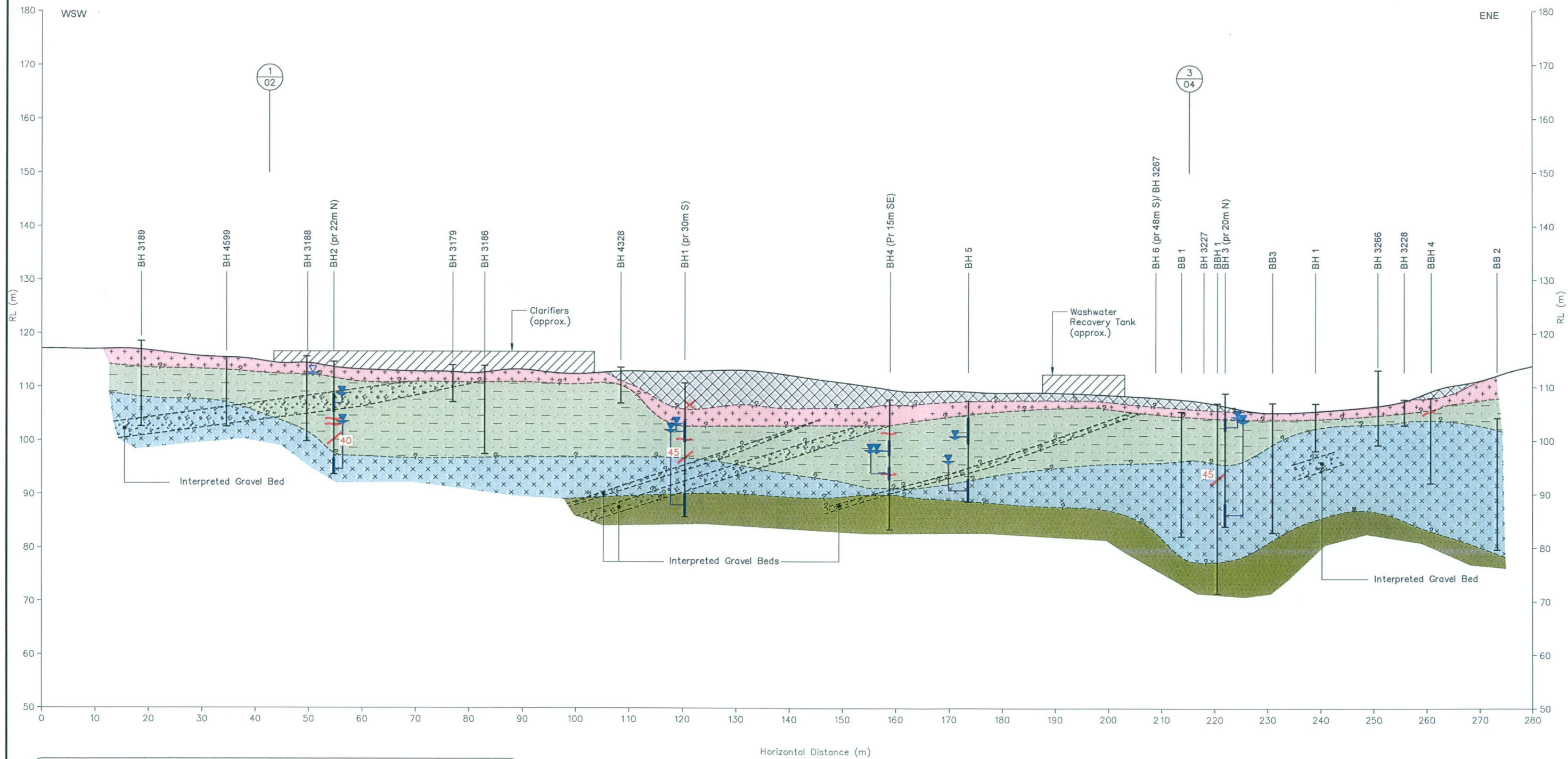
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REVISION DESCRIPTION	BY	DATE
0 First Issue		

NOTES :

- All dimensions are in millimetres unless noted otherwise.

REFERENCE :

DRAWING STATUS: PRELIMINARY DRAFT		
CLIENT, PROJECT		
WATERCARE SERVICES LTD		
HUIA WATER TREATMENT PLANT INVESTIGATION		
TITLE		
PROPOSED INFRASTRUCTURE UPGRADE		
Geological Cross Section 1		
SCALES (AT A3 SIZE)	DWG. No.	REV.
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	HW Cornwallis Formation		Piezometer
	SW Cornwallis Formation		

SECTION 2
SCALE 1:750



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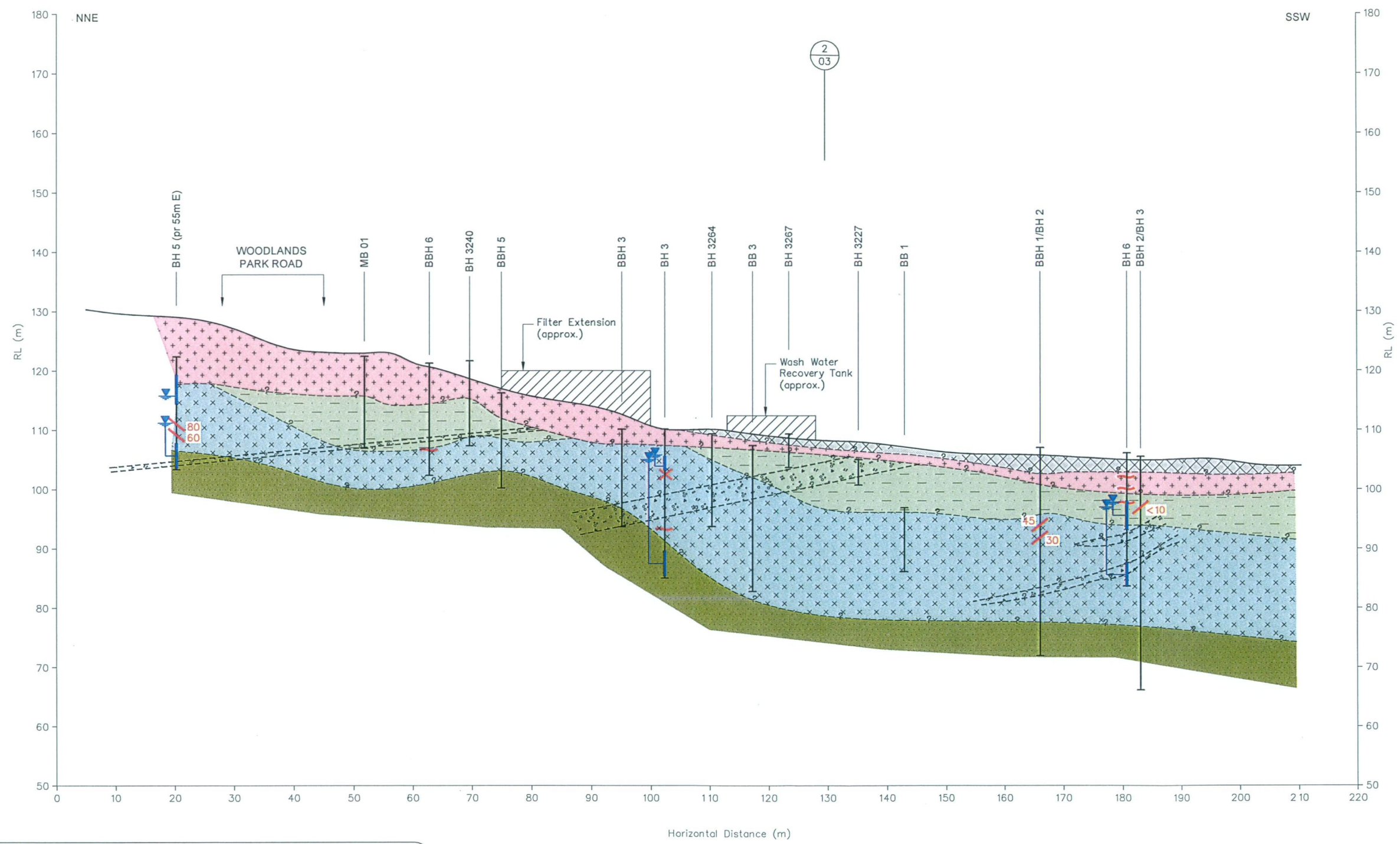
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TITLE	PROPOSED INFRASTRUCTURE UPGRADE Geological Cross Section 2	
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DRAFTING CHECKED :		
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NOTES :

- All dimensions are in millimetres unless noted otherwise.

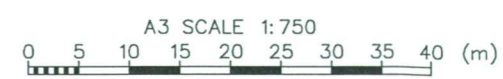
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	Colluvium		Polished surface not following bedding (inclination from horizontal shown)
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	HW Cornwallis Formation		Piezometer
	SW Cornwallis Formation		

SECTION 3
SCALE 1:750



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DRAWN :	AGI	Jul. 10
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- All dimensions are in millimetres unless noted otherwise.

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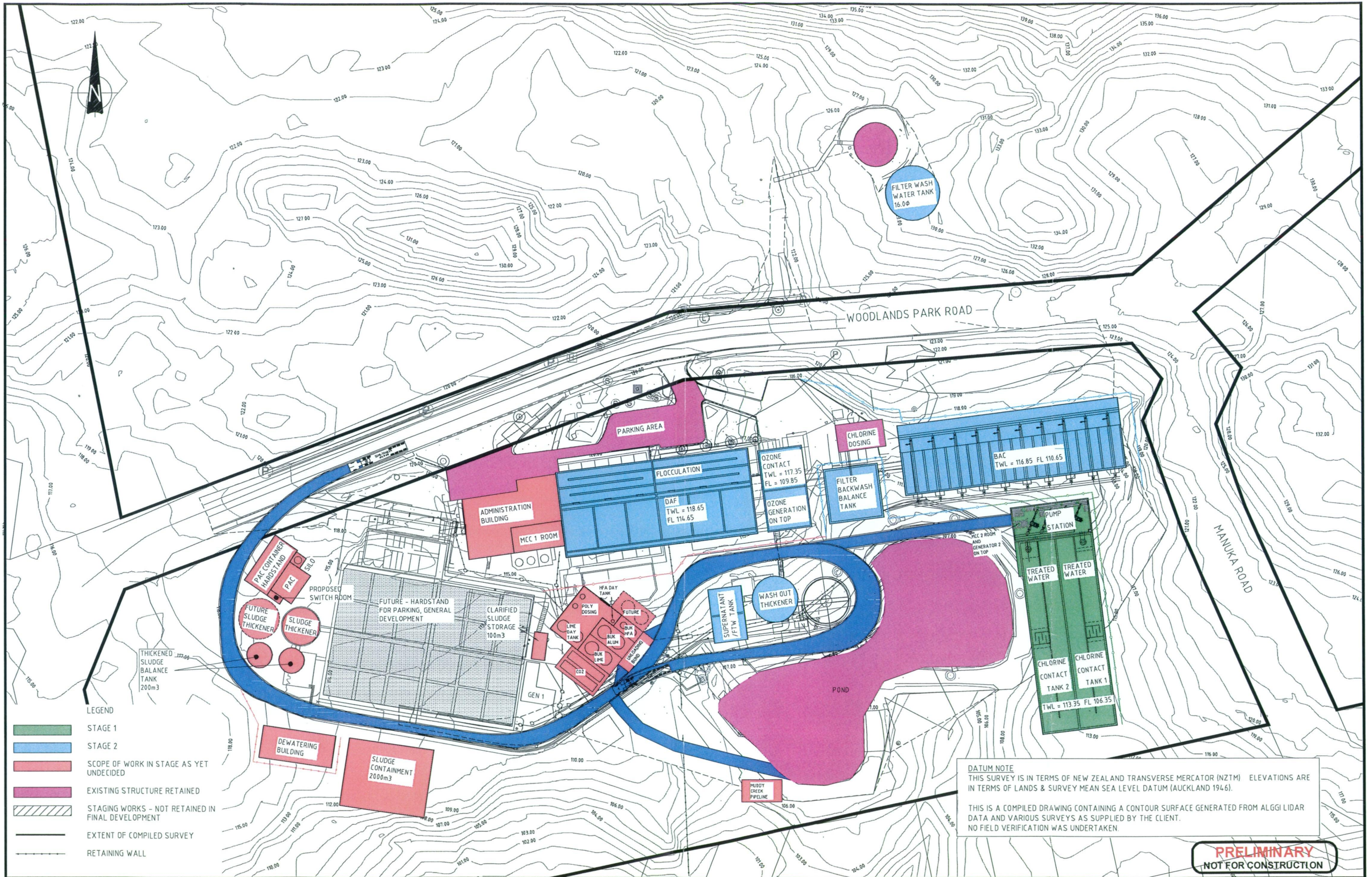
TT Tonkin & Taylor
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DRAWING STATUS: PRELIMINARY DRAFT

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TITLE	PROPOSED INFRASTRUCTURE UPGRADE Geological Cross Section 3	
SCALES (AT A3 SIZE)	DWG. No.	REV.
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Appendix A:

Watercare Site Layout Options



LEGEND

- STAGE 1
- STAGE 2
- SCOPE OF WORK IN STAGE AS YET UNDECIDED
- EXISTING STRUCTURE RETAINED
- STAGING WORKS - NOT RETAINED IN FINAL DEVELOPMENT
- EXTENT OF COMPILED SURVEY
- RETAINING WALL

DATUM NOTE
 THIS SURVEY IS IN TERMS OF NEW ZEALAND TRANSVERSE MERCATOR (NZTM) ELEVATIONS ARE IN TERMS OF LANDS & SURVEY MEAN SEA LEVEL DATUM (AUCKLAND 1946).
 THIS IS A COMPILED DRAWING CONTAINING A CONTOUR SURFACE GENERATED FROM ALGGI LIDAR DATA AND VARIOUS SURVEYS AS SUPPLIED BY THE CLIENT.
 NO FIELD VERIFICATION WAS UNDERTAKEN.

PRELIMINARY
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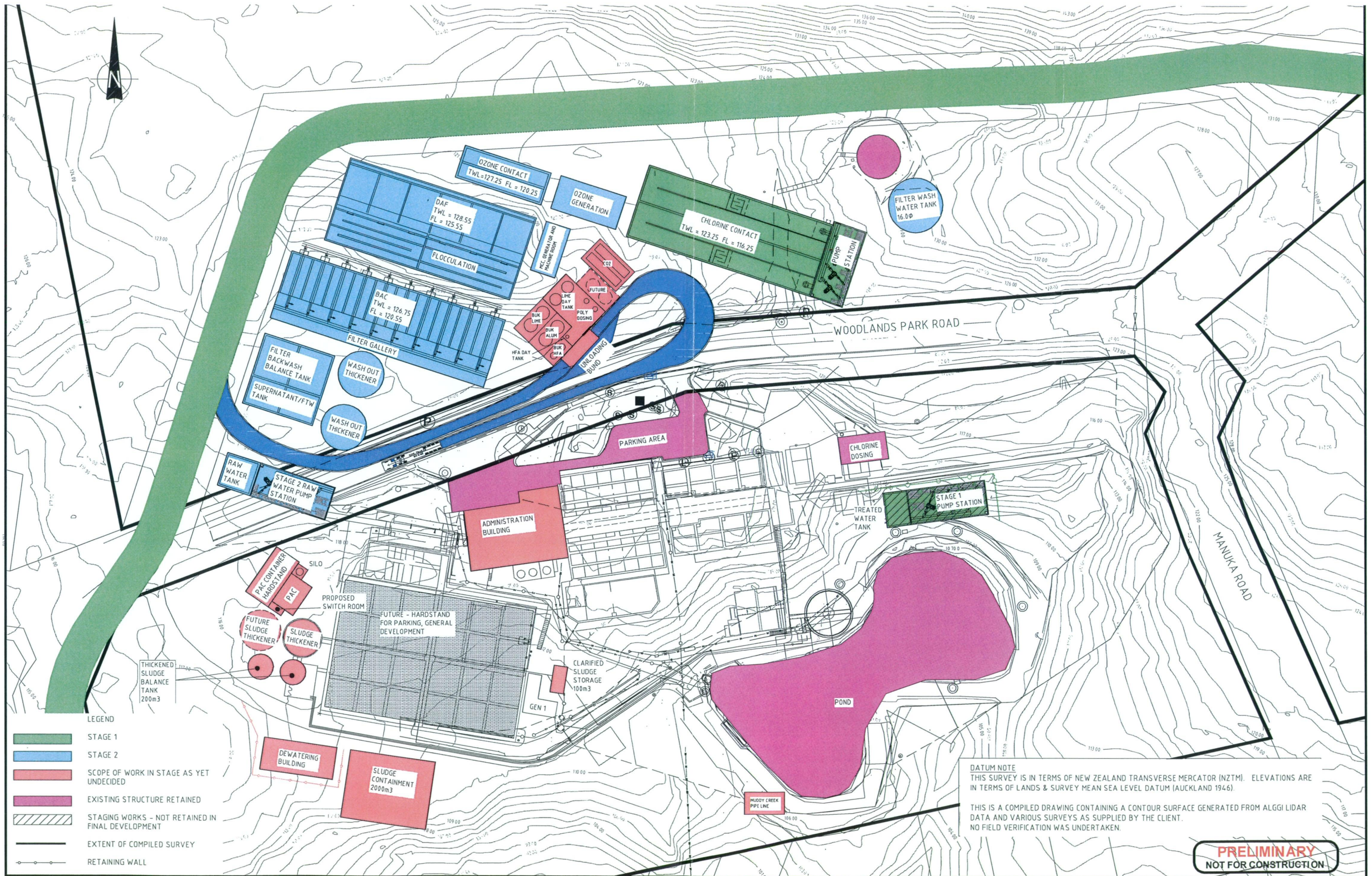
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C	17.5.10	REVISED FOR FACILITY COSTING								
B	7.5.10	REVISED FOR WSL, OPS REVIEW								
A		ISSUED FOR INFORMATION								



**HIUA TREATMENT PLANT
LAYOUT PLAN
OPTION 1**

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CAD FILE 6516050-CK-002A DATE 7-5-2010	CONTRACT No.
ORIGINAL SCALE A1	-
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DRAWING No.	ISSUE
Dwg No .0XX	C



ISSUE	DATE	AMENDMENT	BY	APPD.	BY	DATE
C	17.5.10	REVISED FOR FACILITY COSTING				
B	7.5.10	REVISED FOR WSL, OPS REVIEW				
A		ISSUED FOR INFORMATION				

DESIGNED	
DES. CHECKED	
DRAWN	
DWG. CHECKED	
PROJECT LEADER	
A.M. APPROVED	

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HIUA TREATMENT PLANT
LAYOUT PLAN
OPTION 2

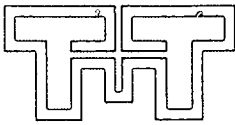
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DATUM NOTE
THIS SURVEY IS IN TERMS OF NEW ZEALAND TRANSVERSE MERCATOR (NZTM). ELEVATIONS ARE IN TERMS OF LANDS & SURVEY MEAN SEA LEVEL DATUM (AUCKLAND 1946).
THIS IS A COMPILED DRAWING CONTAINING A CONTOUR SURFACE GENERATED FROM ALGGI LIDAR DATA AND VARIOUS SURVEYS AS SUPPLIED BY THE CLIENT. NO FIELD VERIFICATION WAS UNDERTAKEN.

Appendix B:

Borehole Logs and Photos



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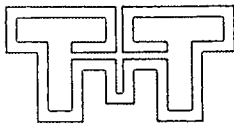
DRILL HOLE LOG

BOREHOLE No: BH1
Hole Location: Garden Shed

SHEET 1 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION	LOCATION: WAIMA, AUCKLAND	JOB No: 27064.001
CO-ORDINATES 6472355.72 mN 2656430.96 mE	DRILL TYPE: 303CR	HOLE STARTED: 14/4/10
DIRECTION: 0.00 °	DATUM: Geodetic 49	HOLE FINISHED: 16/4/10
ANGLE FROM HORIZ.: -90.00 °	R.L. GROUND: 109.20 m	DRILLED BY: Drill Force
	R.L. COLLAR: m	LOGGED BY: STMM CHECKED: CJL

DESCRIPTION OF CORE										ROCK DEFECTS														
GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);	ROCK WEATHERING			ROCK STRENGTH			PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing or natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING	ANGLES ARE NORMAL TO CORE AXIS	DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX	RL (m)
		LW	SW	MW	FW	R4	R2																	
TOPSOIL	Clayey SILT, dark brown, soft, wet, low plasticity, organic fragments																							09.0
	Very coarse GRAVEL, hard siltstone and scoria in clay matrix																							08.5
	Silty CLAY, light grey, mottled dark grey and orange Fe stain, firm to stiff, moist, plastic. Some organic inclusions and angular siltstone gravel, reworked appearance, structureless																							08.0
	Silty SAND, orange/red, very dense, dry to moist, some organic fragments. Some grey and dark grey, sub-rounded inclusions 0.9m: becoming very coarse, at limit of fine/medium gravel, dark grey gravel of various nature, sub-rounded, loose, moist 1.15m: becoming sandy CLAY, slightly gravelly, dark grey, mottles black and orange Fe stain, organic fragments, soft, moist to wet, high plasticity																							07.5
	Organic CLAY, grey, numerous randomly spaced fragments of branches and vegetation, very soft, wet, high plasticity																							07.0
																								06.5
																								06.0
	3.0m: organic content decreases																							05.5
	CLAY, dark grey with some organic fibres, very soft, wet, high plasticity																							05.0
	PUSH TUBE: Sampling failed, organic fibres preventing sample entering the tube																							04.5
																							04.0	
Silty SAND, reddish brown, some grey mottles, loose, moist to dry, some organic fragments. Intermix with grey clay and vegetation remnants at top 50mm																							03.5	
																							03.0	
PUSH TUBE: Sampling failed. Recovered 50% of tube length, but core was vertically halved and not recovered. Material recovered as above																							02.5	
																							02.0	
																							01.5	
																							01.0	
																							00.5	
																							00.0	



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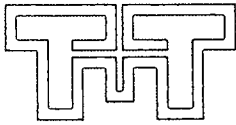
DRILL HOLE LOG

BOREHOLE No: BH1
Hole Location: Garden Shed

SHEET 2 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION	LOCATION: WAIMA, AUCKLAND	JOB No: 27064.001
CO-ORDINATES 6472355.72 mN 2656430.96 mE	DRILL TYPE: 303CR	HOLE STARTED: 14/4/10
DIRECTION: 0.00°	DATUM: Geodetic 49	HOLE FINISHED: 16/4/10
ANGLE FROM HORIZ.: -90.00°	R.L. GROUND: 109.20 m	DRILLED BY: Drill Force
	R.L. COLLAR: m	LOGGED BY: STMM CHECKED: CJL

GEOLOGICAL UNIT	DESCRIPTION OF CORE										ROCK DEFECTS															
	SW	SH	HW	R4	R3	R2	R1	PT	100	30	10	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG	DATE / DEPTH	RQD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX					
FILL	Likely core loss from 5.0 to 5.8m																									
	Silty, fine to medium SAND, orange brown, organic at the base, very loose, wet																									
COLLUVIUM	PUSH TUBE: Core not logged																									
	Silty, fine to coarse SAND, light grey with orange hue, soft, moist, loose, coarse sand is sub-rounded																									
	Fragment of Cornwallis Formation, reworked condition, recovered as fine to medium GRAVEL, orange brown, trace of relict joints visible																									
	Silty, fine to coarse SAND, light grey with orange hue, soft, moist, loose, coarse sand is sub-rounded																									
CW/HW CORNWALLIS FORMATION	SAND, slightly silty, to GRAVEL, loose, wet. Orange colour, gravel is sub-angular. Very loose almost muddy at contact with colluvium																									
	PUSH TUBE: Core not logged																									
	Fine to medium SAND, light grey, pink hue, medium dense, moist																									
	9.66m: relict joint Fe stained (polished?), 20°																									
	9.8m: some carbonaceous layers at 10° and becoming Fe stained for 100mm																									



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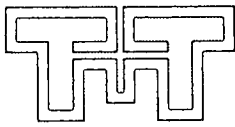
DRILL HOLE LOG

BOREHOLE No: BH1
Hole Location: Garden Shed

SHEET 4 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION		LOCATION: WAIMA, AUCKLAND		JOB No: 27064.001	
CO-ORDINATES 6472355.72 mN 2656430.96 mE		DRILL TYPE: 303CR		HOLE STARTED: 14/4/10	
DIRECTION: 0.00 °		DATUM: Geodetic 49		HOLE FINISHED: 16/4/10	
ANGLE FROM HORIZ.: -90.00 °		R.L. GROUND: 109.20 m		DRILLED BY: Drill Force	
		R.L. COLLAR: m		LOGGED BY: STMM CHECKED: CJL	

GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...)	ROCK DEFECTS																		
		ROCK WEATHERING	ROCK STRENGTH	PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING	ANGLES ARE NORMAL TO CORE AXIS	DATE / DEPTH	RDD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX	
MW CORNWALLIS FORMATION	Likely core loss 15.0m to 15.28m																			
	Medium to coarse GRAVEL, angular to sub-rounded, very loose, moist, likely drilling disturbance																			
	Gravelly SAND, slightly silty, orange brown, very dense, moist, gravel is sub-rounded																			
	SW-MW SANDSTONE, brown pink, extremely weak																			
	CONGLOMERATE, medium grained																			
	CORE LOSS from 18.05m to 19.5m																			
	CORE LOSS from 19.5m to 19.8m																			
	Gravelly, SAND, very loose, wet, recovered as mud, likely drilling induced																			



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DRILL HOLE LOG

BOREHOLE No: BH1
Hole Location: Garden Shed

SHEET 5 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION		LOCATION: WAIMA, AUCKLAND		JOB No: 27064.001															
CO-ORDINATES 6472355.72 mN 2656430.96 mE		DRILL TYPE: 303CR		HOLE STARTED: 14/4/10															
DIRECTION: 0.00 °		DATUM: Geodetic 49		HOLE FINISHED: 16/4/10															
ANGLE FROM HORIZ.: -90.00 °		R.L. GROUND: 109.20 m		DRILLED BY: Drill Force															
		R.L. COLLAR: m		LOGGED BY: STMM CHECKED: CJL															
DESCRIPTION OF CORE				ROCK DEFECTS															
GEOLOGICAL UNIT	ROCK WEATHERING MW, SW, HW, HW	ROCK STRENGTH R4, R3, R2, R1, R0	PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS				DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX
											DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING								
disturbance MW, brown grey SANDSTONE, extremely weak, highly disturbed by drilling													0			89.0			
SW, light grey pink hue, medium SANDSTONE, extremely weak, slightly softened along very thin SILTSTONE layers, <5mm thick													34			88.5			
21m: becoming fine													53			88.0			
22m: becoming fine													80			87.5			
22.3m: 20mm SILTSTONE layer, softened																87.0			
23.05m: Joint 38°, tight (1mm), Fe stained. 23.15m: Joint 20°, planar, smooth, tight, Fe stained. 23.3m: Bedding 20°-25°.													100			86.0			
24m: Joint 90°, planar, rough, tight, Fe stained, 300mm long.													67			85.5			
24.5m: 10mm SILTSTONE layer													67			85.0			
END OF BOREHOLE AT 24.75m. Standpipe piezometers installed, see BHI-PZ for details.																84.5			

mm

Log Scale 1:25

ROCKLG 27064.001.GPJ 16/7/10

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BH 1_Box 01_00.00-03.50m.jpg



BH 1_Box 02_03.50-08.25m.jpg

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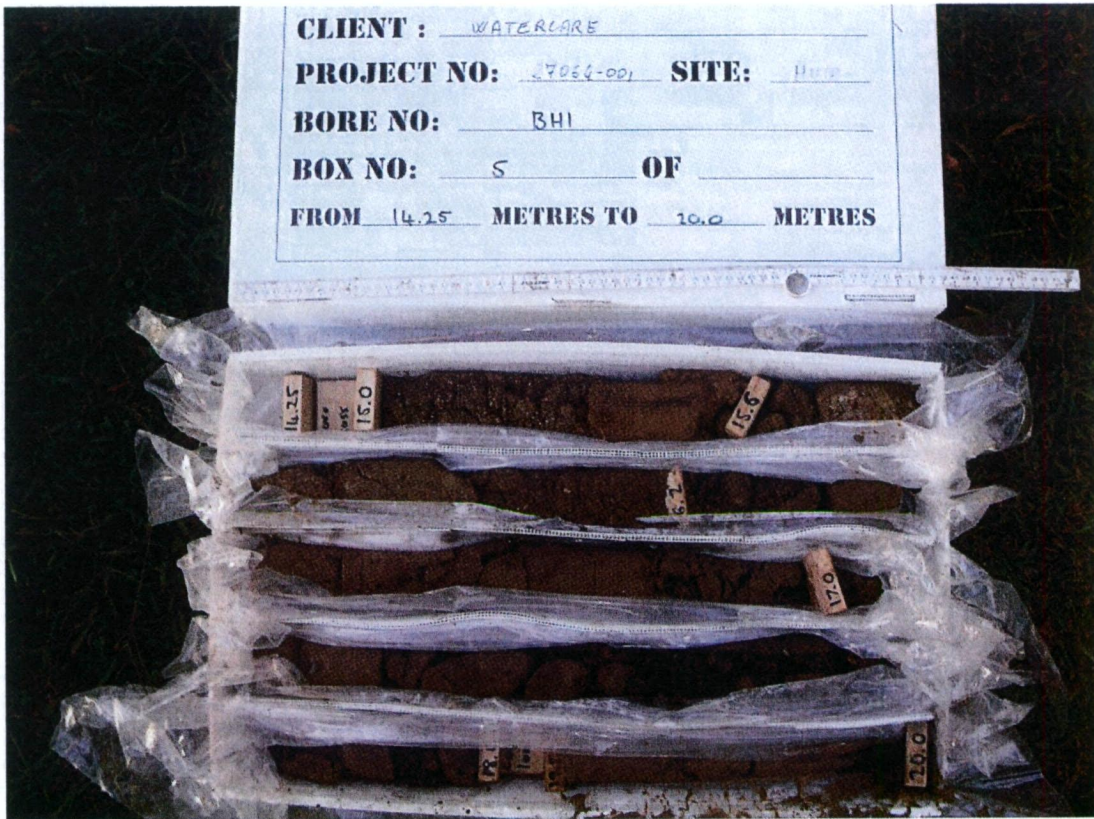


BH 1_Box 03_08.25-11.35m.jpg



BH 1_Box 04_11.35-14.25m.jpg

Watercare Huia WTP



CLIENT : WATERCARE
PROJECT NO: 27064-001 **SITE:** Huia
BORE NO: BH1
BOX NO: 5 **OF** _____
FROM 14.25 **METRES TO** 20.0 **METRES**

BH 1_Box 05_14.25-20.00m.jpg



CLIENT : _____
PROJECT NO: _____ **SITE:** _____
BORE NO: BH1
BOX NO: 6 **OF** _____
FROM 20.0 **METRES TO** 22.75 **METRES**

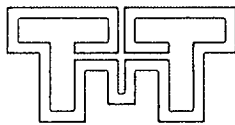
BH 1_Box 06_20.00-22.75m.jpg

Watercare Huia WTP



PROJECT NO: 27064-001 **SITE:** HUIA
BORE NO: BH 1
BOX NO: 7 **OF**
FROM 22.75 **METRES TO** 24.75 **METRES**

BH 1_Box 07_22.75-24.75m_EoB.jpg



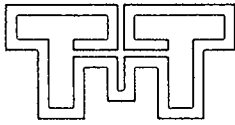
TONKIN & TAYLOR LTD

DRILL HOLE LOG

BOREHOLE No: BH2
 Hole Location: Behind Sludge
 Thickener Tank
 SHEET 1 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION LOCATION: WAIMA, AUCKLAND JOB No: 27064.001
 CO-ORDINATES 6472402.56 mN DRILL TYPE: 303CR HOLE STARTED: 19/4/10
 2656360.03 mE DATUM: Geodetic 49 HOLE FINISHED: 20/4/10
 DIRECTION: 0.00° R.L. GROUND: 115.00 m DRILLED BY: Drill Force
 ANGLE FROM HORIZ.: -90.00° R.L. COLLAR: m LOGGED BY: STMM CHECKED: CJL

DESCRIPTION OF CORE				ROCK DEFECTS																
GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc.);	ROCK WEATHERING	ROCK STRENGTH	PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING	ANGLES ARE NORMAL TO CORE AXIS	DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX	
																				SW
COLLUVIUM	Clayey SILT, dark brown, soft, low plasticity, wet, numerous organic							0.0 - 0.5	X											
	Silty SAND, dark orange, dense but disturbed by hand auger, low plasticity, moist, numerous roots Borehole filled with bentonite and drilling restart HQ. Ground samples piled next to rig and cuttings logged							0.5 - 1.5	X											
	Sandy SILT, light grey orange mottled, soft, plastic, moist, few rare roots 1.45m: becoming orange 1.6m: becoming pink speckled, firm							1.5 - 1.75	X											
	1.75m: 50mm sand inclusions on side of the core							1.75 - 2.0	X											
	Silty, fine to medium SAND, light grey with some pink speckles, dense, moist, some rare medium sand inclusions							2.0 - 2.5	X											
	2.5m: some young roots							2.5 - 2.8	X											
	2.8m: 150mm very loose, recovered as sand, very wet							2.8 - 3.0	X											
PUSH TUBE: Sample core not logged							3.0 - 3.5	X												
CW/HW CORNWALLIS FORMATION	Silty, fine to medium SAND, light grey with some pink speckles, dense, moist						3.5 - 4.0	X												
	SAND, slightly silty, light greyish brown with pink hue, loose, moist, some Fe stained. Upper 100mm are blocky						4.0 - 4.15	X												
	4.15m: 10mm very soft layer at 10°						4.15 - 4.33	X												
	4.33m: 10mm very soft layer dipping at 10°						4.33 - 4.5	X												
4.5m: becoming dense with rare relict joints						4.5 - 4.6	X													
4.6m: 200mm light grey SILTSTONE, extremely weak, highly fractured but interlocking. No polished surfaces, some Fe staining						4.6 - 5.0	X													
							5.0 - 5.5	X												



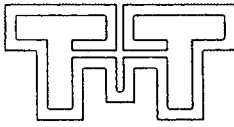
TONKIN & TAYLOR LTD

DRILL HOLE LOG

BOREHOLE No: BH2
Hole Location: Behind Sludge Thickenner Tank
SHEET 2 OF 5

Table with project details: PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION, LOCATION: WAIMA, AUCKLAND, JOB No: 27064.001, CO-ORDINATES, DRILL TYPE: 303CR, HOLE STARTED: 19/4/10, etc.

Main log table with columns: GEOLOGICAL UNIT, ROCK WEATHERING, ROCK STRENGTH, PT LOAD / UCS TEST (MPa), CORE LOSS / LIFT (%), TEST SYMBOL, DEPTH (m), GRAPHIC LOG, DEFECT LOG, FRACTURE LOG, ROCK DEFECTS, DATE / DEPTH, ROD (%), WATER, DRILL WATER LOSS (%), CORE BOX, CORE BOX RL (m).



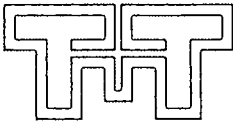
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DRILL HOLE LOG

BOREHOLE No: BH2
 Hole Location: Behind Sludge Thickener Tank
 SHEET 3 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION	LOCATION: WAIMA, AUCKLAND	JOB No: 27064.001
CO-ORDINATES 6472402.56 mN 2656360.03 mE	DRILL TYPE: 303CR DATUM: Geodetic 49	HOLE STARTED: 19/4/10 HOLE FINISHED: 20/4/10
DIRECTION: 0.00 ° ANGLE FROM HORIZ.: -90.00 °	R.L. GROUND: 115.00 m R.L. COLLAR: m	DRILLED BY: Drill Force LOGGED BY: STMM CHECKED: CJL

DESCRIPTION OF CORE					ROCK DEFECTS										
GEOLOGICAL UNIT	ROCK WEATHERING	ROCK STRENGTH	PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG	DATE / DEPTH	RQD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX	
HW/CW CORNWALLIS FORMATION	HW, orange brown, grey pink hue, coarse SANDSTONE, extremely weak, sub-rounded to sub-angular clasts 11.7m: 10mm SILTSTONE, weak, softened 12.1m: 10mm softened CORE LOSS from 12.3m to 12.7m	[Rock Strength Column with patterns: horizontal lines, vertical lines, etc.]	[PT Load / UCS Test Column with numerical values]	[Core Loss / Lift Column with numerical values]	[Test Symbol Column with 'TT' entries]	[Depth Column from 9.95 to 15]	[Graphic Log Column with fracture symbols]	[Defect Log Column with text descriptions]	[Fracture Log Column with spacing of natural fractures]	[Date / Depth Column]	[RQD (%) Column]	[Water Column]	[Drill Water Loss (%) Column]	[Core Box Column]	
															9.95m: Bedding 10°, white clay infilling.
															10.25m: Bedding 10°, possibly slickensided, softened across 10mm and white silty clay filling 1mm thick.
															10.4m: Some relict joints, Fe stained.
															10.65m: Bedding 10°, Fe stained.
															10.8m: Bedding 10°, Fe stained.
															11m: Joint 60°, Fe stained.
															11.3m: Bedding 10°, planar, slickensided, tight (1mm), clay gouge white silt striated.
															11.7m: Bedding 10°.
															12.7m: Joint 90°, planar, Fe stained.
															12.8m: Joint 20°, planar, smooth to slickensided, Fe stained and clay gouge, tight.
															13.1m: Joint 60°, planar, smooth, tight, Fe stained and clay gouge.
															13.9m: Joint 15°, irregular, rough, tight, Fe stained.
															13.95m: Joint 10°, planar, smooth, tight, clay gouge and Fe stained, white clay shining.
															14.35m: Joint 40°, planar, smooth, open (10mm), fragments.
14.6m: Joint 40°, planar, slickensided, tight, Fe stained and clay gouge, slickensided and striated.															



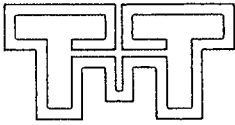
TONKIN & TAYLOR LTD

DRILL HOLE LOG

BOREHOLE No: BH2
 Hole Location: Behind Sludge
 Thickener Tank
 SHEET 4 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION	LOCATION: WAIMA, AUCKLAND	JOB No: 27064.001
CO-ORDINATES 6472402.56 mN 2656360.03 mE	DRILL TYPE: 303CR	HOLE STARTED: 19/4/10
DIRECTION: 0.00 °	DATUM: Geodetic 49	HOLE FINISHED: 20/4/10
ANGLE FROM HORIZ.: -90.00 °	R.L. GROUND: 115.00 m	DRILLED BY: Drill Force
	R.L. COLLAR: m	LOGGED BY: STMM CHECKED: CJL

DESCRIPTION OF CORE				ROCK DEFECTS																	
GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);	ROCK WEATHERING			PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing or natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING	ANGLES ARE NORMAL TO CORE AXIS	DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX	RL (m)
		LW	SW	HW																	
HW/CW CORNWALLIS FORMATION	MW, grey with pink hue, medium to coarse SANDSTONE, extremely weak, clasts are sub-rounded to sub-angular																				98.0
	15.5m: becoming brown, Fe stained												15.5m: Bands of Fe stained material dipping at 50°.								99.5
	15.95m: 5mm SILTSTONE												15.6m: Joint 50°, white clay filling 1mm.								99.0
													15.95m: Bedding 10°.								98.5
													16.6m: Joint 90°, planar, smooth, tight, clay gouge, white.								98.0
													17.35m: Joint 70°, irregular, rough, Fe stained, tight, length 100mm.								97.5
													18.1m: Joint 60°, planar, rough, open (2mm), fragments.								97.0
													18.55m: Highly fractured recovered as gravel.								96.5
													18.95m: Highly fractured, recovered as gravel.								96.0
													19.85m: Joint 90°, planar, rough, tight, clay gouge, white.								95.5
MW CORNWALLIS FORMATION	MW, grey with pink hue, medium to coarse SANDSTONE, weak. Clasts are sub-rounded to sub-angular																				95.0
	CORE LOSS from 18.55m to 18.95m																				95.0
	18.95 to 19.2m: core is very wet																				95.0



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DRILL HOLE LOG

BOREHOLE No: BH2
 Hole Location: Behind Sludge
 Thickener Tank
 SHEET 5 OF 5

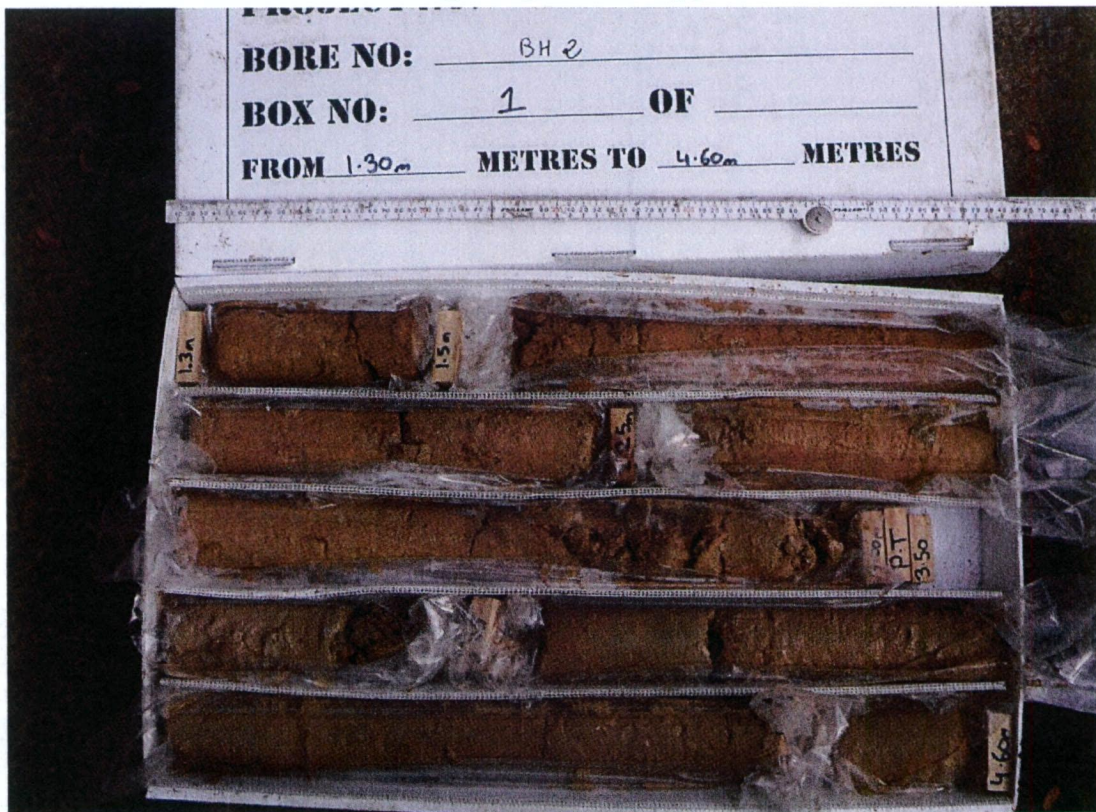
PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION	LOCATION: WAIMA, AUCKLAND	JOB No: 27064.001
CO-ORDINATES 6472402.56 mN 2656360.03 mE	DRILL TYPE: 303CR	HOLE STARTED: 19/4/10
DIRECTION: 0.00 °	DATUM: Geodetic 49	HOLE FINISHED: 20/4/10
ANGLE FROM HORIZ.: -90.00 °	R.L. GROUND: 115.00 m	DRILLED BY: Drill Force
	R.L. COLLAR: m	LOGGED BY: STMM CHECKED: CJL

GEOLOGICAL UNIT	DESCRIPTION OF CORE										ROCK DEFECTS								
	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);	ROCK WEATHERING	ROCK STRENGTH	PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING	ANGLES ARE NORMAL TO CORE AXIS	DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX
MW CORNWALLIS FORMATION	SANDSTONE, as previous					TT	20.5								59				94.5
	END OF BOREHOLE AT 21.0m.						21.0												95.0
	Standpipe piezometers installed; see BH2-PZ for details.						21.5												93.5
							22.0												93.0
							22.5												92.5
							23.0												92.0
							23.5												91.5
							24.0												91.0
							24.5												90.5

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BH 2_Box 00_00.00-01.30m.jpg

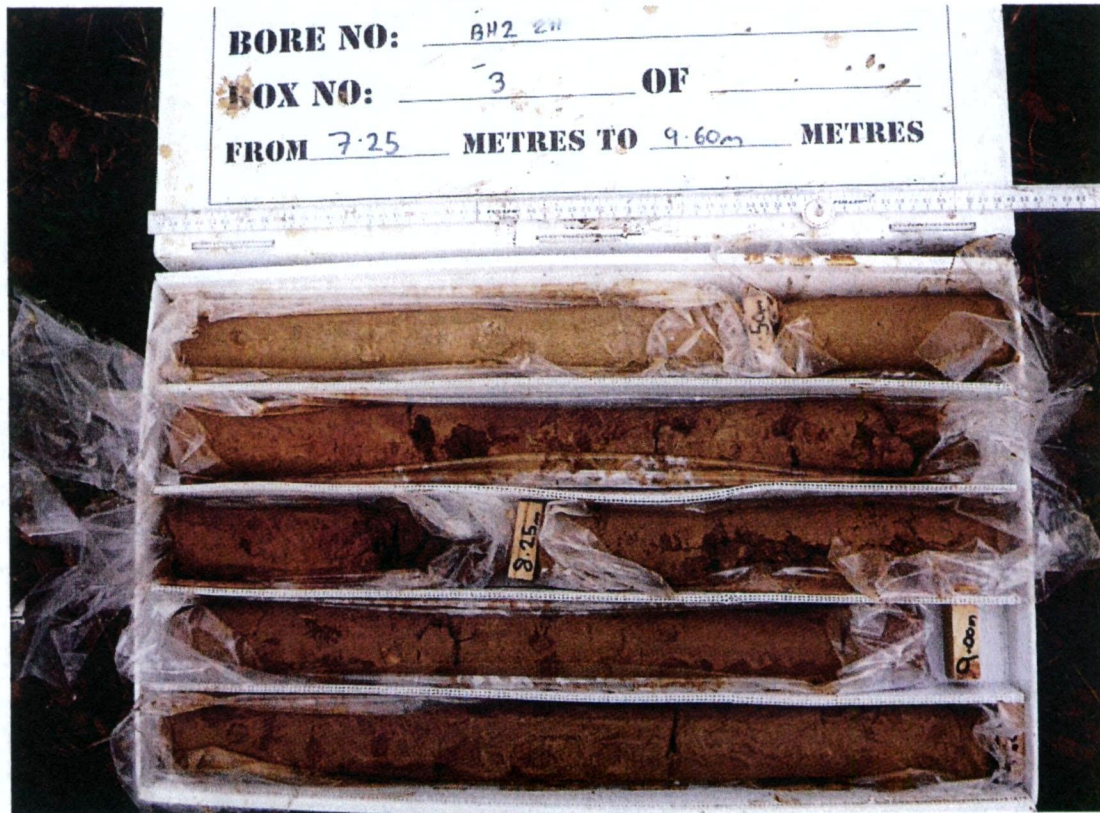


BH 2_Box 01_01.30-04.60m.jpg

Watercare Huia WTP



BH 2_Box 02_04.60-07.25m.jpg



BH 2_Box 03_07.25-09.60m.jpg

Watercare Huia WTP



BH 2_Box 04_09.60-12.00m.jpg



BH 2_Box 05_12.00-15.15m.jpg

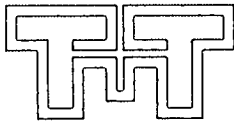
Watercare Huia WTP



BH 2_Box 06_15.15-17.85m.jpg



BH 2_Box 07_17.85-21.00_EoB.jpg



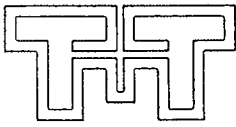
TONKIN & TAYLOR LTD

DRILL HOLE LOG

BOREHOLE No: BH3
 Hole Location: Behind Washwater Thickener
 SHEET 1 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION		LOCATION: WAIMA, AUCKLAND		JOB No: 27064.001	
CO-ORDINATES 6472421.61 mN 2656522.94 mE		DRILL TYPE: 303CR		HOLE STARTED: 21/4/10	
DIRECTION: 0.00 °		DATUM: Geodetic 49		HOLE FINISHED: 22/4/10	
ANGLE FROM HORIZ.: -90.00 °		R.L. GROUND: 109.28 m		DRILLED BY: Drill Force	
		R.L. COLLAR: m		LOGGED BY: STMM CHECKED: CJL	

DESCRIPTION OF CORE										ROCK DEFECTS										
GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);	ROCK WEATHERING SW MW HW	ROCK STRENGTH R4 R3 R2 R1 R0	PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%) 10 5	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING	ANGLES ARE NORMAL TO CORE AXIS	DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX	RL (m)
	Clayey SILT, dark brown, dry, non-plastic, thickness 10mm Rubbles of dark grey SANDSTONE, 100mm								X											09.0
	Silty SAND, orange brown with some Fe stain								X											08.5
	Silty SAND, dark grey								X											08.0
	Fine to medium SAND, dark grey, greenish blue hue, medium dense to loose, wet, some Fe stain								X											07.5
	2.35m: becoming very loose, wet								X											07.0
MW CORNWALLIS FORMATION	HW, dark orange brown, fine to medium SANDSTONE, extremely weak, Fe stained CORE LOSS from 2.85 to 3.1m								X											06.5
	SW-MW, grey greenish, highly fractured, medium SANDSTONE, extremely weak								X											06.0
	Fine to medium SAND, brown orange, very loose, wet								X											05.5
	4.2m: fine SAND, dark grey, moist								X											05.0
	4.4m: becoming loose to very loose, wet								X											04.5
	COBBLES and PEBBLES of SANDSTONE, loose								X											04.5



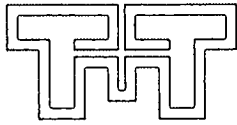
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DRILL HOLE LOG

BOREHOLE No: BH3
 Hole Location: Behind Washwater Thickener
 SHEET 2 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION	LOCATION: WAIMA, AUCKLAND	JOB No: 27064.001
CO-ORDINATES 6472421.61 mN 2656522.94 mE	DRILL TYPE: 303CR DATUM: Geodetic 49 R.L. GROUND: 109.28 m R.L. COLLAR: m	HOLE STARTED: 21/4/10 HOLE FINISHED: 22/4/10 DRILLED BY: Drill Force LOGGED BY: STMM CHECKED: CJL
DIRECTION: 0.00 ° ANGLE FROM HORIZ.: -90.00 °		

DESCRIPTION OF CORE	ROCK DEFECTS																					
GEOLOGICAL UNIT	ROCK WEATHERING		ROCK STRENGTH			PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING	ANGLES ARE NORMAL TO CORE AXIS	DATE / DEPTH	RQD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX	
	SW	MW	R1	R2	R3																	
MW CORNWALLIS FORMATION								TT		5.5											04.0	
	Dark grey SAND, loose, moist							SPT		5.5											03.5	
	5.8m: becoming wet							TT		6.0											03.0	
	SANDSTONE, some brown discolouration and patches							TT		6.3											03.0	
	6.3m: highly fractured to pebble size							TT		6.5											03.0	
	6.65m: wet PEBBLES of grey sandstone							TT		6.65												02.5
	6.7m: becoming very weak SANDSTONE							TT		6.7					6.7m: Joint 60°, planar, smooth, Fe stained.							02.0
	7.1m: highly fractured from pebbles to fine gravel size, wet							TT		7.1					7.1m: Fragments of polish striated surface Fe stain. Orientation unknown.							02.0
	UW, dark grey, medium SANDSTONE, weak							TT		7.65					7.65m: Joint 80°, planar, rough, tight (1mm), silica coating.							02.0
	Dark grey, medium SAND, very loose, wet							TT		8.0					8.1m: some disk breaking							01.0
8.8m: pebbles, drilling induced disturbance									8.8												00.0	
MW, dark grey, medium SANDSTONE, weak									9.0												00.0	
SAND, very loose, wet									9.5												99.5	
Dark grey SILTSTONE, extremely weak									9.9												99.5	
9.9m: becoming soft SILT, moist									10.0												99.5	



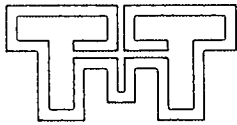
TONKIN & TAYLOR LTD

DRILL HOLE LOG

BOREHOLE No: BH3
 Hole Location: Behind
 Washwater Thickener
 SHEET 3 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION		LOCATION: WAIMA, AUCKLAND	JOB No: 27064.001
CO-ORDINATES	6472421.61 mN 2656522.94 mE	DRILL TYPE: 303CR	HOLE STARTED: 21/4/10
DIRECTION:	0.00 °	DATUM: Geodetic 49	HOLE FINISHED: 22/4/10
ANGLE FROM HORIZ.:	-90.00 °	R.L. GROUND: 109.28 m	DRILLED BY: Drill Force
		R.L. COLLAR: m	LOGGED BY: STMM CHECKED: CJL

DESCRIPTION OF CORE										ROCK DEFECTS												
GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);	SW MW HW	R4 R3 R2 R1 R0	PT LOAD / UCS TEST (MPa)	CORE LOSS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING	ANGLES ARE NORMAL TO CORE AXIS	DATE / DEPTH	RQD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX	RL (m)	
MW	10m: Silty, fine SAND, very loose, wet																					
SW CORNWALLIS FORMATION	Fine SANDSTONE, extremely weak							TT	10.5				10.67m: Bedding 38°.			10					99.0	
	10.67m: SILTSTONE, extremely weak 10.7m: fine SANDSTONE, very weak 10.72m: medium to coarse SANDSTONE, very weak							TT	11.0				11.35m: Drill induced fractures along run.			80					98.5	
	11.25m: Core softened to SAND, end of run							TT	11.5				11.5m: Joint 60°, planar, rough, tight, clean.			40				98.0		
	CONGLOMERATE, very weak, sub-angular clasts, white, black and green in colour. Grey overall colour, pinkish hue							TT	12.0				12.1m: Drilling induced fractures along run.								97.5	
	CORE LOSS							TT	12.5				12.85m: Drilling induced fractures along run.			28					97.0	
	CONGLOMERATE, as previous							TT	13.0				13.2m: Joint 70°, planar, rough, tight, clean.			34					96.5	
	13.12m: Fine to medium SANDSTONE, extremely weak							TT	13.5												96.0	
	CORE LOSS from 13.6 to 14.25m Ground completely loosed overnight and washed away at drilling start							TT	14.0													95.5
	CONGLOMERATE, as above							TT	14.5													95.0
	14.45m: becoming medium to fine SANDSTONE CORE LOSS from 14.5 to 14.8m							TT	15.0					14.8m: Joint 70°, planar, rough, tight, clean.			0					94.5
CONGLOMERATE							TT	15.5					14.9m: Bedding 20°.			0					94.5	



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DRILL HOLE LOG

BOREHOLE No: BH3
 Hole Location: Behind Washwater Thickener
 SHEET 4 OF 5

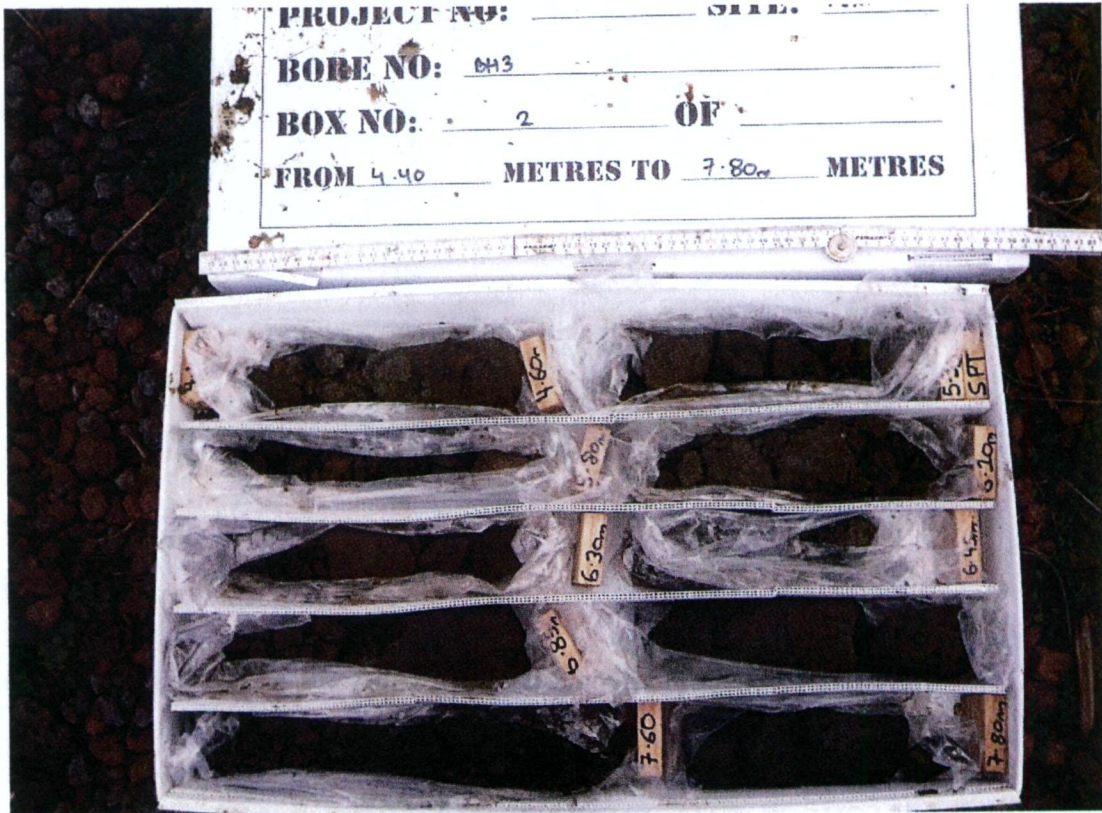
PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION	LOCATION: WAIMA, AUCKLAND	JOB No: 27064.001
CO-ORDINATES 6472421.61 mN 2656522.94 mE	DRILL TYPE: 303CR	HOLE STARTED: 21/4/10
DIRECTION: 0.00°	DATUM: Geodetic 49	HOLE FINISHED: 22/4/10
ANGLE FROM HORIZ.: -90.00°	R.L. GROUND: 109.28 m	DRILLED BY: Drill Force
	R.L. COLLAR: m	LOGGED BY: STMM CHECKED: CJL

GEOLOGICAL UNIT	DESCRIPTION OF CORE										ROCK DEFECTS																			
	UW	SW	WW	HW	RM	R2	R1	RO	1	10	100	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DATE / DEPTH	RQD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX								
SW CORNWALLIS FORMATION	UW, dark grey SILTSTONE, extremely weak CORE LOSS from 15.1 to 15.65m											X X X X																		
	15.65m: fine SANDSTONE, extremely weak 15.8m: coarse SANDSTONE, very weak CORE LOSS from 15.85 to 16.4m																													
	Coarse gravel with fragments of coarse SANDSTONE SILTSTONE, extremely weak 16.6m: SWITCH TO MUD DRILLING Fine SANDSTONE, extremely weak											X X																		
	17.15m: becoming very fine SANDSTONE, with inclusions of fine sandstone, dark grey																													
	17.9m: becoming coarse SANDSTONE, extremely weak, uncemented top 100mm																													
	18.1m: Joint 90°, planar, rough, tight, clean.																													
	18.3m: Joint 40°, planar, rough, tight, clean, spacing 70mm.																													
	16.55m: Bedding 10°.																													
	16.85m: Polished surface 18°, possibly singenetic.																													
	15.75m: Sub-horizontal carbonaceous layer.																													
	19.6 to 20.35m: softened																													

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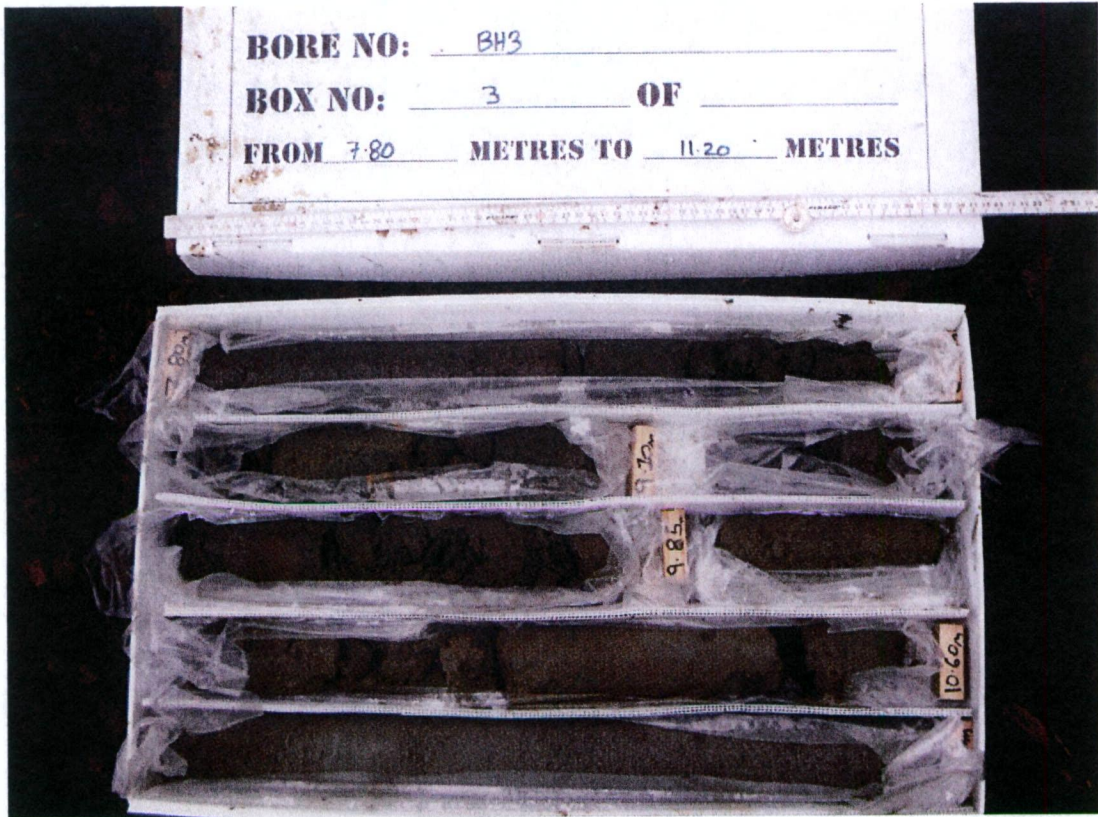


BH 3_Box 01_00.00-04.40m.jpg



BH 3_Box 02_04.40-07.80m.jpg

Watercare Huia WTP



BH 3_Box 03_07.80-11.20m.JPG



BH 3_Box 04_11.20-15.10m.JPG

Watercare Huia WTP



BH 3_Box 05_15.10-19.00m.JPG

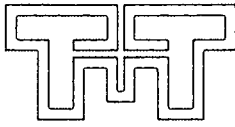


BH 3_Box 06_19.00-22.60m.JPG

Watercare Huia WTP



BH 3_Box 07_22.60-24.85_EoB.JPG



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DRILL HOLE LOG

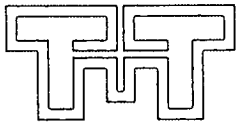
BOREHOLE No: BH4
Hole Location: Side of Lagoon

SHEET 1 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION LOCATION: WAIMA, AUCKLAND JOB No: 27064.001

CO-ORDINATES 6472370.84 mN DRILL TYPE: 303CR HOLE STARTED: 26/4/10
2656466.7 mE DATUM: Geodetic 49 HOLE FINISHED: 27/4/10
DIRECTION: 0.00 ° R.L. GROUND: 108.34 m DRILLED BY: Drill Force
ANGLE FROM HORIZ.: -90.00 ° R.L. COLLAR: m LOGGED BY: STMM CHECKED: CJL

DESCRIPTION OF CORE										ROCK DEFECTS														
GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);	ROCK WEATHERING			ROCK STRENGTH			PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING	ANGLES ARE NORMAL TO CORE AXIS	DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX	
		SW	MW	RW	R4	R2	R3																	R1
FILL	COBBLES and GRAVEL, in a sandy matrix, dark brown. Cobbles and gravel of scoria, dry Some steel nails at top											0.5												08.0
	Clayey SILT, light grey, orange mottled, very soft, plastic, moist to wet, some rare organic fragments											1.0												07.5
COLLUVIUM	PUSH TUBE: Sample only 50% recovered. Core not logged											1.5												07.0
	Clayey SILT, as previous											2.0												06.5
	3.2m: becoming dark green grey with white sub-rounded small gravel											3.0												06.0
	Silty SAND, green grey, very loose, wet											3.5												05.5
	Reddish brown, slightly silty, medium to coarse SAND, sub-angular											4.0												05.0
	PUSH TUBE: Core not logged											4.5												



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DRILL HOLE LOG

BOREHOLE No: BH4
Hole Location: Side of Lagoon

SHEET 2 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION LOCATION: WAIMA, AUCKLAND JOB No: 27064.001

CO-ORDINATES 6472370.84 mN
2656466.7 mE

DRILL TYPE: 303CR
DATUM: Geodetic 49

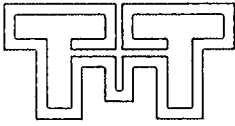
HOLE STARTED: 26/4/10
HOLE FINISHED: 27/4/10

DIRECTION: 0.00 °
ANGLE FROM HORIZ.: -90.00 °

R.L. GROUND: 108.34 m
R.L. COLLAR: m

DRILLED BY: Drill Force
LOGGED BY: STMM CHECKED: CJL

DESCRIPTION OF CORE										ROCK DEFECTS								
GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);	ROCK WEATHERING	ROCK STRENGTH	PT LOAD / LUCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX	RL (m)	
CVM	Reddish brown, slightly silty, medium to coarse SAND, sub-angular																	
	Medium to coarse SAND, slightly silty, light grey, orange laminated, dense, moist 5.35m: becoming lighter grey with orange lamination, sub-vertical									5.35m: Sub-vertical lamination.								
CW/HW CORNWALLIS FORMATION	6m: becoming fine grained and 100mm light grey colour 6.2m: Below polished surfaces becoming coarser sand with some Fe stain									6.16m: 2 polished surfaces 30° dipping, spacing 50mm.								
	PUSH TUBE: Core not logged																	
	SAND, orange brown, very loose, wet, becoming dense																	
	8.25m: some lens/layers of dense, grey, medium SAND									8.25m: Sub-horizontal lamination. Relict sub-vertical joint.								
	8.4m: fine sand to silt layer, light grey with orange lamination, becoming medium dense																	
	8.75m: Contact with coarse SAND, orange brown, loose, wet									8.75m: Bedding 30°.								
	Medium GRAVEL, orange brown, dense, moist 9m: becoming dense																	
	9.25m: loose, sub-rounded to sub-angular, coarse to very coarse gravel, wet																	
	Possible core loss from 9.6 to 9.75m																	
	9.75m: strong Fe stain, wet 9.8m: grading to medium gravel, loose, wet, Fe stained																	



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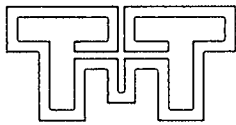
DRILL HOLE LOG

BOREHOLE No: BH4
Hole Location: Side of Lagoon

SHEET 3 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION		LOCATION: WAIMA, AUCKLAND		JOB No: 27064.001	
CO-ORDINATES 6472370.84 mN 2656466.7 mE		DRILL TYPE: 303CR		HOLE STARTED: 26/4/10	
DIRECTION: 0.00 °		DATUM: Geodetic 49		HOLE FINISHED: 27/4/10	
ANGLE FROM HORIZ.: -90.00 °		R.L. GROUND: 108.34 m		DRILLED BY: Drill Force	
		R.L. COLLAR: m		LOGGED BY: STMM CHECKED: CJL	

GEOLOGICAL UNIT	DESCRIPTION OF CORE										ROCK DEFECTS					DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX								
	ROCK WEATHERING	ROCK STRENGTH	PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING	ANGLES ARE NORMAL TO CORE AXIS															
CW/HW CORNWALLIS FORMATION	GRAVEL, as previous															26/04/2010				98								
	10.5m: becoming very dark grey to black due to Fe stain																				97.5							
	10.7m: 150mm coarse sub-rounded gravel, loose, wet																					97						
	10.85m: mix of coarse gravel and coarse sand, loose to medium dense, wet																						96.5					
	11.25m: becoming dense, moist																							96				
	11.6m: becoming orange brown																								95.5			
	Grey, coarse SAND, some Fe stain, dense, moist																									95		
	13.25m: striated polished surface 10°, likely intraformational.																										94.0	
	14.25m: becoming orange brown with numerous Fe stained bands																											93.5



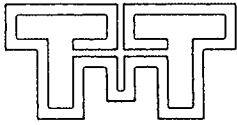
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DRILL HOLE LOG

BOREHOLE No: BH4
Hole Location: Side of Lagoon

SHEET 4 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION		LOCATION: WAIMA, AUCKLAND		JOB No: 27064.001															
CO-ORDINATES 6472370.84 mN 2656466.7 mE		DRILL TYPE: 303CR		HOLE STARTED: 26/4/10															
DIRECTION: 0.00 °		DATUM: Geodetic 49		HOLE FINISHED: 27/4/10															
ANGLE FROM HORIZ.: -90.00 °		R.L. GROUND: 108.34 m		DRILLED BY: Drill Force															
		R.L. COLLAR: m		LOGGED BY: STMM CHECKED: CJL															
DESCRIPTION OF CORE			ROCK DEFECTS																
GEOLOGICAL UNIT	ROCK WEATHERING	ROCK STRENGTH	PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING	ANGLES ARE NORMAL TO CORE AXIS	DATE / DEPTH	RQD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX	RL (m)
	UW SW MW HW	R4 R3 R2 R1 R0	3 10 30 100	3 10 30 100						50 10 5 1									
CW/HW CORNWALLIS FORMATION	15.2m: becoming dark almost black, numerous Fe stained, some gravel inclusions towards end of run																		
	15.75m: becoming very dark grey almost black along Fe stain, dry																		
MW CORNWALLIS FORMATION	MW, bluish grey SANDSTONE, softened top 50mm, extremely weak 16.3m: 10mm very soft SILT																		
	16.6m: Coarse SAND, uncemented SANDSTONE, 100mm thick 16.75m: 300mm uncemented SANDSTONE																		
	CONGLOMERATE, dark grey, moist, uncemented																		
	17.2m: becoming extremely weak 17.25m: completely uncemented, getting wet																		
SW/UW CORNWALLIS FORMATION	SANDSTONE, extremely weak																		
	SW, grey, coarse SANDSTONE, extremely weak																		
	Sharp contact with 100mm CONGLOMERATE, extremely weak, poorly cemented, sub-angular clasts Sharp contact grey, medium SANDSTONE, extremely weak, poorly cemented 18.75m: Grey with pink hue, medium SANDSTONE, cemented																		
	19m: uncemented																		
	19.5m: 50mm thick progressive passage to coarse cemented SANDSTONE																		
	18.3m: Bedding 20°. 18.4m: Bedding 20°.																		



TONKIN & TAYLOR LTD

DRILL HOLE LOG

BOREHOLE No: BH4
Hole Location: Side of Lagoon

SHEET 5 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION	LOCATION: WAIMA, AUCKLAND	JOB No: 27064.001
CO-ORDINATES 6472370.84 mN 2656466.7 mE	DRILL TYPE: 303CR	HOLE STARTED: 26/4/10
DIRECTION: 0.00 °	DATUM: Geodetic 49	HOLE FINISHED: 27/4/10
ANGLE FROM HORIZ.: -90.00 °	R.L. GROUND: 108.34 m	DRILLED BY: Drill Force
	R.L. COLLAR: m	LOGGED BY: STMM CHECKED: CJL

GEOLOGICAL UNIT	DESCRIPTION OF CORE										ROCK DEFECTS										
	ROCK WEATHERING	ROCK STRENGTH	PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING	ANGLES ARE NORMAL TO CORE AXIS	DATE / DEPTH	RDD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX			
UW CORNWALLIS FORMATION						TT	20.25														
	20.25m: 50mm progressive passage to fine SANDSTONE, cemented																				
	20.7m: Progressive passage 10mm to medium SANDSTONE, uncemented																				
	20.75m: uncemented conglomerate																				
	20.85m: medium SANDSTONE, uncemented																				
	21m: medium SANDSTONE, extremely weak, cemented																				
	21.6m: inclusions of green, medium SANDSTONE, 50mm thick on side of core																				
	CONGLOMERATE, extremely weak, cemented																				
	110mm SILTSTONE, extremely weak, partly cemented																				
	Sharp contact with medium SANDSTONE, extremely weak, cemented, softened upper 50mm																				
22.45m: becoming coarse																					
23.3m: fine to medium SANDSTONE, partly cemented																					
23.5m: Highly fractured, possibly drilling induced.																					
21.35m: Joint 50°, planar, rough, tight, clean.																					
21.75m: Bedding 10°.																					
22.01m: Bedding 20°.																					
END OF BOREHOLE AT 24m.																					
Standpipe piezometer installed. See BH4-PZ for details.																					

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BH 4_Box 01_00.00-03.75m.jpg



BH 4_Box 02_03.75-07.25m.jpg

Watercare Huia WTP



BH 4_Box 03_07.25-10.70m.jpg



BH 4_Box 04_10.70-13.25m.jpg

Watercare Huia WTP



BH 4_Box 05_13.25-15.60m.jpg

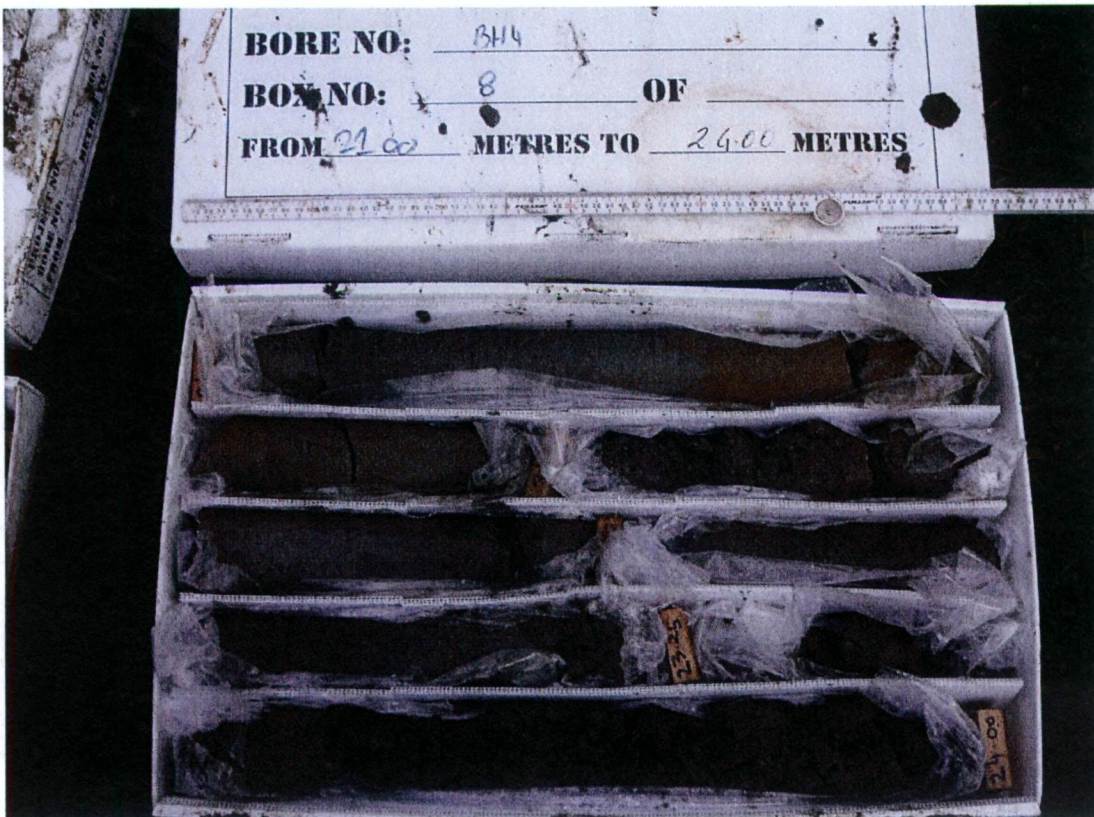


BH 4_Box 06_15.60-18.20m.jpg

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BH 4_Box 07_18.20-21.00m.jpg



BH 4_Box 08_21.00-24.00m_EoB.jpg



TONKIN & TAYLOR LTD

DRILL HOLE LOG

BOREHOLE No: BH4a
 Hole Location: Bush at Service Road Crossing
 SHEET 1 OF 1

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION LOCATION: WAIMA, AUCKLAND JOB No: 27064.001

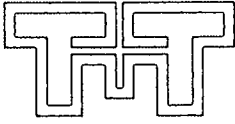
CO-ORDINATES 6472388.01 mN DRILL TYPE: Hand Auger HOLE STARTED: 23/4/10
 2656452.49 mE DATUM: Geodetic 49 HOLE FINISHED: 23/4/10
 DIRECTION: 0.00 ° R.L. GROUND: 109.00 m DRILLED BY: Drill Force
 ANGLE FROM HORIZ.: -90.00 ° R.L. COLLAR: m LOGGED BY: STMM CHECKED: CJL

DESCRIPTION OF CORE										ROCK DEFECTS										
GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);										SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS									
	UW	SW	HW	WW	R4	R2	R1	PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm)	DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX RL (m)
FILL	Silty SAND, dark brown on top becoming orange brown, hard to auger. Fragments of metals, bolts and asbestos																			
	0.9m: CONCRETE END OF BOREHOLE AT 0.9m. Unable to Penetrate. Hole backfilled.																			

Watercare Huia WTP



BH 4A_Box 01_00.00-00.90m_EoB.jpg



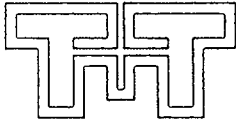
TONKIN & TAYLOR LTD

DRILL HOLE LOG

BOREHOLE No: BH5
Hole Location: Water Tank off Woodlands Park Road
SHEET 1 OF 4

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION **LOCATION:** WAIMA, AUCKLAND **JOB No:** 27064.001
CO-ORDINATES 6472514.35 mN **DRILL TYPE:** 303CR **HOLE STARTED:** 28/4/10
2656481.19 mE **DATUM:** Geodetic 49 **HOLE FINISHED:** 30/4/10
DIRECTION: 0.00 ° **R.L. GROUND:** 121.00 m **DRILLED BY:** Drill Force
ANGLE FROM HORIZ.: -90.00 ° **R.L. COLLAR:** m **LOGGED BY:** STMM **CHECKED:** CJL

DESCRIPTION OF CORE												ROCK DEFECTS									
GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);										DEPTH (m)	GRAPHIC LOG	DEFECT LOG	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX	RL (m)	
	SW	MW	HW	RA	RS	RT	RR	PT	3	10											100
FILL	Clayey SILT, dark brown to orange brown grey mottled. Some cobbles at top, moist, plastic										21.0										
	1m: brick fragments										20.5										
	Silty CLAY, light grey, orange brown mottled, soft, moist, plastic. Some organic fragments and <5mm size lenses of loose, grey, medium SAND										20.0										
COLLUVIUM	2m: size of sandy inclusions increases but <10mm										19.5										
	PUSH TUBE: Core not logged										19.0										
	3.1m: becoming grey clayey SILT, some orange mottles, soft, moist, plastic										18.5										
	3.25m: Fe stained band along relict bedding Silty SAND, grey with medium black and white crystals, loose, moist 3.5m: very loose, wet										18.0										
MW CF	4.15m: 200mm Fe stain										17.5										
	MW, dark grey, medium to coarse SANDSTONE, extremely weak, clasts from sub-rounded to sub-angular										17.0										
											16.5										
											16.0										
											15.5										
											15.0										
											14.5										
											14.0										
											13.5										
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											7.0										
											6.5										
											6.0										
											5.5										
											5.0										



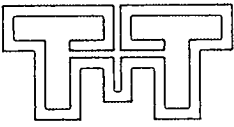
TONKIN & TAYLOR LTD

DRILL HOLE LOG

BOREHOLE No: BH5
 Hole Location: Water Tank off
 Woodlands Park Road
 SHEET 2 OF 4

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION	LOCATION: WAIMA, AUCKLAND	JOB No: 27064.001
CO-ORDINATES 6472514.35 mN 2656481.19 mE	DRILL TYPE: 303CR	HOLE STARTED: 28/4/10
DIRECTION: 0.00 °	DATUM: Geodetic 49	HOLE FINISHED: 30/4/10
ANGLE FROM HORIZ.: -90.00 °	R.L. GROUND: 121.00 m	DRILLED BY: Drill Force
	R.L. COLLAR: m	LOGGED BY: STMM CHECKED: CJL

DESCRIPTION OF CORE				ROCK DEFECTS																		
GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc.);	ROCK WEATHERING		PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm)	ROCK DEFECTS											
		SW	MW								DATE / DEPTH	RCD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX							
MW CORNWALLIS FORMATION	5m: 300mm dark grey, fine SANDSTONE						TT															
	6.35m: 50mm softened, wet						TT															
	6.4m: 150mm SILSTONE, extremely weak, possible contact dipping 10-20°						TT	X X X														
	6.9m: 60mm softened, wet at contact with 100mm coarse SANDSTONE						TT															
	7.85m: 100mm SILTSTONE						TT	X X														
	8.35m: some sub-angular gravel inclusions						TT															
	8.6m: some <10mm coarse loose SAND inclusions						TT															
	9.9m: 10mm wet, uncemented						TT															
							TT															
							TT															



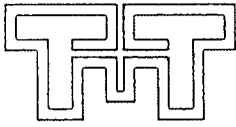
TONKIN & TAYLOR LTD

DRILL HOLE LOG

BOREHOLE No: BH5
 Hole Location: Water Tank off
 Woodlands Park Road
 SHEET 3 OF 4

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION	LOCATION: WAIMA, AUCKLAND	JOB No: 27064.001
CO-ORDINATES 6472514.35 mN 2656481.19 mE	DRILL TYPE: 303CR	HOLE STARTED: 28/4/10
DIRECTION: 0.00 °	DATUM: Geodetic 49	HOLE FINISHED: 30/4/10
ANGLE FROM HORIZ.: -90.00 °	R.L. GROUND: 121.00 m	DRILLED BY: Drill Force
	R.L. COLLAR: m	LOGGED BY: STMM CHECKED: CJL

GEOLOGICAL UNIT	DESCRIPTION OF CORE										ROCK DEFECTS							
	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);	ROCK WEATHERING	ROCK STRENGTH	PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX	RL (m)
MW CORNWALLIS FORMATION	9.95m: 10mm wet, uncemented Grey SILTSTONE, extremely weak										10.25m: Bedding 10°. 10.35m: Polished surface 80°, curved.	80					11.0	
	SILTSTONE, extremely weak, with poorly graded sandy layers 10-20mm thick spacing 50-100mm										10.6m: Bedding 10°.						10.5	
	Dark grey, coarse SANDSTONE, with gravel										11.7m: 100mm highly fractured. Likely drilling induced on sub-vertical joints.	80					10.0	
	12.2m: Grey, medium SANDSTONE, with some inclusion of dark coarse sandstone										12.2m: Bedding 10-20°.						10.5	
	12.5m: Polished surface 60° planar. Softened above for 10mm.										12.5m: Polished surface 60° planar. Softened above for 10mm.	87					08.5	
	12.7m: Crushed 70mm across 2 sub-vertical joints.										12.7m: Crushed 70mm across 2 sub-vertical joints.						08.0	
	13.5m: Highly fractured, coarse SANDSTONE, very weak											13.5m: Joint 90°, planar, rough, tight, clay veneer.	0					07.5
	13.7m: Grey, medium SANDSTONE and inclusions of dark grey, medium sandstone, extremely weak												0					07.0
	14m: Joint 60°, planar, slickensided, tight, clay veneer.										14m: Joint 60°, planar, slickensided, tight, clay veneer.	0						06.5
	SILTSTONE, with poorly cemented 10-20mm thick SANDSTONE												64					15



TONKIN & TAYLOR LTD

DRILL HOLE LOG

BOREHOLE No: BH5
 Hole Location: Water Tank off
 Woodlands Park Road
 SHEET 4 OF 4

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION	LOCATION: WAIMA, AUCKLAND	JOB No: 27064.001
CO-ORDINATES 6472514.35 mN 2656481.19 mE	DRILL TYPE: 303CR DATUM: Geodetic 49	HOLE STARTED: 28/4/10 HOLE FINISHED: 30/4/10
DIRECTION: 0.00 ° ANGLE FROM HORIZ.: -90.00 °	R.L. GROUND: 121.00 m R.L. COLLAR: m	DRILLED BY: Drill Force LOGGED BY: STMM CHECKED: CJL

GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);	ROCK WEATHERING		ROCK STRENGTH		PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING	ANGLES ARE NORMAL TO CORE AXIS	DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX
		UW	SW	MW	FW																
MW CORNWALLIS	SILTSTONE, as previous 15.1m: 150mm medium to coarse SANDSTONE, weak									15.1	TT										Box 6
	SW, dark grey, medium SANDSTONE, extremely weak									15.5	TT										105.5
SW CORNWALLIS FORMATION	SW, dark grey, medium SANDSTONE, extremely weak									16.0	TT			15.95m: Bedding 10°, Fe stained, 10mm softened above.						105.0	
	CONGLOMERATE, poorly cemented, with sub-rounded clasts									16.5	TT									104.5	
	SW, dark grey, medium SANDSTONE, extremely weak									17.0	TT									104.0	
	SW, dark grey, medium SANDSTONE, extremely weak									17.5	TT									103.5	
	END OF BOREHOLE AT 18.85m. Standpipe piezometers installed. See BH5-PZ for details.									18.0	TT									103.0	
										18.5	TT									102.5	
										19.0	TT									102.0	
										19.5	TT									101.5	

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BH 5_Box 01_00.00-03.00m.jpg



BH 5_Box 02_03.00-05.55m.jpg

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BH 5_Box 03_05.55-08.35m.jpg



BH 5_Box 04_08.35-10.55m.jpg

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BH 5_Box 05_10.55-12.95m.jpg

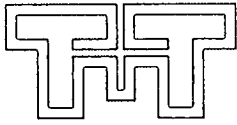


BH 5_Box 06_12.95-15.85m.jpg

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BH 5_Box 07_15.85-18.85m_EoB.jpg



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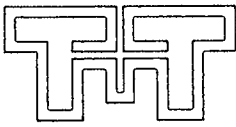
DRILL HOLE LOG

BOREHOLE No: BH6

Hole Location: Spillway

SHEET 3 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION		LOCATION: WAIMA, AUCKLAND		JOB No: 27064.001																	
CO-ORDINATES 6472345.08 mN 2656517.81 mE		DRILL TYPE: 303CR		HOLE STARTED: 3/5/10																	
DIRECTION: 0.00 °		DATUM: Geodetic 49		HOLE FINISHED: 4/5/10																	
ANGLE FROM HORIZ.: -90.00 °		R.L. GROUND: 106.75 m		DRILLED BY: Drill Force																	
		R.L. COLLAR: m		LOGGED BY: STMM CHECKED: CJL																	
DESCRIPTION OF CORE				ROCK DEFECTS																	
GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);	ROCK WEATHERING			PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing or natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING	ANGLES ARE NORMAL TO CORE AXIS	DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX	RL (m)
		UW	SW	MW																	
HW/CW CORNWALLIS FORMATION	SANDSTONE, as previous												9.95m: Sub-vertical joint 5mm opened, Fe stained.								96.5
	10.35m: becoming very coarse, dense, wet																				96.0
	11m: 100mm Fe stain													11.2m: 2 relict joints 50°, spaced 150mm.							95.5
	11.75m: becoming medium grained																				95.0
MW CORNWALLIS FORMATION	Light grey, medium SANDSTONE, weak, highly fractured at top																				94.5
	Light grey pink hue, medium SANDSTONE, weak, highly fractured, likely drilling induced																				94.0
	SW CONGLOMERATE, weak													13.4m: 2x Joints 60° cross-cutting, planar, smooth, clean.			33				93.5
														13.6m: Joint 80°, irregular, rough, tight, clean.							93.0
																					92.5
	MW, grey, medium SANDSTONE, very weak													14.2m: Joint 40°, irregular, rough, tight, clean.							92.0
														14.75m: Joint 80-90°, irregular, rough, tight, clean, core highly fractured all around.							92.0



TONKIN & TAYLOR LTD

DRILL HOLE LOG

BOREHOLE No: BH6

Hole Location: Spillway

SHEET 5 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION LOCATION: WAIMA, AUCKLAND JOB No: 27064.001

CO-ORDINATES 6472345.08 mN DRILL TYPE: 303CR HOLE STARTED: 3/5/10
 2656517.81 mE DATUM: Geodetic 49 HOLE FINISHED: 4/5/10
 DIRECTION: 0.00° R.L. GROUND: 106.75 m DRILLED BY: Drill Force
 ANGLE FROM HORIZ.: -90.00° R.L. COLLAR: m LOGGED BY: STMM CHECKED: CJL

DESCRIPTION OF CORE										ROCK DEFECTS					
GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc.);										SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS				
	PT LOAD / UCS TEST (MPa)	ROCK WEATHERING	ROCK STRENGTH	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG	DATE / DEPTH	RQD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX RL (m)
MW CORNWALLIS FORMATION	20.4m: 100mm layer of SANDSTONE, extremely weak	SW	W	3	TT	TT	20.4		5		0			86.5	
	21.15m: becoming fine grained	SW	W	10	TT	TT	21.15		10		0			86.0	
	21.7m: becomes coarse	SW	W	100	TT	TT	21.7		5		0			85.0	
	Contact sharp, SILTSTONE, extremely weak	SW	W	100	TT	TT	22.2	XXXXXX	1		0			84.5	
END OF BOREHOLE AT 22.5m.						22.5							84.0		
Standpipe piezometers installed. See BH6-PZ for details.						23.0							83.5		
						23.5							83.0		
						24.0							82.5		
						24.5							82.0		

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BH 6_Box 01_00.00-03.90m.jpg



BH 6_Box 02_03.90-07.40m.jpg

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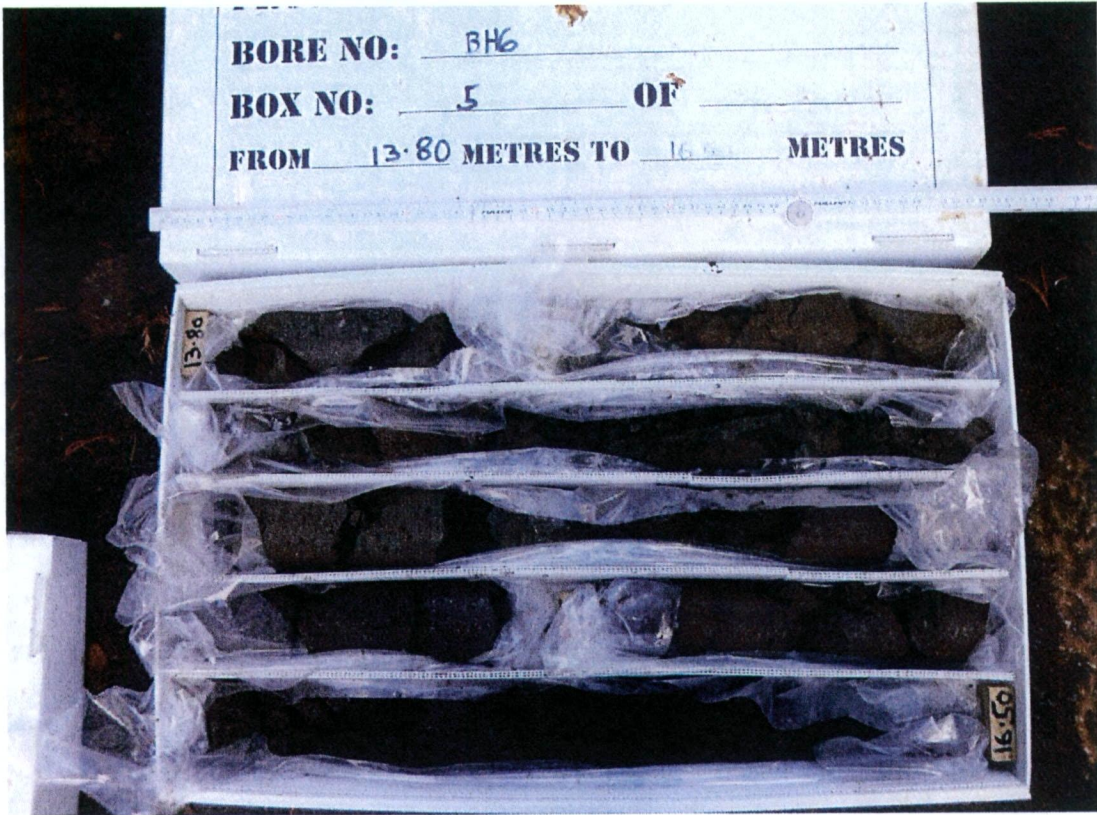


BH 6_Box 03_07.40-10.10m.jpg



BH 6_Box 04_10.10-13.80m.jpg

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BH 6_Box 05_13.80-16.50m.jpg

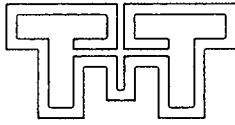


BH 6_Box 06_16.50-19.50m.jpg

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BH 6_Box 07_19.50-22.50m_EoB.jpg



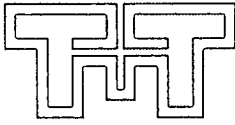
TONKIN & TAYLOR LTD

DRILL HOLE LOG

BOREHOLE No: BH7
 Hole Location: Bush Next to
 Creek
 SHEET 1 OF 3

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION	LOCATION: WAIMA, AUCKLAND	JOB No: 27064.001
CO-ORDINATES 6472523.43 mN 2656412.11 mE	DRILL TYPE: Sonic Rig	HOLE STARTED: 5/5/10
DIRECTION: 0.00°	DATUM: Geodetic 49	HOLE FINISHED: 5/5/10
ANGLE FROM HORIZ.: -90.00°	R.L. GROUND: 120.50 m	DRILLED BY: DCN Drilling Ltd
	R.L. COLLAR: m	LOGGED BY: STMM CHECKED: CJL

DESCRIPTION OF CORE										ROCK DEFECTS												
GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);	ROCK WEATHERING		ROCK STRENGTH		PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING	ANGLES ARE NORMAL TO CORE AXIS	DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX	
		UW	SW	R4	R3																	R2
COLLUVIUM	Silty CLAY, slightly sandy, soft to firm, moist, low plasticity, some organic fragments. Some white laminations possibly sub-horizontal																					
	Silty CLAY, light grey orange mottled, stiff, moist, plastic, numerous Fe stains																					
	Sandy SILT, soft, moist, non-plastic																					
	1.5m: Silty CLAY, as above 1.6m: Fe stain increasing for 200mm 1.7m: becoming more sandy																					
	Sandy SILT, light grey orange mottled, very soft, wet, plastic, some Fe stain																					
MW CORNWALLIS FORMATION	2.75m: becoming grey, some Fe stained																					
	CLAY, silty in places, very stiff to hard, moist, plastic Some silty-sandy layers 10-15mm thick, moderately dense, few carbonaceous fragments																					
	3.6m: 50mm sandy layer, loose, wet																					
	3.8m: ripped clasts of black carbonaceous clayey SILT																					
	4m: becoming dark grey, carbonaceous content increases, soft, moist 4.1m: 100mm black carbonaceous clay band 4.2m: some ripped sandy clasts																					
4.6m: 100mm very soft, wet																						



TONKIN & TAYLOR LTD

DRILL HOLE LOG

BOREHOLE No: BH7

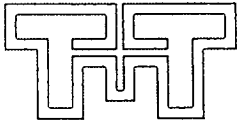
Hole Location: Bush Next to Creek

SHEET 2 OF 3

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION LOCATION: WAIMA, AUCKLAND JOB No: 27064.001

CO-ORDINATES 6472523.43 mN
2656412.11 mE DRILL TYPE: Sonic Rig HOLE STARTED: 5/5/10
DIRECTION: 0.00° DATUM: Geodetic 49 HOLE FINISHED: 5/5/10
ANGLE FROM HORIZ.: -90.00° R.L. GROUND: 120.50 m DRILLED BY: DCN Drilling Ltd
R.L. COLLAR: m LOGGED BY: STMM CHECKED: CJL

DESCRIPTION OF CORE										ROCK DEFECTS												
GEOLOGICAL UNIT	ROCK WEATHERING			ROCK STRENGTH			PT LOAD / UCS TEST (MPa)	CORE LOSS TEST (MPa) /LIFT (%)	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING	ANGLES ARE NORMAL TO CORE AXIS	DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX	CORE BOX RL (m)
	UN	SW	MM	RM	R4	R2																
MW CORNWALLIS FORMATION	4.95m: carbonaceous inclusions																					
	Sandy SILT, very stiff, moist, low plasticity. Interbed 2+3mm thick purple clay, firm, plastic, dipping 10-15°, some green-blue gravel clasts																					
	Clayey SILT, slightly sandy, dark purple grey mottled, firm, moist, high plasticity, some sub-rounded fine gravel inclusions Clasts of dark grey, brown hue fine to medium SANDSTONE, extremely weak within area of SAND																					
	Silty CLAY, grey orange mottled, with dark grey sandy inclusions, very stiff, moist, plastic																					
	Medium SAND, dark grey, with some gravel clasts, medium dense, wet, some clasts of sandstone																					
	Sandy SILT, light grey brown mottled, firm, moist, non-plastic, with sandy inclusions																					
	Silty SAND, light grey, very dense																					
	9.1m: some sandstone inclusions 9.15m: becoming SAND, very loose, wet																					
	9.4m: becoming very dense																					
	5.25m: Bedding 10-15°.																					
9.15m: Fragments of polished surface of unknown orientation.																						
9.4m: 10-15° parting.																						



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DRILL HOLE LOG

BOREHOLE No: BH7
 Hole Location: Bush Next to
 Creek
 SHEET 3 OF 3

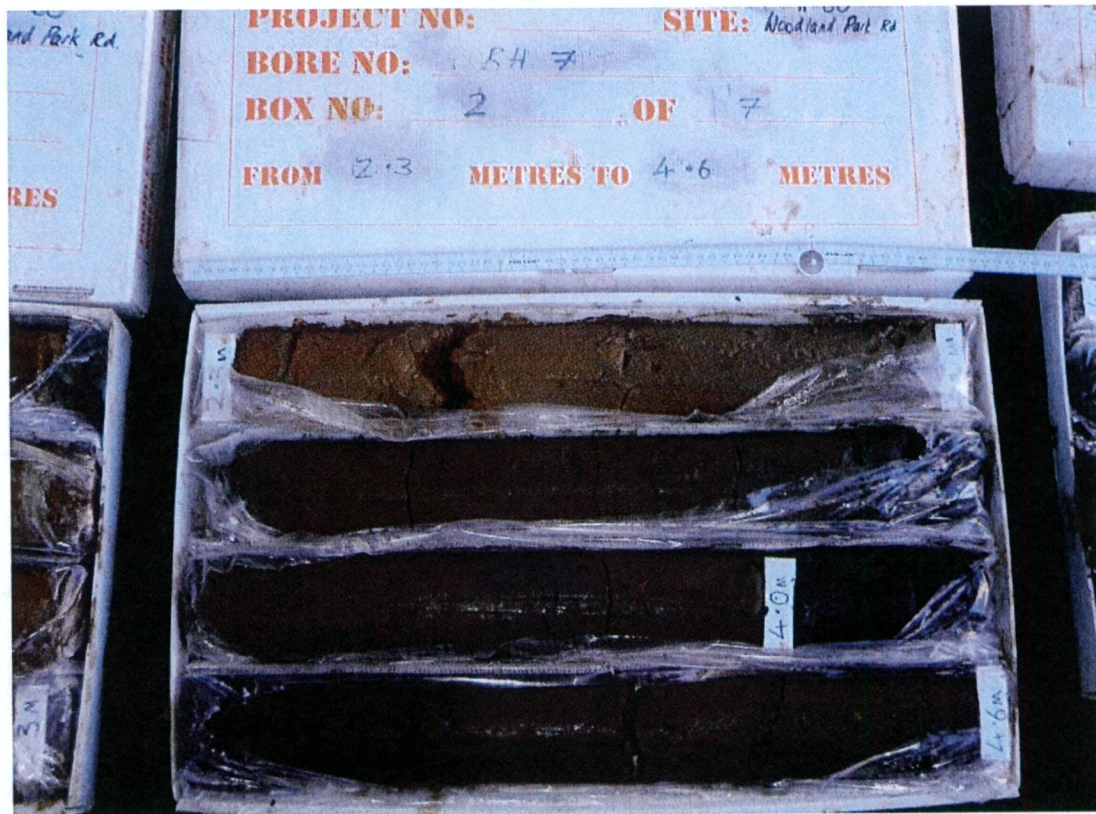
PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION	LOCATION: WAIMA, AUCKLAND	JOB No: 27064.001
CO-ORDINATES 6472523.43 mN 2656412.11 mE	DRILL TYPE: Sonic Rig	HOLE STARTED: 5/5/10
DIRECTION: 0.00°	DATUM: Geodetic 49	HOLE FINISHED: 5/5/10
ANGLE FROM HORIZ.: -90.00°	R.L. GROUND: 120.50 m	DRILLED BY: DCN Drilling Ltd
	R.L. COLLAR: m	LOGGED BY: STMM CHECKED: CJL

DESCRIPTION OF CORE	ROCK DEFECTS																			
GEOLOGICAL UNIT	ROCK WEATHERING	ROCK STRENGTH	PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS									
											DATE / DEPTH	RQD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX					
Grey, medium to coarse SANDSTONE, extremely weak, clasts in sub-angular																				
10.5m: becoming coarse							10.5													
11.1m: becoming medium grained							11.0													
Grey, CONGLOMERATE, extremely weak							11.5													
SW CORNWALLIS FORMATION							12.0													
	Fine SANDSTONE, with some 10mm thick SILTSTONE layers						12.5													
							13.0													
							13.5													
Grey, coarse SANDSTONE, very weak							14.0													
							14.5													
END OF BOREHOLE AT 15m. Standpipe piezometers installed. See BH7-PZ for details.							15.0													

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BH 7_Box 01_00.00-02.30m.jpg



BH 7_Box 02_02.30-04.60m.jpg

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BH 7_Box 03_04.60-06.70m.jpg



BH 7_Box 04_06.70-08.80m.jpg

Watercare Huia WTP

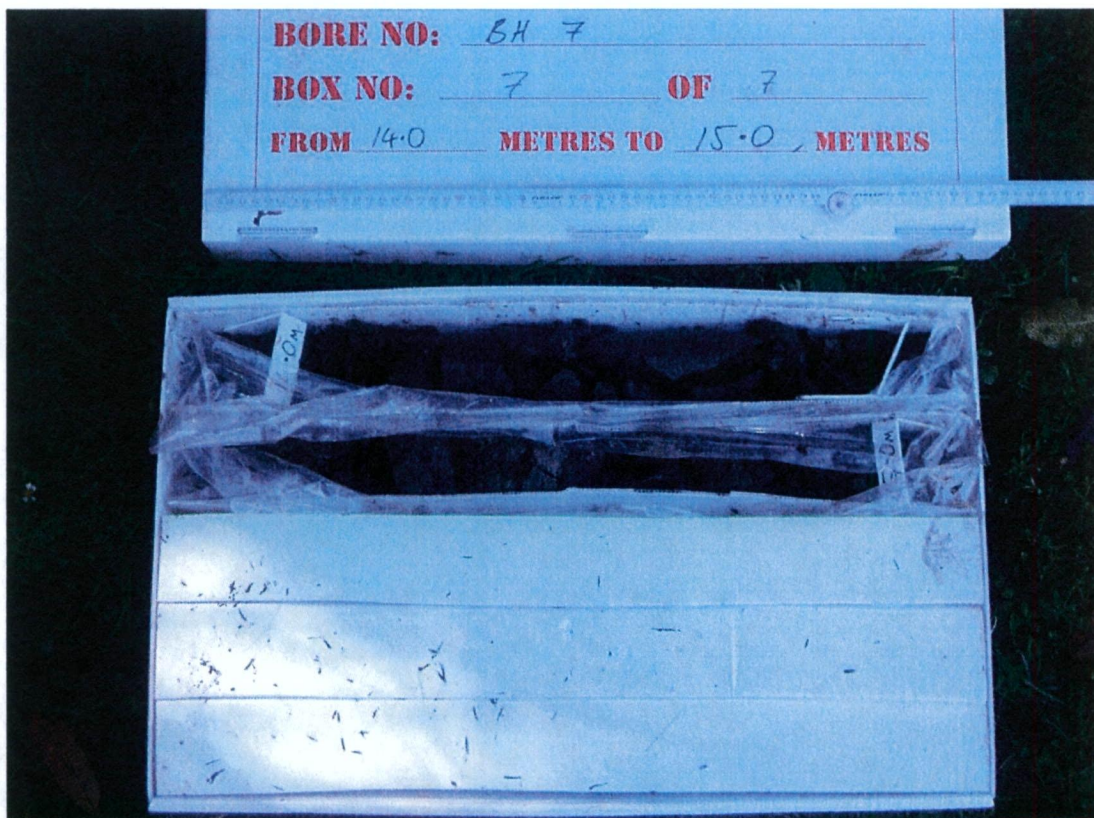


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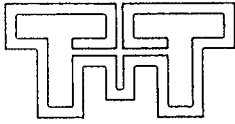


BH 7_Box 06_11.10-14.00m.jpg

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BH 7_Box 07_14.00-15.00m_EoB.jpg



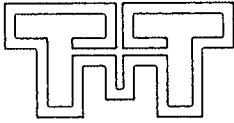
TONKIN & TAYLOR LTD

DRILL HOLE LOG

BOREHOLE No: BH8
 Hole Location: North of Raw
 Water Aqueduct
 SHEET 2 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION LOCATION: WAIMA, AUCKLAND JOB No: 27064.001
 CO-ORDINATES 6472495. mN DRILL TYPE: Sonic Rig HOLE STARTED: 6/5/10
 2656365. mE DATUM: Geodetic 49 HOLE FINISHED: 7/5/10
 DIRECTION: 0.00 ° R.L. GROUND: 124.00 m DRILLED BY: DCN Drilling Ltd
 ANGLE FROM HORIZ.: -90.00 ° R.L. COLLAR: m LOGGED BY: CJL/STMM CHECKED: CJL

GEOLOGICAL UNIT	ROCK WEATHERING	ROCK STRENGTH	PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX	
COLLUVIUM	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc.):										DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING						
	Clayey, medium to coarse SAND, orange brown, loose, rare light brown clay seams 5.45m: coarse grained with rare fine gravels 5.7m: 5mm bluish grey clay seam, orientation unknown, very soft Below 5.7m becoming medium to coarse, with rare carbonaceous fragments																
CW/HW CORNWALLIS FORMATION	SILT/CLAY, orange brown, very soft, moderate plasticity																
	Medium to coarse SAND, orange brown, dense 6.8m: 5mm light brown clay seam at 45°, with carbonaceous inclusions, very soft Below 7.3m: as previous but relict bedding visible in places with 20mm zones of fine sand or silt, bedding orientation approx. 20°, silt clay zones along bedding in places up to 5-10mm thick											7.3m: Bedding 20°.					
	Clayey, medium to coarse SAND, orange brown, dense, some zones of core more clay rich than others 9.4m: becoming coarse 9.6m: becoming medium coarse Brown, fine SANDSTONE/SILTSTONE, extremely weak											9.4m: 5mm clay seam 1° dipping at contact, some Fe stain. 9.6m: Clay seam at 45°, 2mm thick, brown to black Fe stain. 9.8m: Bedding 20°.					



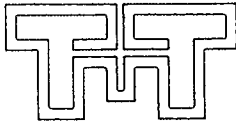
TONKIN & TAYLOR LTD

DRILL HOLE LOG

BOREHOLE No: BH8
 Hole Location: North of Raw
 Water Aqueduct
 SHEET 3 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION		LOCATION: WAIMA, AUCKLAND		JOB No: 27064.001	
CO-ORDINATES 6472495. mN 2656365. mE		DRILL TYPE: Sonic Rig		HOLE STARTED: 6/5/10	
DIRECTION: 0.00 °		DATUM: Geodetic 49		HOLE FINISHED: 7/5/10	
ANGLE FROM HORIZ.: -90.00 °		R.L. GROUND: 124.00 m		DRILLED BY: DCN Drilling Ltd	
		R.L. COLLAR: m		LOGGED BY: CJL/STMM CHECKED: CJL	

DESCRIPTION OF CORE										ROCK DEFECTS													
GEOLOGICAL UNIT	ROCK WEATHERING					PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING	ANGLES ARE NORMAL TO CORE AXIS	DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX	RL (m)	
	SW	MW	NW	R4	R2																		
SANDSTONE, as previous Clayey, medium to coarse SAND, orange brown, dense, some zones of core more clay rich than others 11.6m: becoming loose to medium dense 11.82m: 10mm brown CLAY seam, soft, moist, plastic. Breaking in sub-horizontal laminae, not polished Brown, medium SANDSTONE, extremely weak, some sub-rounded clasts 12.6m: becoming coarse, moist, disaggregated to SAND 13.2m: becoming medium SANDSTONE, extremely weak CONGLOMERATE, wet, recovered as medium dense, coarse SAND. Clasts are sub-rounded to sub-angular, white, brown and green in colour Coarse SANDSTONE, with up to 50mm long fragments of coarse sandstone, extremely weak																							



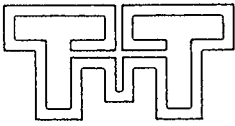
TONKIN & TAYLOR LTD

DRILL HOLE LOG

BOREHOLE No: BH8
 Hole Location: North of Raw Water Aqueduct
 SHEET 4 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION	LOCATION: WAIMA, AUCKLAND	JOB No: 27064.001
CO-ORDINATES 6472495. mN 2656365. mE	DRILL TYPE: Sonic Rig	HOLE STARTED: 6/5/10
DIRECTION: 0.00 °	DATUM: Geodetic 49	HOLE FINISHED: 7/5/10
ANGLE FROM HORIZ.: -90.00 °	R.L. GROUND: 124.00 m	DRILLED BY: DCN Drilling Ltd
	R.L. COLLAR: m	LOGGED BY: CJL/STMM CHECKED: CJL

GEOLOGICAL UNIT	DESCRIPTION OF CORE										ROCK DEFECTS							
	ROCK WEATHERING	ROCK STRENGTH	PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX		
CW/HW CORNWALLIS FORMATION	SANDSTONE, as previous																	
	Medium SAND, dense, moist																	
	Coarse SANDSTONE, extremely weak, clasts are from sub-angular to sub-rounded																	
	16.2m: softened and becoming wet, medium SANDSTONE, with some sub-rounded clasts up to 10mm size														15.6m: Joint 30°, planar, rough.			
	16.6m: 200mm medium SANDSTONE, extremely weak														15.9m: Joint 30°, planar, rough.			
MW CORNWALLIS FORMATION	17.1m: becoming CONGLOMERATE, recovered as dense, coarse SAND, moist to wet														16.2m: 10mm Fe stained band, 10° dipping.			
	Grey, brown hue CONGLOMERATE, very weak														17.1m: Bedding 10-20°.			
	19m: recovered only few fragments of conglomerate														18.5m: 100mm highly fractured along Joint 80°, planar, rough, Fe stained.			
	CORE LOSS from 19.5 to 20m																	



TONKIN & TAYLOR LTD

DRILL HOLE LOG

BOREHOLE No: BH8

Hole Location: North of Raw Water Aqueduct

SHEET 5 OF 5

PROJECT: HUIA WATER TREATMENT PLANT INVESTIGATION		LOCATION: WAIMA, AUCKLAND		JOB No: 27064.001	
CO-ORDINATES 6472495. mN 2656365. mE		DRILL TYPE: Sonic Rig		HOLE STARTED: 6/5/10	
DIRECTION: 0.00 °		DATUM: Geodetic 49		HOLE FINISHED: 7/5/10	
ANGLE FROM HORIZ.: -90.00 °		R.L. GROUND: 124.00 m		DRILLED BY: DCN Drilling Ltd	
		R.L. COLLAR: m		LOGGED BY: CJL/STMM CHECKED: CJL	

DESCRIPTION OF CORE										ROCK DEFECTS										
GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...)	ROCK WEATHERING		ROCK STRENGTH		PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%)	METHOD, CORE & CASING	TEST SYMBOL DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG Sign of natural fractures (cm)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS	DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING	ANGLES ARE NORMAL TO CORE AXIS	DATE / DEPTH	ROD (%)	WATER	DRILL WATER LOSS (%)	CORE BOX RL (m)
		UW	SW	WV	WV															
MW CORNWALLIS	MW, grey with brown hue, coarse SANDSTONE, very weak								TT											04.6
SW CORNWALLIS FORMATION	20.5m: becoming a CONGLOMERATE								TT				20.5m: 30° contact, heavy Fe stain.							03.5
	SW CONGLOMERATE, grey, sub-rounded to sub-angular clasts, very weak								TT											03.0
	Sharp contact with dark grey SILTSTONE, very weak, 50mm thick Sharp contact with grey, fine SANDSTONE, very weak									TT				21.55m: Bedding 22°. 21.6m: Bedding 22°.						02.5
22.2m: becoming medium grained									TT				22.1m: Disk breaking. 22.15m: Carbonaceous band, dipping 20°. 22.25m: Carbonaceous band, dipping 20°.						02.0	
END OF BOREHOLE AT 22.5m.	Standpipe piezometers installed. See BH8-PZ for details.																			01.5
																				01.0
																				00.5
																				00.0
																				99.5

Watercare Huia WTP



BH 8_Box 01_00.00-02.50m.jpg



BH 8_Box 02_02.50-04.90m.jpg

Watercare Huia WTP



BH 8_Box 03_04.90-07.00m.jpg



BH 8_Box 04_07.00-09.10m.jpg

Watercare Huia WTP



BH 8_Box 05_09.10-11.20m.jpg

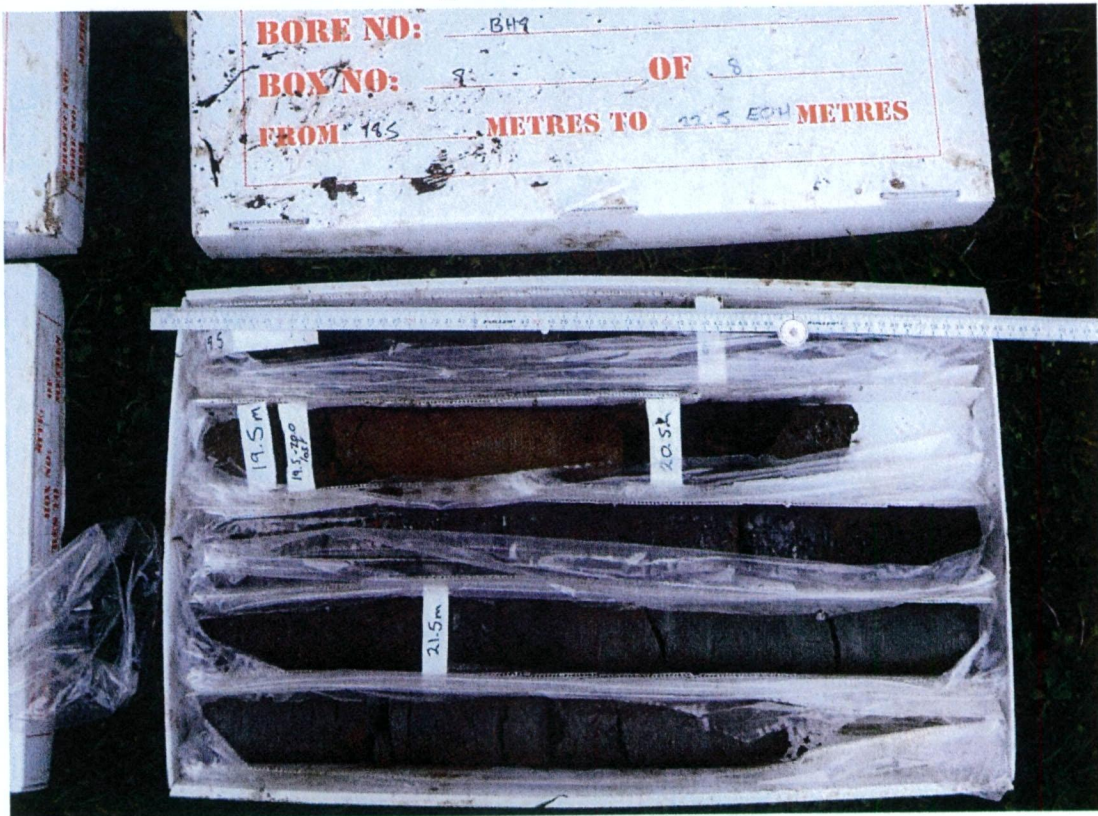


BH 8_Box 06_11.20-14.30m.jpg

Watercare Huia WTP



BH 8_Box 07_14.30-18.50m.jpg



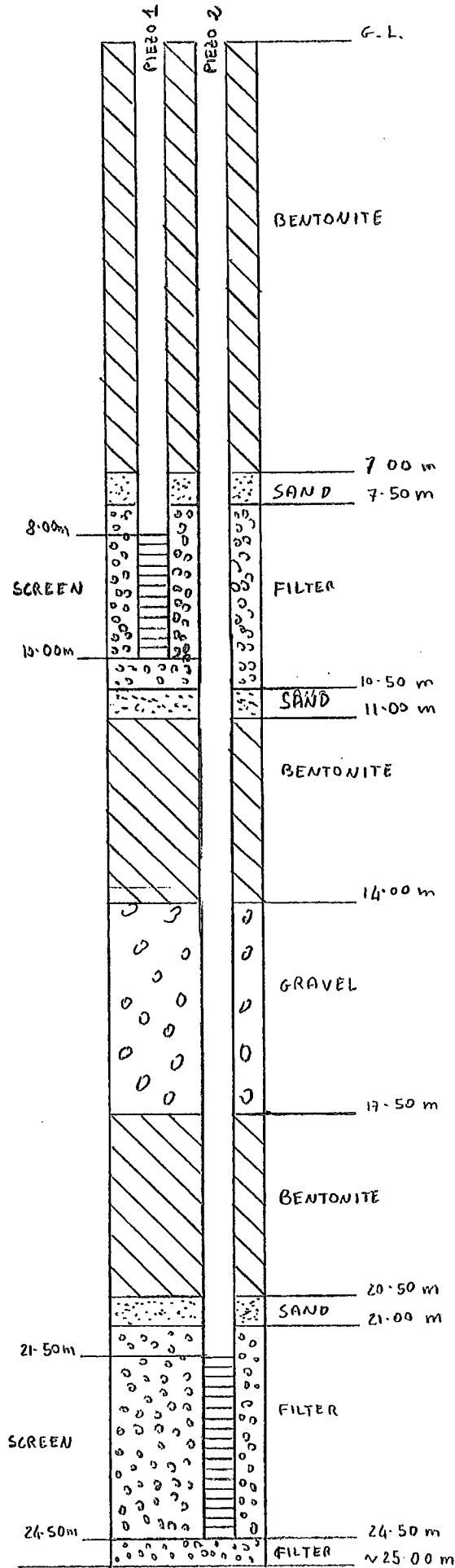
BH 8_Box 08_18.50-22.50m_EoB.jpg

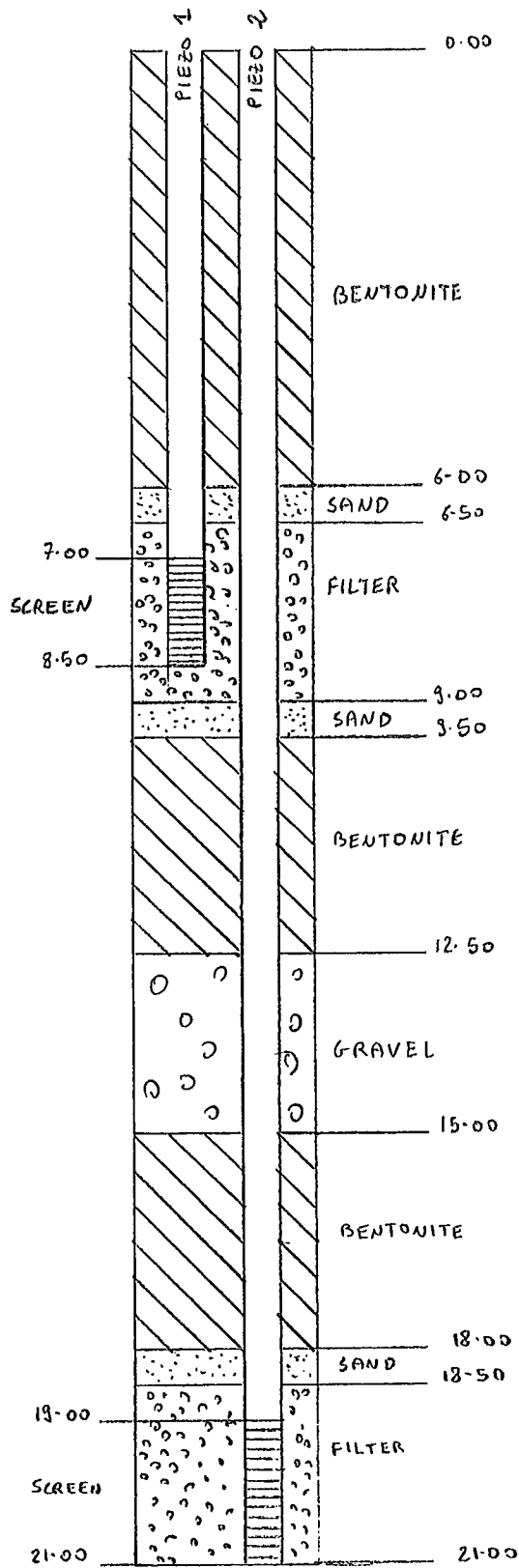
Appendix C:

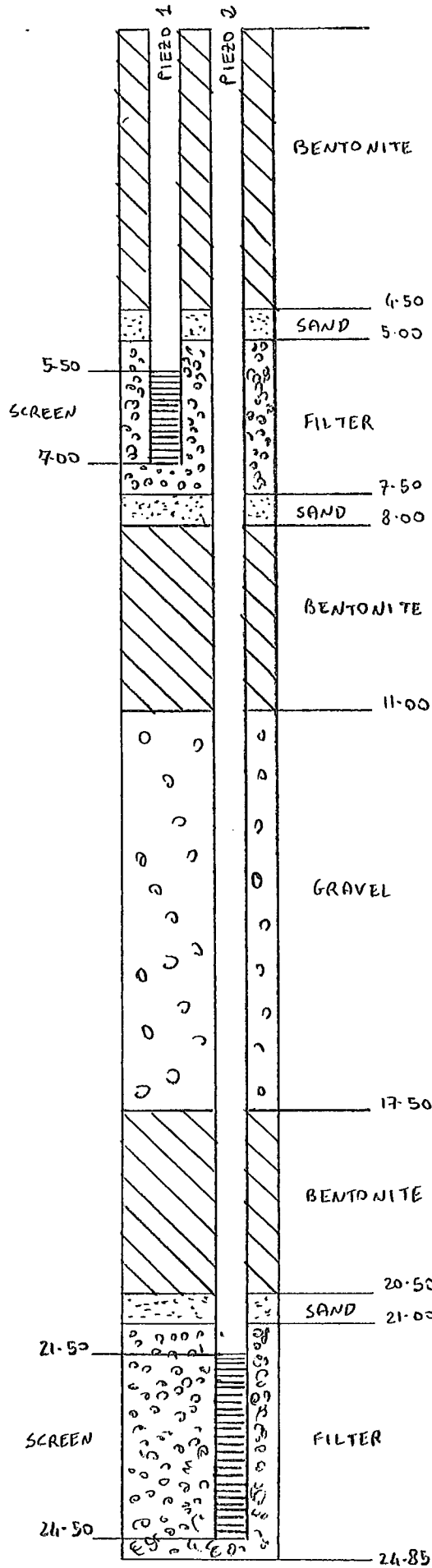
Piezometer and groundwater data

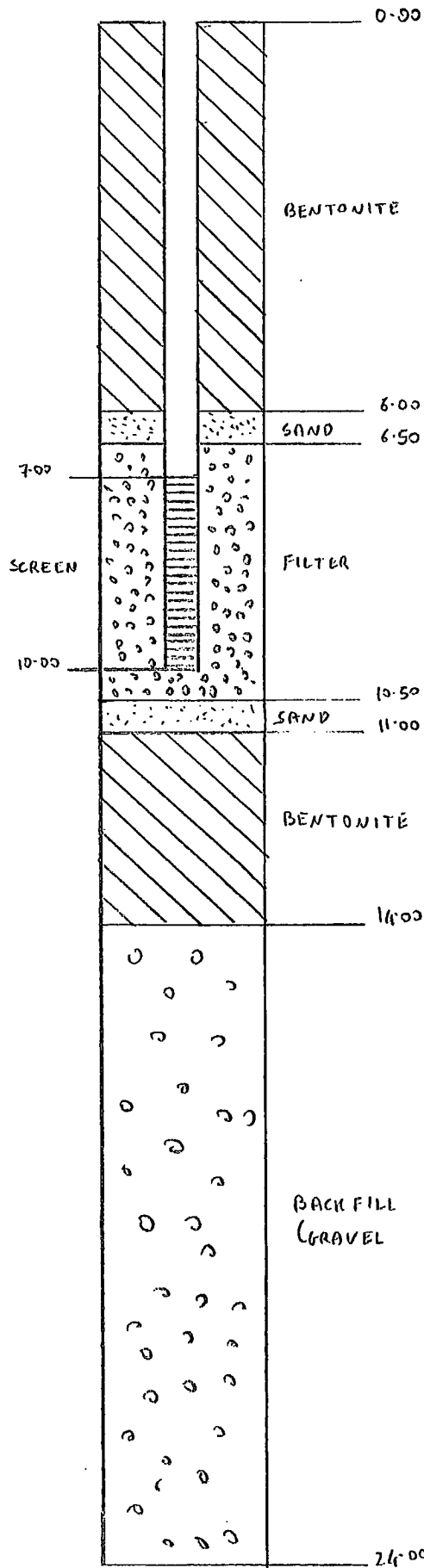
Table 3 – Summary of piezometer and diver installations

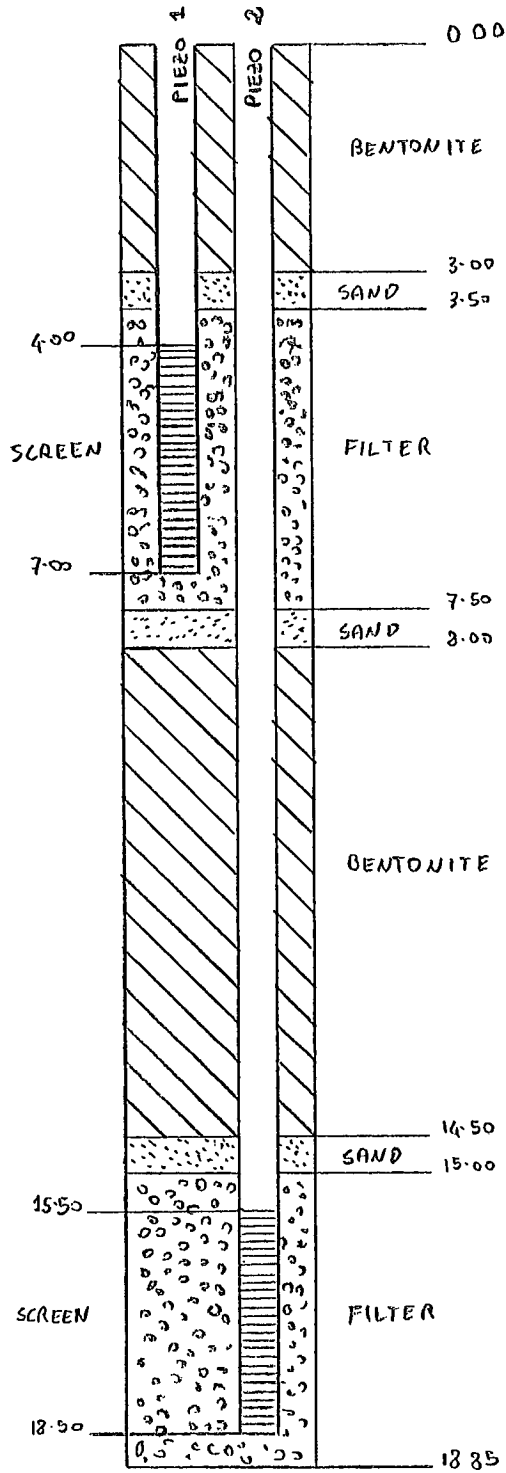
Borehole	Piezometer	Piezometer screen	Piezometer filter	Diver depth
BH 1	Piezometer 1	8.0-10.0 m	7.0-11.0 m	9.3 m
	Piezometer 2	21.5-24.5 m	20.5-25.0 m	Not installed
BH 2	Piezometer 1	7.0-8.5 m	6.0-9.5 m	Not installed
	Piezometer 2	19.0-21.0 m	18.0-21.0 m	Not installed
BH 3	Piezometer 1	5.5-7.0 m	4.5-8.0 m	Not installed
	Piezometer 2	21.5-24.5 m	20.5-24.85 m	23.3 m
BH 4	Piezometer 1	7.0-10.0 m	6.0-11.0 m	Not installed
BH 5	Piezometer 1	4.0-7.0 m	3.0-8.0 m	5.3 m
	Piezometer 2	15.5-18.5 m	14.5-18.85 m	Not installed
BH 6	Piezometer 1	9.0-12.0 m	8.0-13.0 m	10.7 m
	Piezometer 2	19.5-22.5 m	18.5-22.5 m	Not installed
BH 7	Piezometer 1	8.0-10.0 m	7.5-10.5 m	Not installed
	Piezometer 2	13.0-15.0 m	12.5-15.0 m	Not installed
BH 8	Piezometer 1	4.5-6.5 m	3.5-7.5 m	Not installed
	Piezometer 2	17.5-19.5 m	16.5-20.5 m	Not installed

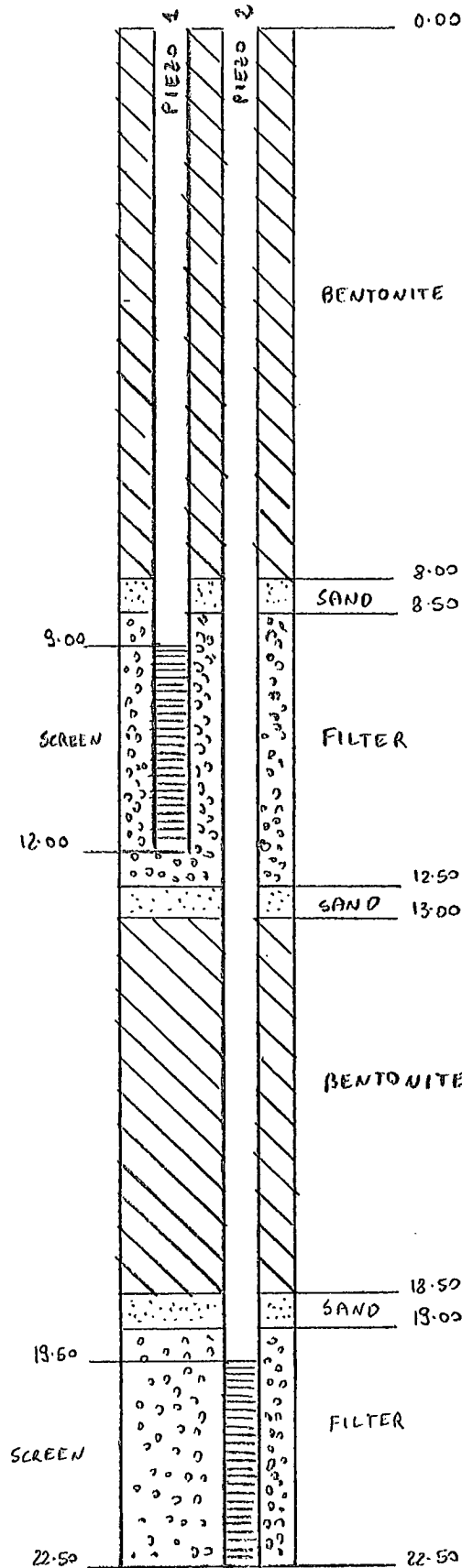


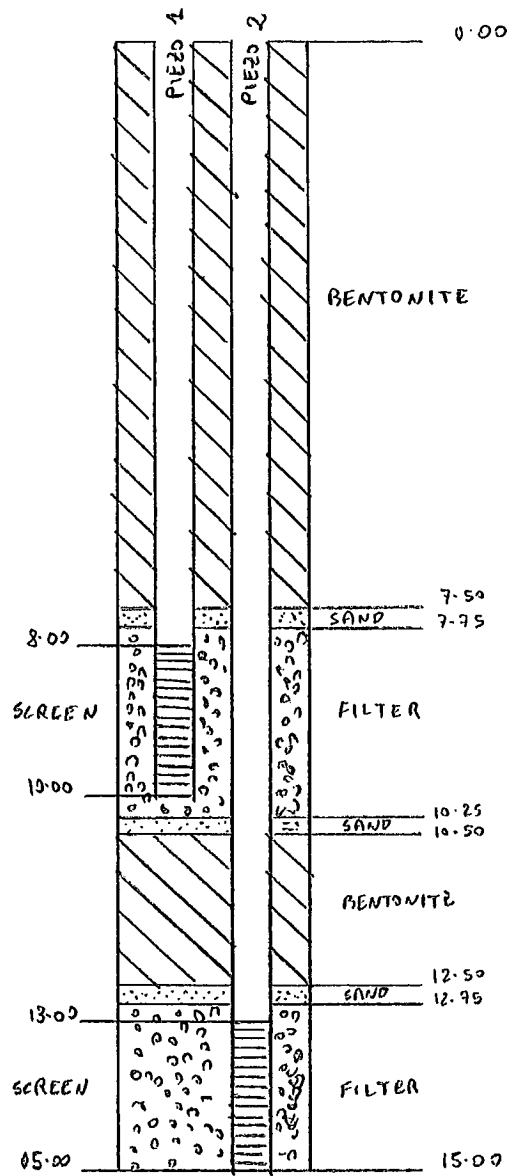


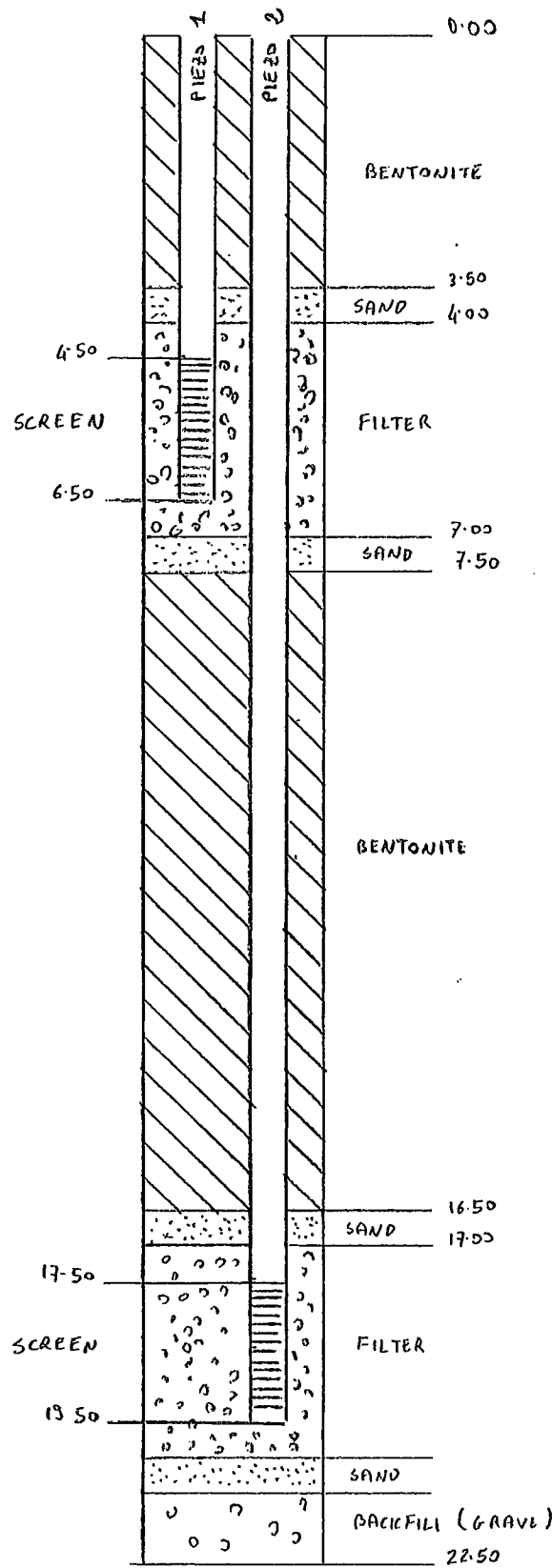




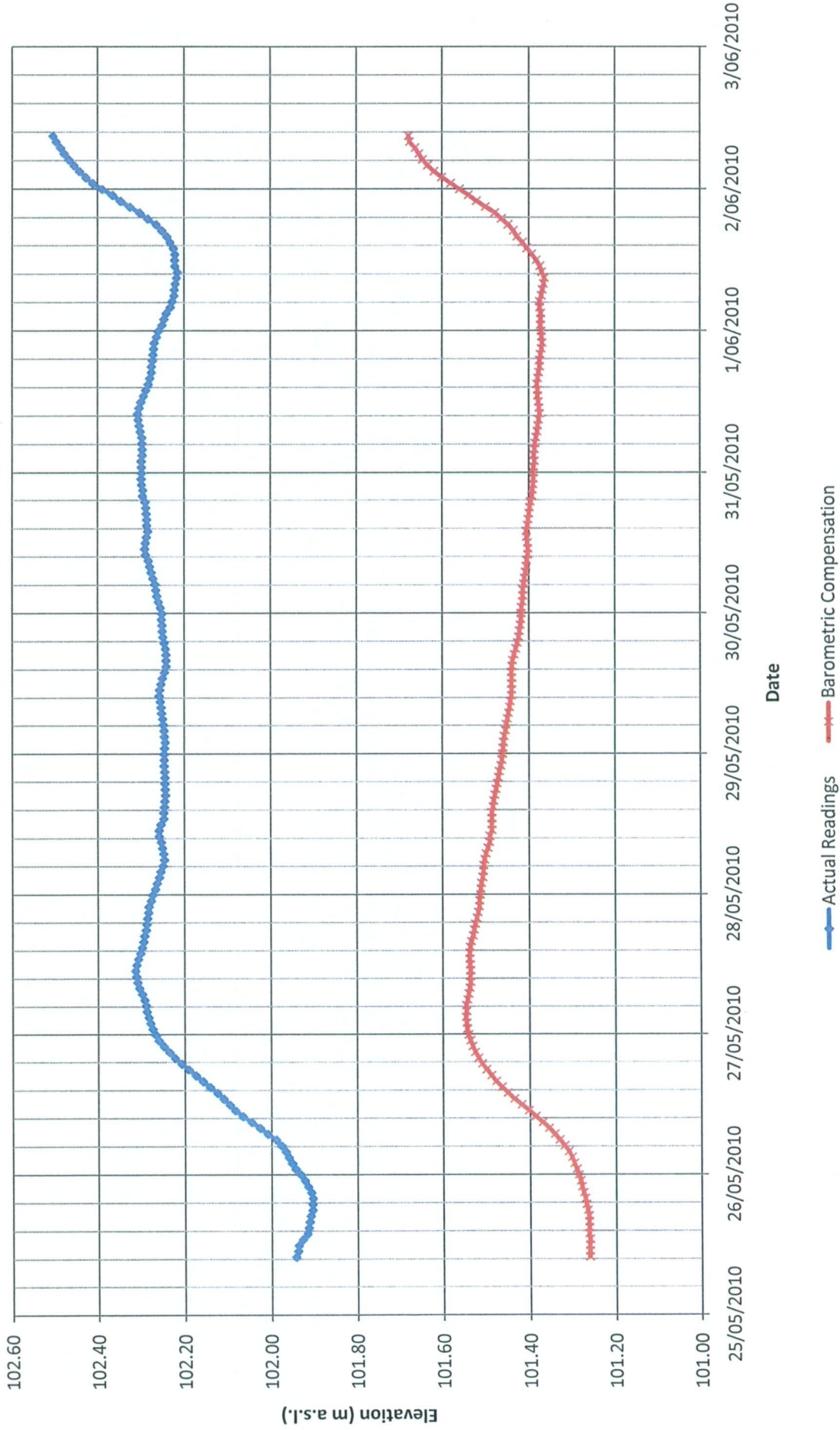




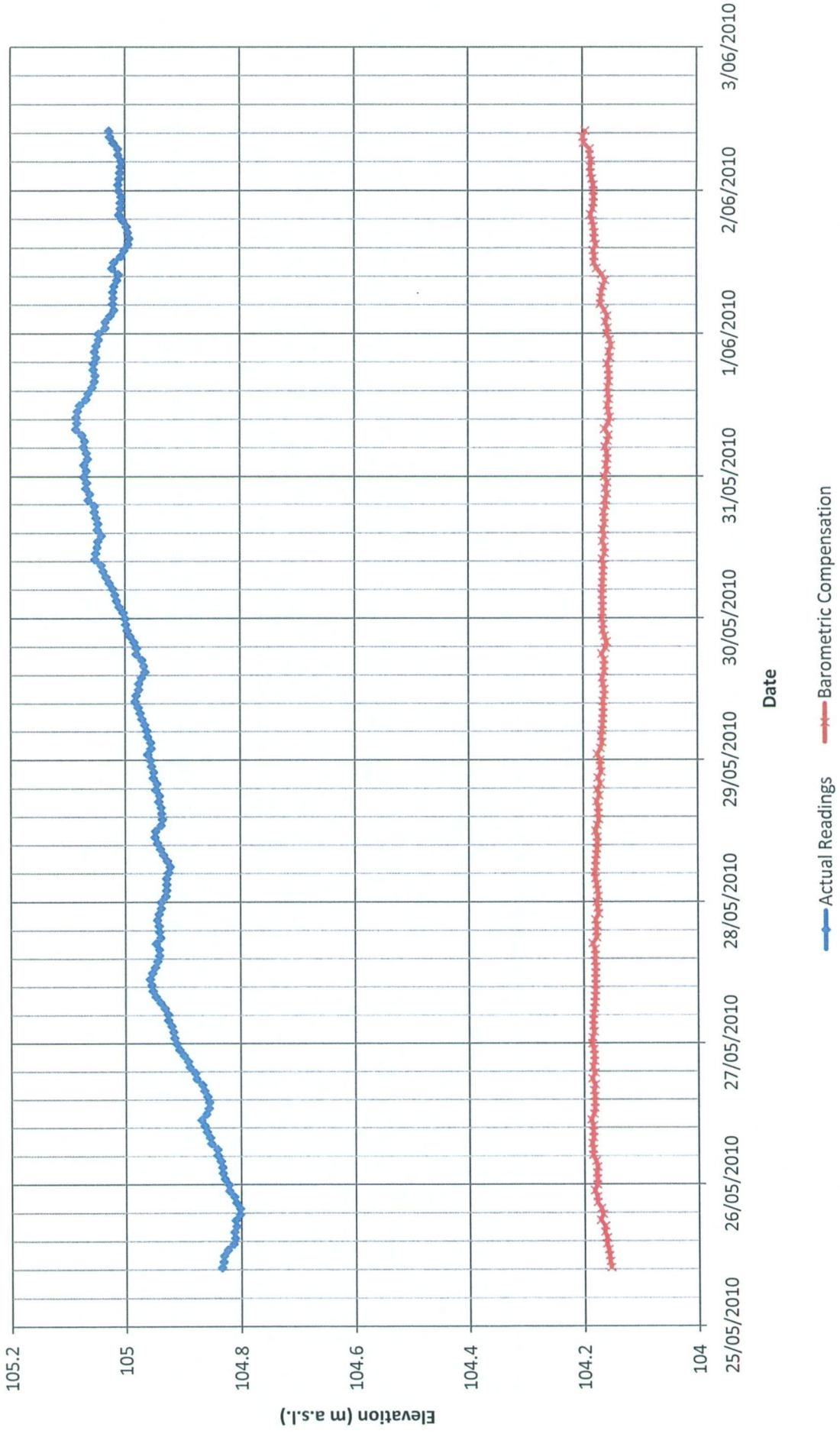




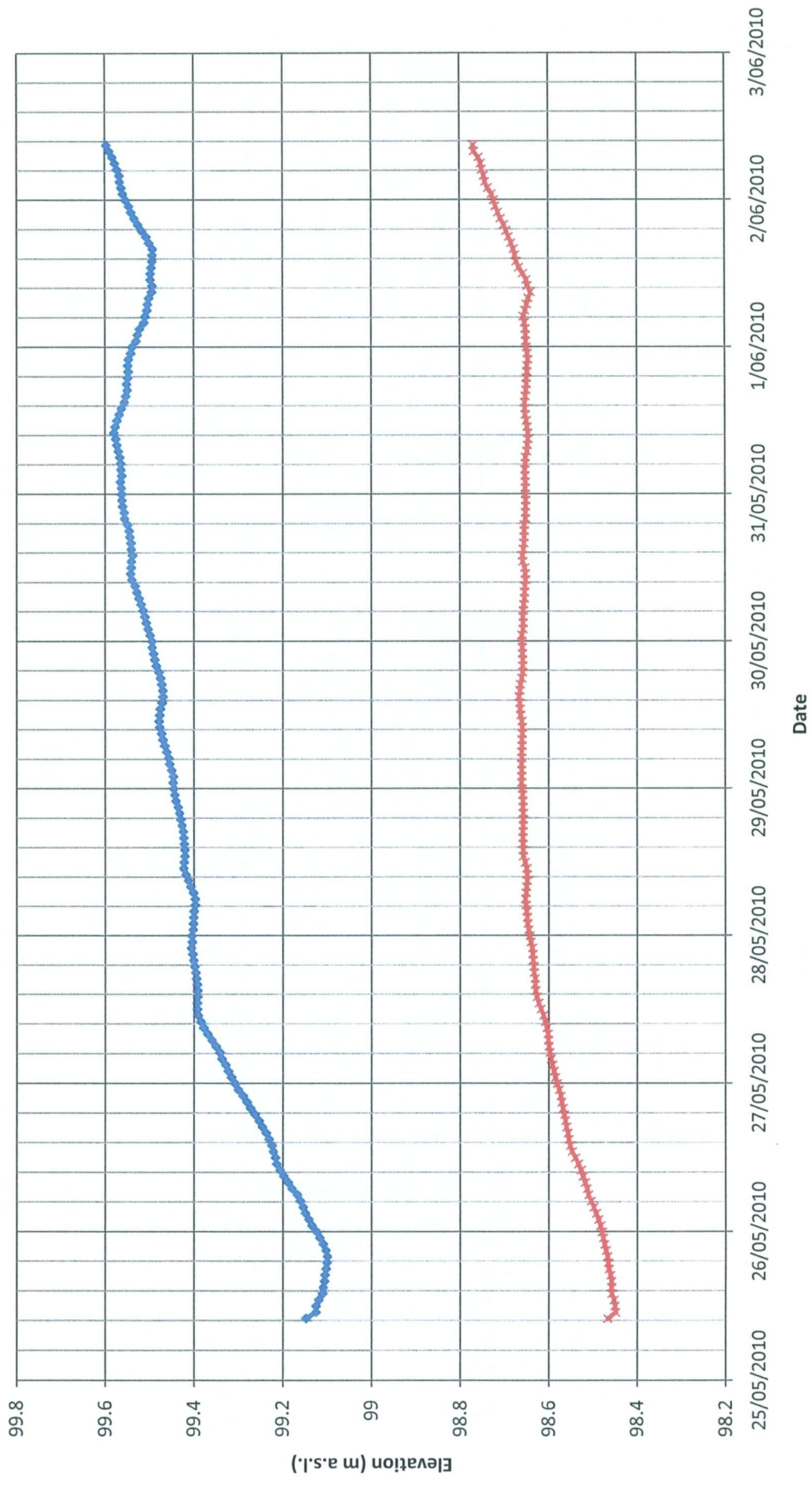
Huia Watercare Treatment Plant - Diver BH 1; depth 9.3m b.c. (CW-HW Cornwallis Formation)



**Huia Watercare Treatment Plant - Diver BH 3; depth 23.3m b.c.
(MW-SW Cornwallis Formation)**



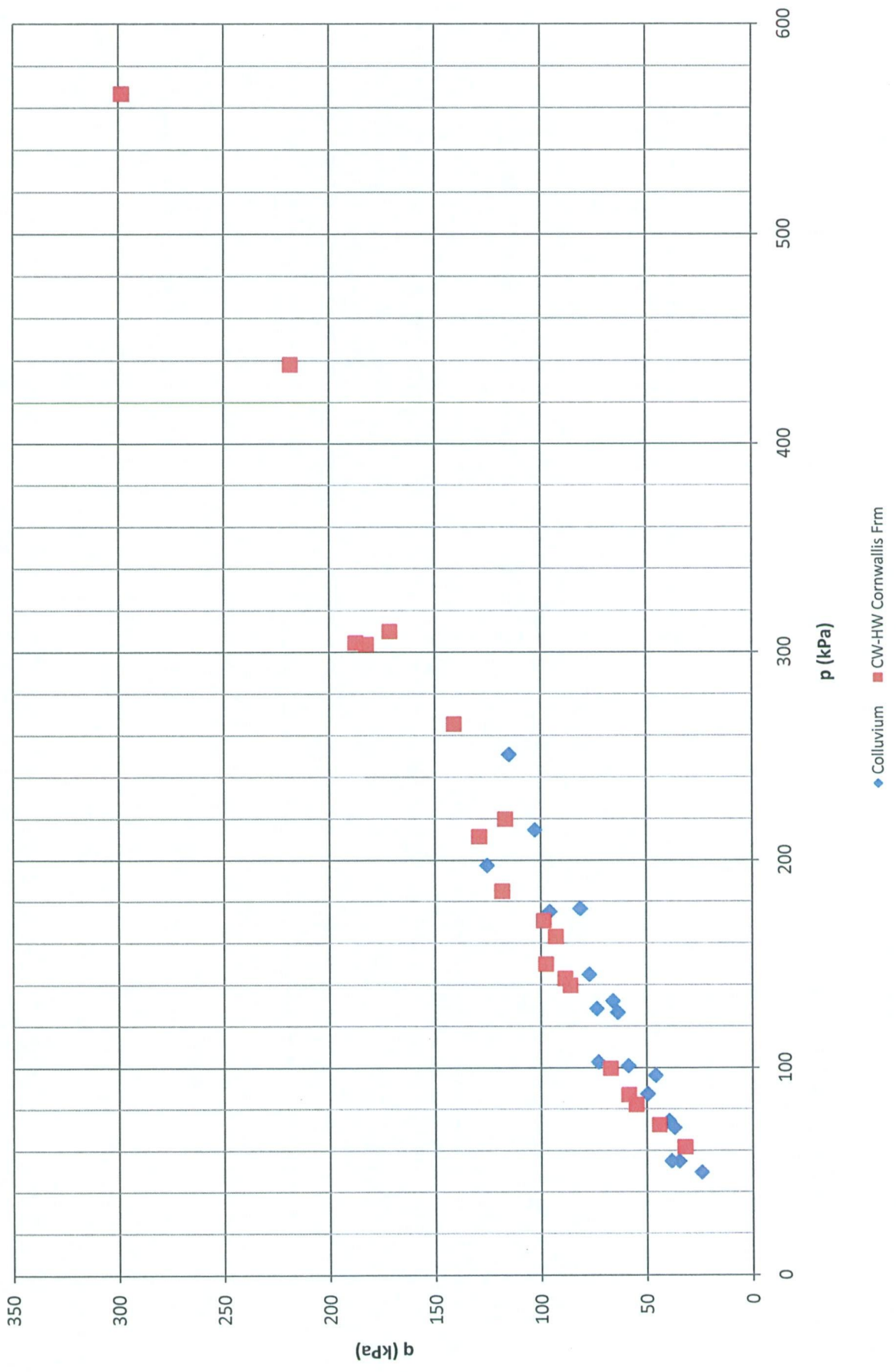
Huia Watercre Treatment Plant - Diver BH 6; depth 10.7m b.c.
(CW-HW Cornwallis Formation)



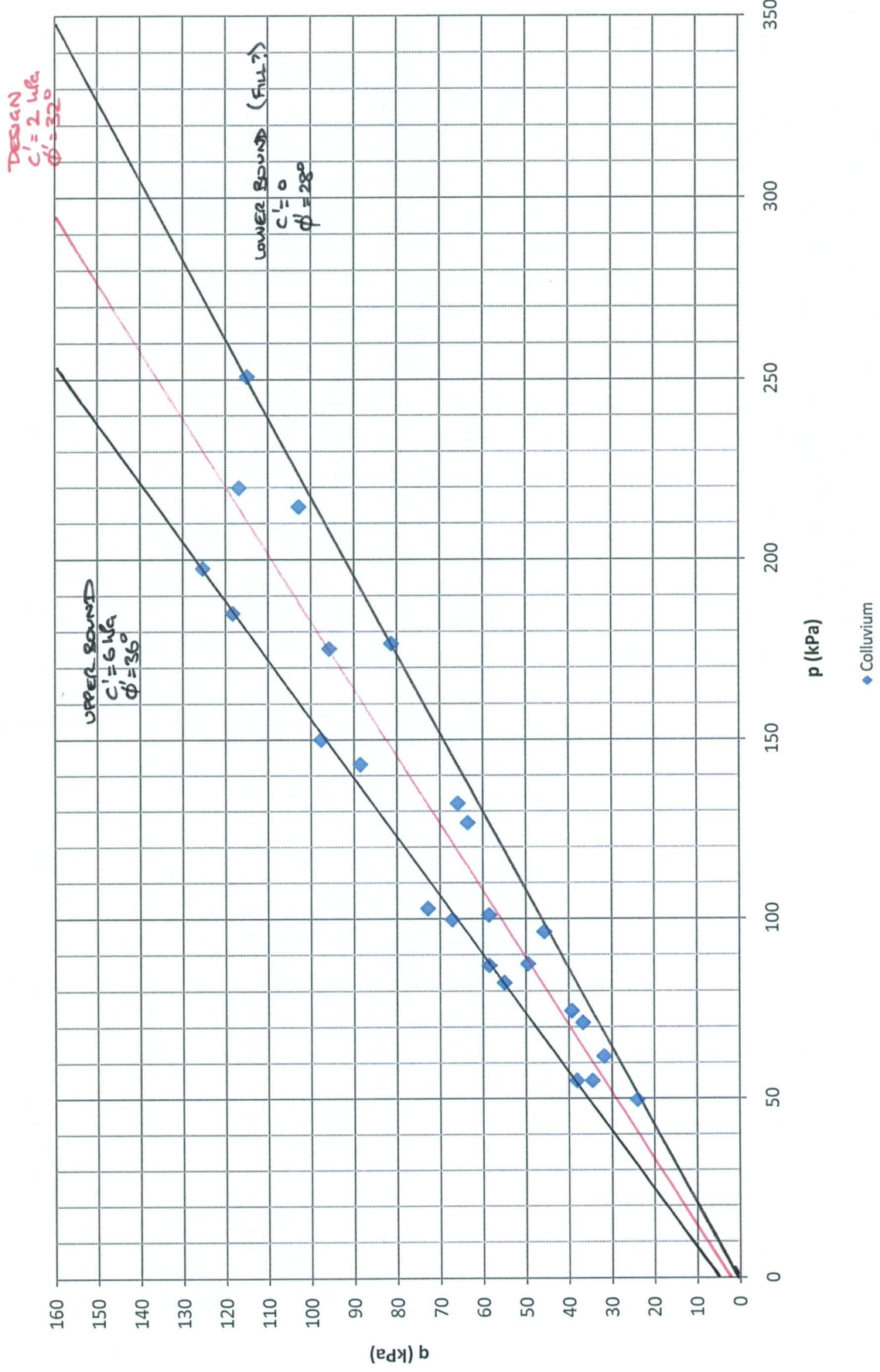
Appendix D:

Laboratory Testing Results

Watercare Huia Treatment Plant - Triaxial Test Results All Data



Watercare Huia Treatment Plant - Triaxial Test Results All Data Colluvium



Watercare Huia Treatment Plant - Triaxial Test Results All Data Cornwallis

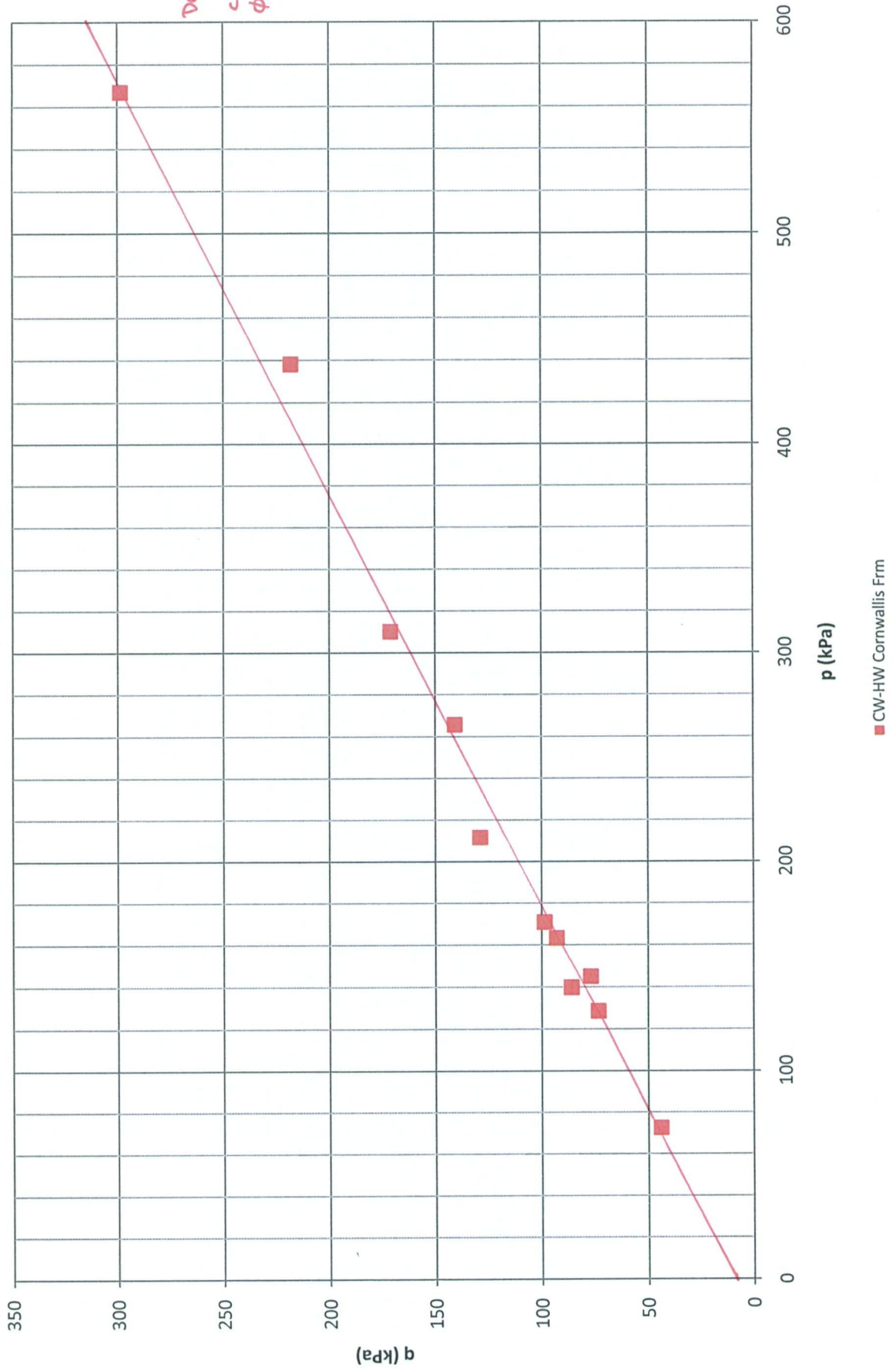
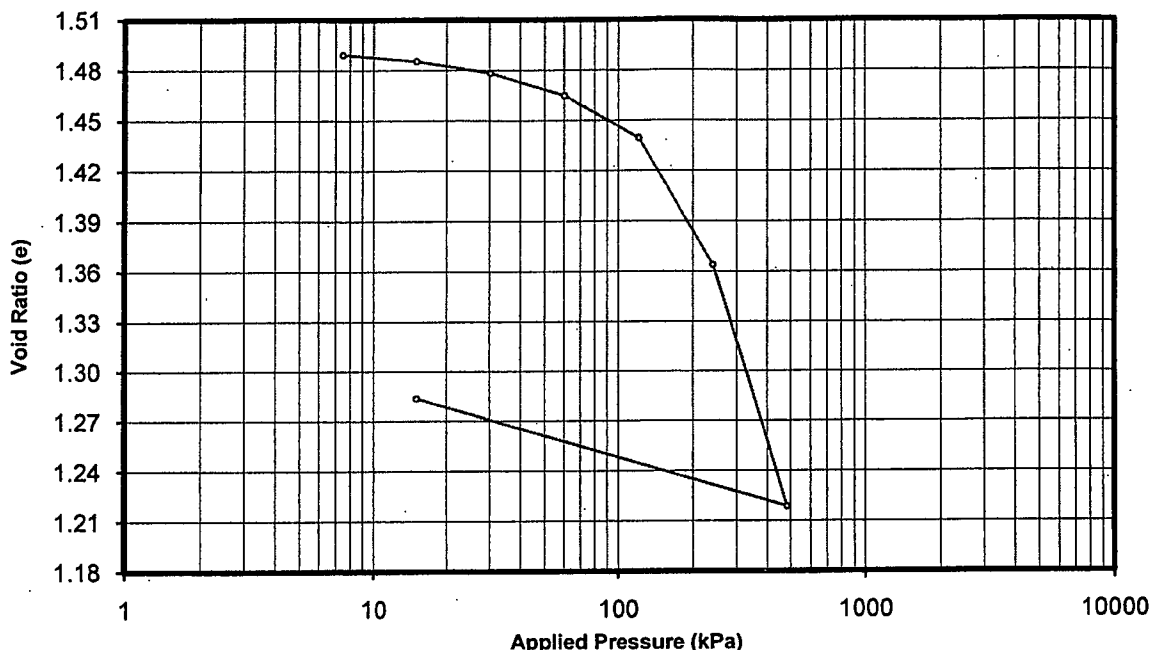




Plate No.: _____ Page of _____ Your Job No.: **27064.001**
 Site: **Huia Watercare Plant, Titirangi** Our Job No.: **615300.000**
 BH No.: **BH2** Sample No.: **PT1** Depth: **3.35-3.40 (m)**
 Test Method Used: **NZS 4402:1986 Test 7.1 One-Dimensional Consolidation**

ONE-DIMENSIONAL CONSOLIDATION TEST



Pressure (kPa)	Void Ratio (e)	Pressure Increment (kPa)	Coefficient of Consolidation C_v (m ² /yr)	Coefficient of Volume Compressibility M_v (m ² /MN)	
As received	0	1.493			
Preload	7.5	1.489	0 to 7.5	NA	0.22
	15.1	1.485	7.5 to 15.1	23	0.21
	30.2	1.478	15.1 to 30.2	20	0.19
	60.3	1.465	30.2 to 60.3	17	0.18
	121	1.440	60.3 to 121	13	0.17
	241	1.364	121 to 241	6.3	0.26
	483	1.219	241 to 483	3.6	0.25
Unload	15.1	1.284	483 to 15.1	NA	NA

Sample History: Undisturbed core trimmed at NWC. SQR of time fitting method used.

Description: clayey SILT with minor sand, soft to firm, light greenish grey with light yellowish brown, medium-high plasticity, slightly dilatant.

Initial Dry Density (t/m³): 1.06 Initial Water Content: 55.0%

Solid Density (t/m³): 2.65 (Assumed) Initial Saturation: 98%

Temperature During Testing: Max = 22 °C Min = 21 °C

Remarks: The calculations of void ratio are affected by the solid density value. We have assumed a value of 2.65 t/m³.

Sample description is not IANZ endorsed.

Entered by: **ST** Date: **25/5/10** Checked by: **SJA** Date: **25/5/10**



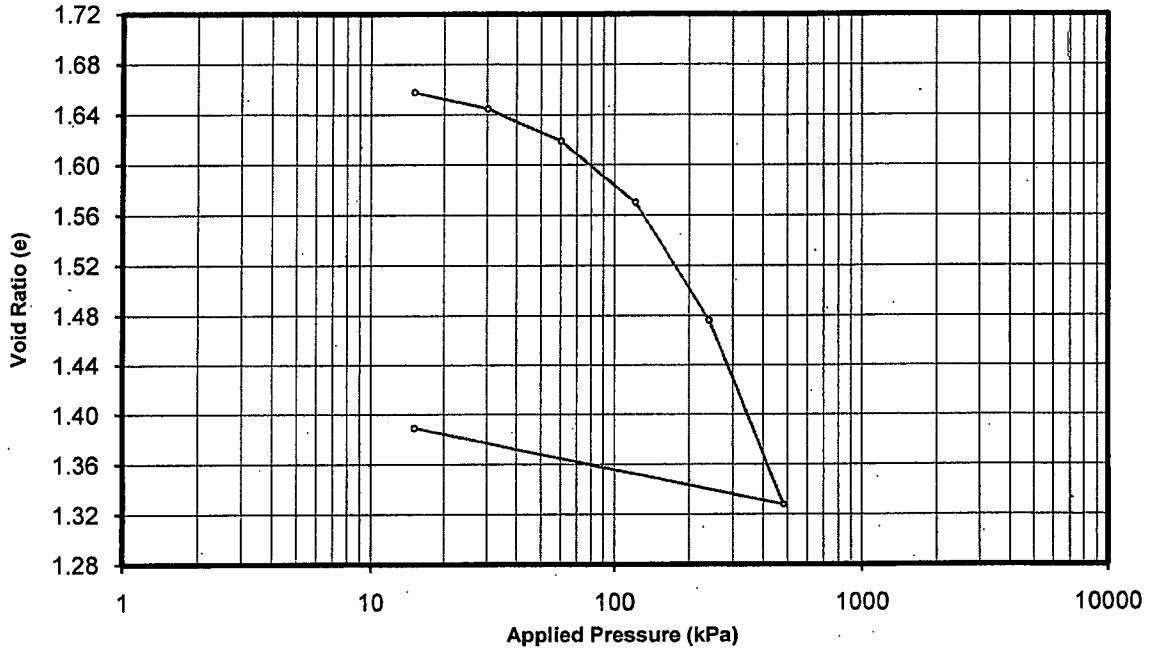
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Form No.: P13 B
Form Date.: Sep 2001

File P:\Working Materials\11300.000\BH4_PT2_1.75-4.80m_Consol.dwg

Plate No.: _____ Page of _____ Your Job No.: **27064.001**
 Site: **Huia Watercare Plant, Titirangi** Our Job No.: **615300.000**
 BH No.: **BH4** Sample No.: **PT2** Depth: **4.70-4.75 (m)**
 Test Method Used: **NZS 4402:1986 Test 7.1 One-Dimensional Consolidation**

ONE-DIMENSIONAL CONSOLIDATION TEST



Pressure (kPa)	Void Ratio (e)	Pressure Increment (kPa)	Coefficient of Consolidation C_v (m ² /yr)	Coefficient of Volume Compressibility M_v (m ² /MN)	
As received	0	1.671			
Preload	15.1	1.658	0 to 15.1	NA	0.34
	30.2	1.645	15.1 to 30.2	27	0.33
	60.3	1.619	30.2 to 60.3	26	0.32
	121	1.570	60.3 to 121	22	0.31
	241	1.476	121 to 241	20	0.30
	483	1.328	241 to 483	18	0.25
Unload	15.1	1.389	483 to 15.1	NA	NA

Sample History: Undisturbed core trimmed at NWC. SQR of time fitting method used.

Description: sandy SILT with trace of clay, soft, light greenish grey, low plasticity, dilatant.

Initial Dry Density (t/m³): 0.99 Initial Water Content: 61.6%
 Solid Density (t/m³): 2.65 (Assumed) Initial Saturation: 98%
 Temperature During Testing: Max = 22 °C Min = 21 °C

Remarks: The calculations of void ratio are affected by the solid density value. We have assumed a value of 2.65 t/m³.
 Sample description is not IANZ endorsed.

Entered by: *SG* Date: *25/5/10* Checked by: *MJRA* Date: *25/5/10*



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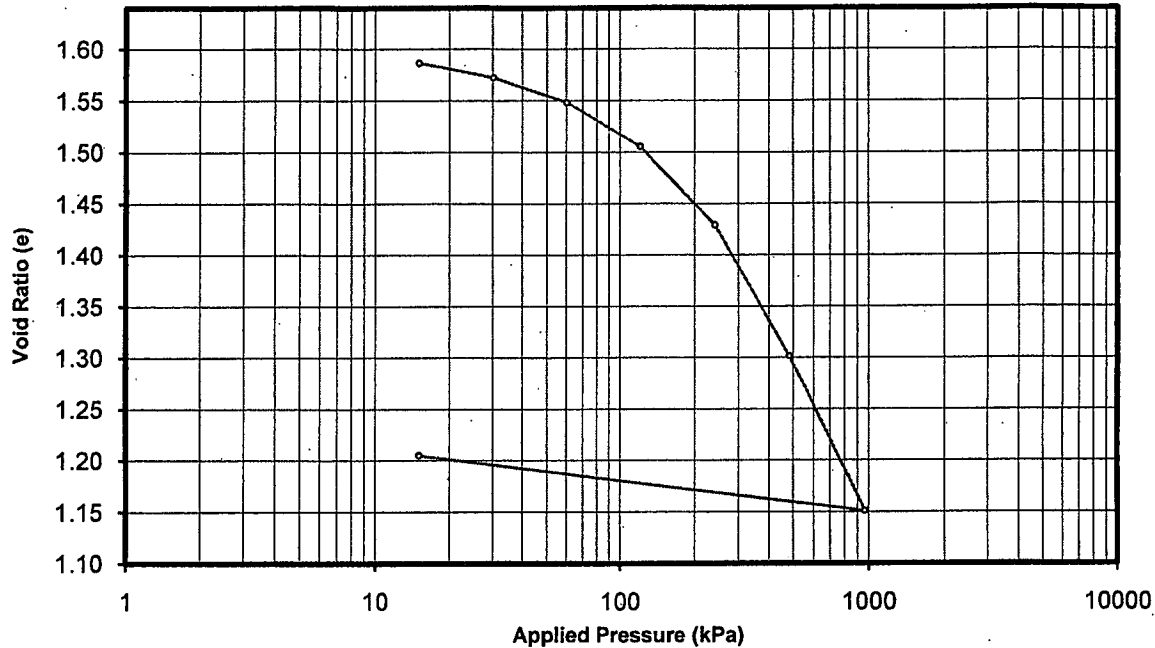
Form No.: P13 B

Form Date.: Sep 2001

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Plate No.: _____ Page of _____ Your Job No.: 27064.001
Site: **Huia Watercare Plant, Titirangi** Our Job No.: 615300.000
BH No.: **BH4** Sample No.: **PT3** Depth: **7.85-7.90 (m)**
Test Method Used: NZS 4402:1986 Test 7.1 One-Dimensional Consolidation

ONE-DIMENSIONAL CONSOLIDATION TEST



Pressure (kPa)	Void Ratio (e)	Pressure Increment (kPa)	Coefficient of Consolidation C_v (m ² /yr)	Coefficient of Volume Compressibility M_v (m ² /MN)
As received	0			
Preload	15.1	0 to 15.1	NA	0.39
	30.2	15.1 to 30.2	47	0.36
	60.3	30.2 to 60.3	35	0.31
	121	60.3 to 121	30	0.28
	241	121 to 241	27	0.25
	483	241 to 483	22	0.22
	966	483 to 966	20	0.14
Unload	15.1	966 to 15.1	NA	NA

Sample History: Undisturbed core trimmed at NWC. SQR of time fitting method used.

Description: silty SAND with trace of clay, loosely packed, light greenish grey with light yellowish orange brown.

Initial Dry Density (t/m³): 1.02 Initial Water Content: 58.8%
Solid Density (t/m³): 2.65 (Assumed) Initial Saturation: 97%
Temperature During Testing: Max = 22 °C Min = 21 °C

Remarks: The calculations of void ratio are affected by the solid density value. We have assumed a value of 2.65 t/m³.

Sample description is not IANZ endorsed.

Entered by: ST

Date: 25/5/10

Checked by: WJRA

Date: 25/5/10

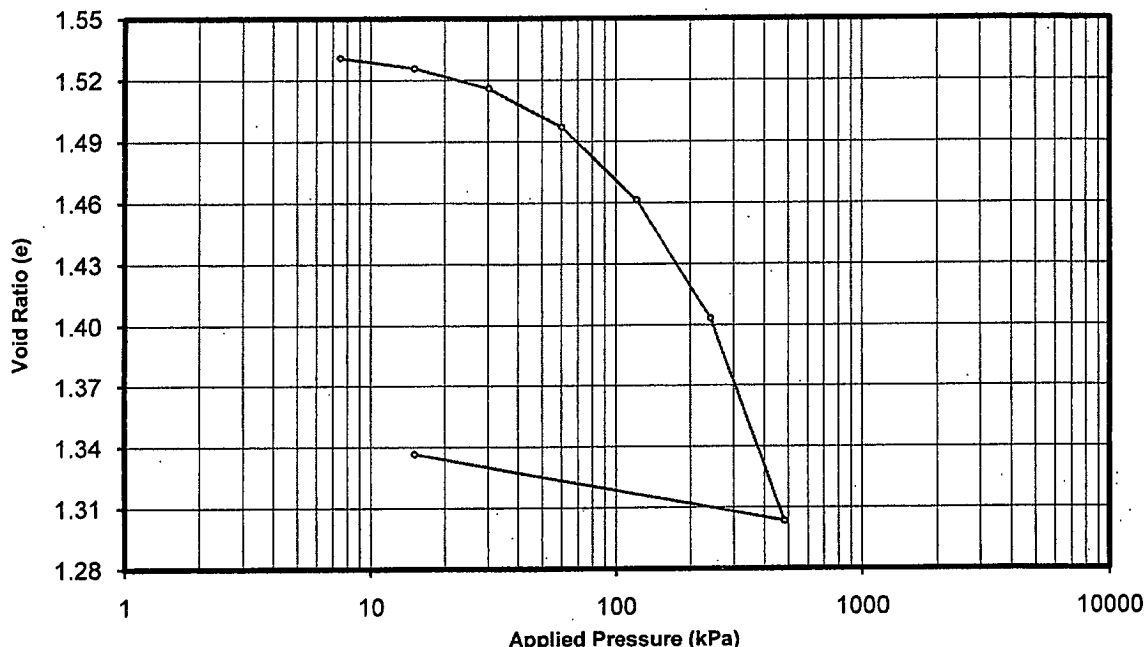


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Plate No.: _____ Page of _____ Your Job No.: **27064.001**
Site: **Huia Watercare Plant, Titirangi** Our Job No.: **615300.000**
BH No.: **BH5** Sample No.: **PT1** Depth: **2.85-2.90 (m)**
Test Method Used: **NZS 4402:1986 Test 7.1 One-Dimensional Consolidation**

ONE-DIMENSIONAL CONSOLIDATION TEST



Pressure (kPa)	Void Ratio (e)	Pressure Increment (kPa)	Coefficient of Consolidation Cv (m ² /yr)	Coefficient of Volume Compressibility Mv (m ² /MN)	
As received	0	1.536			
Preload	7.5	1.531	0 to 7.5	NA	0.28
	15.1	1.526	7.5 to 15.1	25	0.27
	30.2	1.516	15.1 to 30.2	24	0.26
	60.3	1.497	30.2 to 60.3	23	0.25
	121	1.461	60.3 to 121	21	0.24
	241	1.403	121 to 241	19	0.20
	483	1.303	241 to 483	17	0.17
Unload	15.1	1.337	483 to 15.1	NA	NA

Sample History: Undisturbed core trimmed at NWC. SQR of time fitting method used.

Description: clayey SILT with some sand, soft to firm, light brown, mottled black, medium-high plasticity, dilatant.

Initial Dry Density (t/m³): 1.04 Initial Water Content: 56.4%
Solid Density (t/m³): 2.65 (Assumed) Initial Saturation: 97%
Temperature During Testing: Max = 22 °C Min = 21 °C

Remarks: The calculations of void ratio are affected by the solid density value. We have assumed a value of 2.65 t/m³.
Sample description is not IANZ endorsed.

Entered by: *ST* Date: *25/5/10* Checked by: *MURA* Date: *25/5/10*



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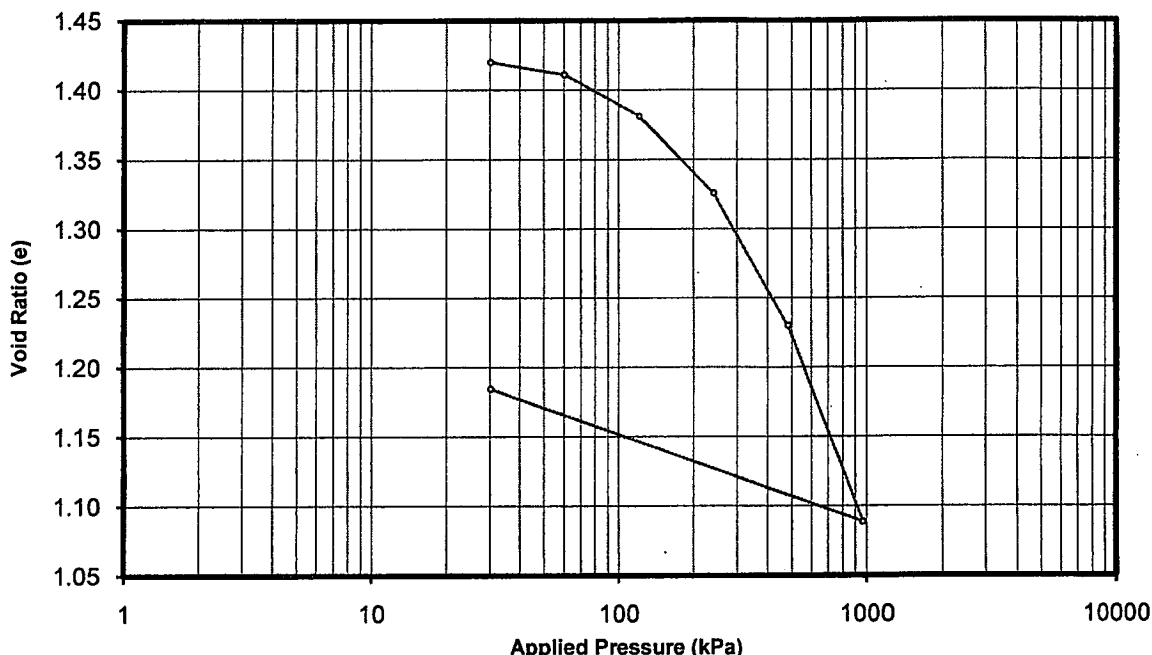
Form No.: P13 B

Form Date.: Sep 2001

File: P:\Working Materials\1300.000\BH6_PT2_2.60-2.65m_Consol.xls

Plate No.: _____ Page of _____ Your Job No.: 27064.001
Site: **Huia Watercare Plant, Titirangi** Our Job No.: 615300.000
BH No.: **BH6** Sample No.: **PT2** Depth: 2.60-2.65 (m)
Test Method Used: NZS 4402:1986 Test 7.1 One-Dimensional Consolidation

ONE-DIMENSIONAL CONSOLIDATION TEST



Pressure (kPa)	Void Ratio (e)	Pressure Increment (kPa)	Coefficient of Consolidation C_v (m ² /yr)	Coefficient of Volume Compressibility M_v (m ² /MN)
As received	0			
Preload	30.2	0 to 30.2	NA	0.14
	60.3	30.2 to 60.3	2.1	0.12
	121	60.3 to 121	1.8	0.20
	241	121 to 241	0.96	0.19
	483	241 to 483	0.78	0.17
	966	483 to 966	0.70	0.13
Unload	30.2	966 to 30.2	NA	NA

Sample History: Undisturbed core trimmed at NWC. SQR of time fitting method used.

Description: clayey SILT with trace of sand, firm to stiff, orange brown with light greenish grey, mottled black, high plasticity, slightly dilatant.

Initial Dry Density (t/m³): 1.09 Initial Water Content: 52.9%

Solid Density (t/m³): 2.65 (Assumed) Initial Saturation: 98%

Temperature During Testing: Max = 22 °C Min = 21 °C

Remarks: The calculations of void ratio are affected by the solid density value. We have assumed a value of 2.65 t/m³.

Sample description is not IANZ endorsed.

Entered by: ST

Date: 25/5/10

Checked by: MJRA

Date: 25/5/10



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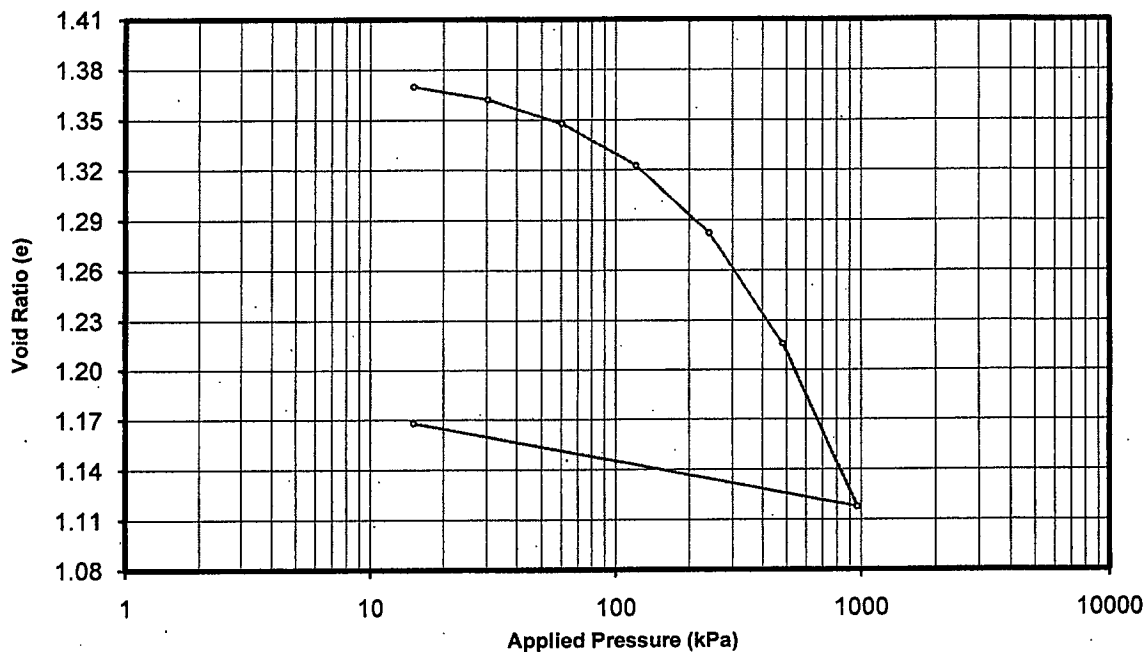
Form No.: P13 B

Form Date.: Sep 2001

File: P:\Working Material\13202\020804_P13_B\04.05m_Consolid

Plate No.: _____ Page of _____ Your Job No.: **27064.001**
 Site: **Huia Watercare Plant, Titirangi** Our Job No.: **615300.000**
 BH No.: **BH6** Sample No.: **PT5** Depth: **6.90-6.95 (m)**
 Test Method Used: **NZS 4402:1986 Test 7.1 One-Dimensional Consolidation**

ONE-DIMENSIONAL CONSOLIDATION TEST



Pressure (kPa)	Void Ratio (e)	Pressure Increment (kPa)	Coefficient of Consolidation C_v (m ² /yr)	Coefficient of Volume Compressibility M_v (m ² /MN)	
As received	0	1.378			
Preload	15.1	1.370	0 to 15.1	NA	0.22
	30.2	1.362	15.1 to 30.2	47	0.21
	60.3	1.348	30.2 to 60.3	43	0.20
	121	1.323	60.3 to 121	38	0.18
	241	1.282	121 to 241	30	0.14
	483	1.216	241 to 483	28	0.12
	966	1.118	483 to 966	24	0.092
Unload	15.1	1.168	966 to 15.1	NA	NA

Sample History: Undisturbed core trimmed at NWC. SQR of time fitting method used.

Description: silty SAND with a few moderately weathered sand sized clasts of grey SILTSTONE and trace of clay, loosely packed, light greenish grey with orange brown.

Initial Dry Density (t/m³): 1.11 Initial Water Content: 50.4%
 Solid Density (t/m³): 2.65 (Assumed) Initial Saturation: 97%
 Temperature During Testing: Max = 22 °C Min = 21 °C

Remarks: The calculations of void ratio are affected by the solid density value. We have assumed a value of 2.65 t/m³.
 Sample description is not IANZ endorsed.

Entered by: **ST** Date: **25/5/10** Checked by: **MJA** Date: **25/5/10**

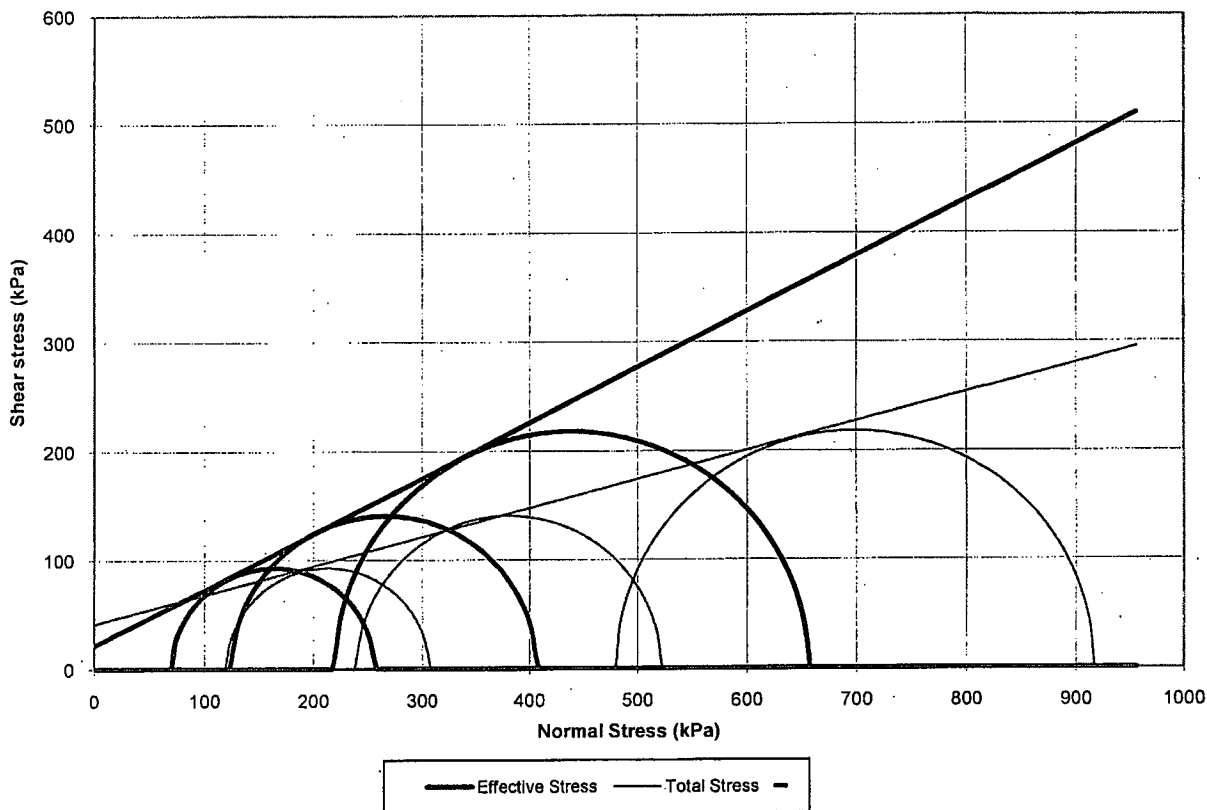


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Plate No.:		Page	of
Site:	Huia Watercare Plant, Titirangi	Your Ref No.:	27064.001
Test pit/Bh No.:	BH1	Sample No.:	PT1
Test method used:	BS1377:Part 8:1990:Clause 5 Saturation	BS1377:Part 8:1990:Clause 6 Consolidation	
	BS1377:Part 8:1990:Clause 7 Consolidated-undrained triaxial compression test with pore pressure measurement		

CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST (3 STAGES) MOHR CIRCLES OF TOTAL AND EFFECTIVE STRESSES



Initial Sample Height:	115.20	mm	Initial Water Content:	47.1	%
Initial Sample Diameter:	53.89	mm	Initial Bulk Density:	1.73	t/m ³
Initial B Value:	--	%	Initial Dry Density:	1.18	t/m ³
B Value before Consolidation:	96	%	Final Water Content:	43.4	%

	Consolidation Stage			Failure Values				
	Cell Pressure (kPa)	Back Pressure (kPa)	Eff. Consol. Stress	Deviator Stress (kPa)	Pore Pressure Change During Shearing Δu (kPa)	Effective Principal Stress (kPa)		Vertical Strain (%)
						Major σ_1'	Minor σ_3'	
STAGE 1	470	350	120	186.01	49.7	256.31	70.30	3.37
STAGE 2	590	350	240	281.62	115.2	406.42	124.80	2.15
STAGE 3	830	350	480	436.35	260.1	656.25	219.90	2.37

Angle of Frictional Resistance:	$\phi =$	15	°	Effective	$\phi' =$	27	°
Cohesion:	$c =$	42	kPa	Effective	$c' =$	22	kPa
Linear Regression Coefficient:	$r =$	0.998		Effective	$r =$	1.000	

Sample History: Undisturbed core trimmed at natural water content.

Soil description: SILT, sandy, firm, light grey with dark grey, white, orange brown and reddish brown, low plasticity, dilatant.

Failure Mode: Planar / Plastic Test Speed: 0.032 (mm/min)

Test Remarks: The sample was saturated by increments of cell pressure and back pressure. Failure for each stage was determined by either the maximum effective stress ratio or the maximum deviator stress. Strength parameters have been derived by using a linear regression fitting method.

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Plate No.:

Page of

Site: Huia Watercare Plant, Your Ref No.: 27064.001

Job No.: 615300.001

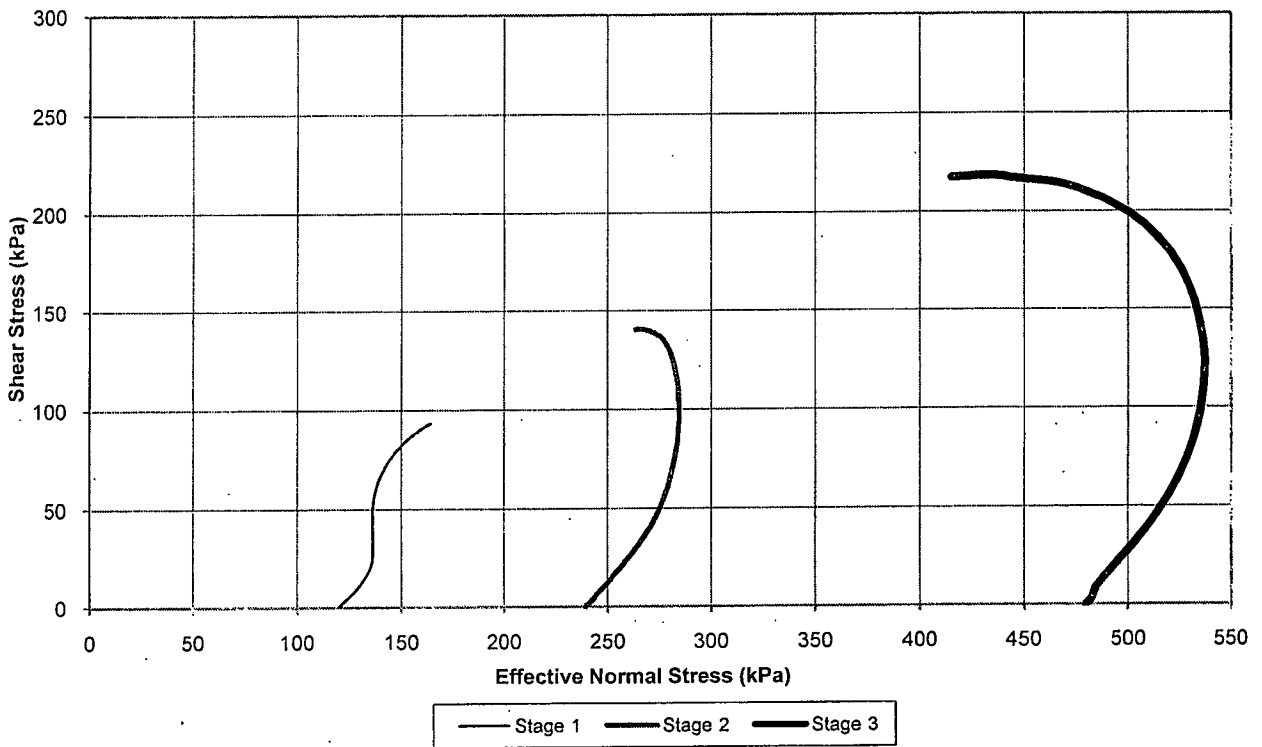
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Sample No.: PT1

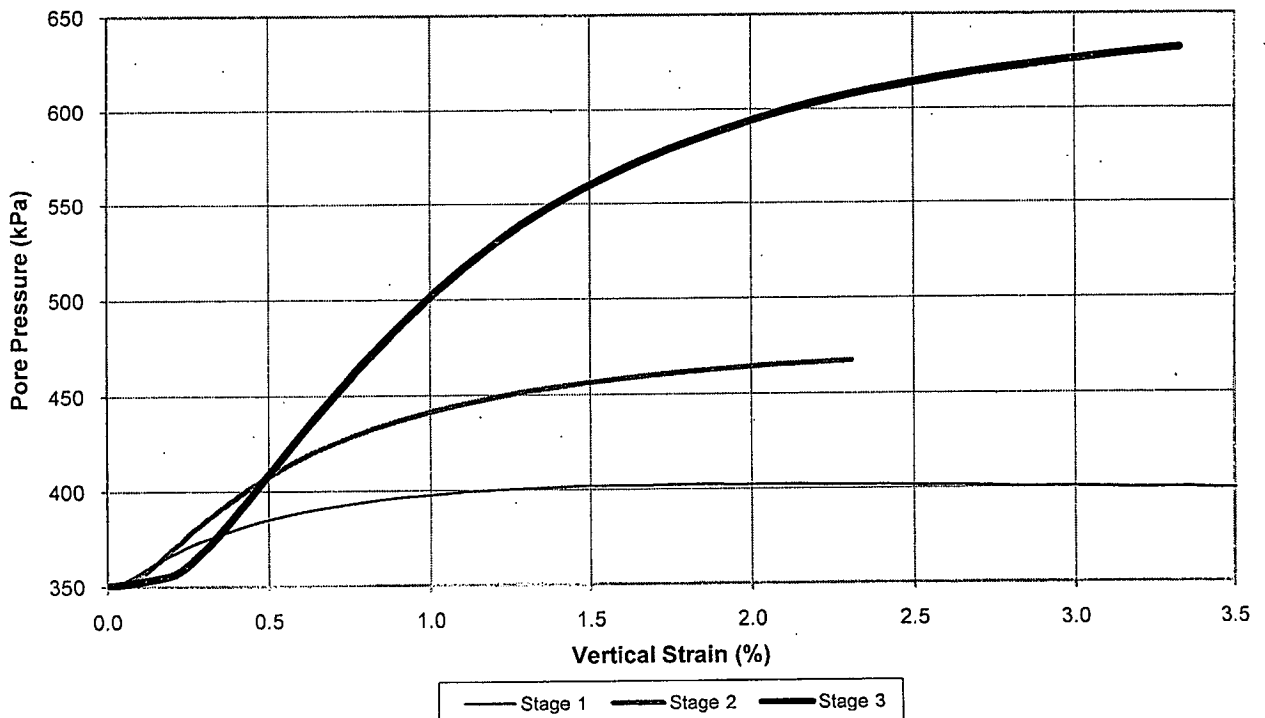
Depth: 6.25 -- 6.37 (m)

GRAPHS

STRESS PATH



PORE PRESSURE Vs VERTICAL STRAIN



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Site: Huia Watercare Plant, Your Ref No.: 27064.001

Job No.: 615300.001

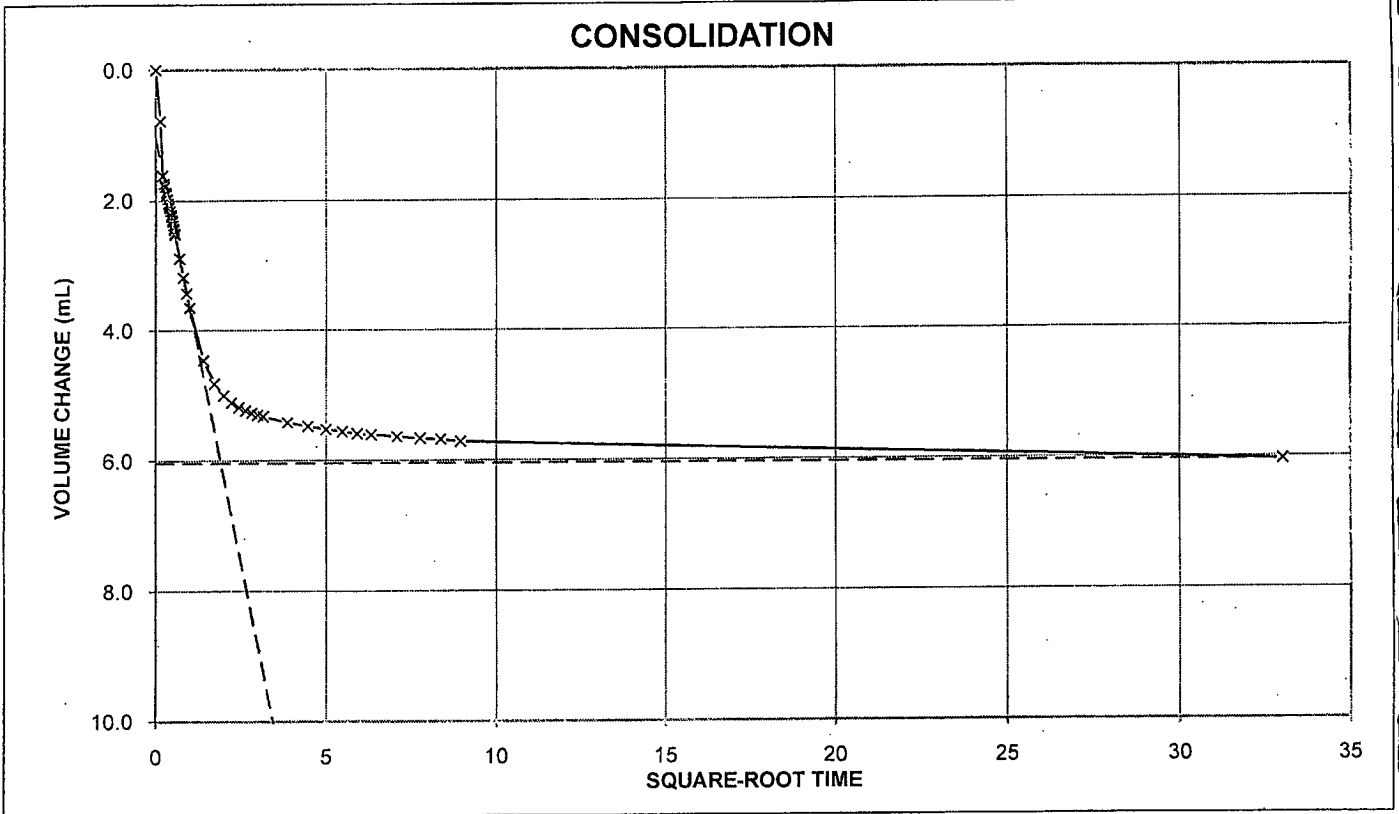
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Sample No.: PT1

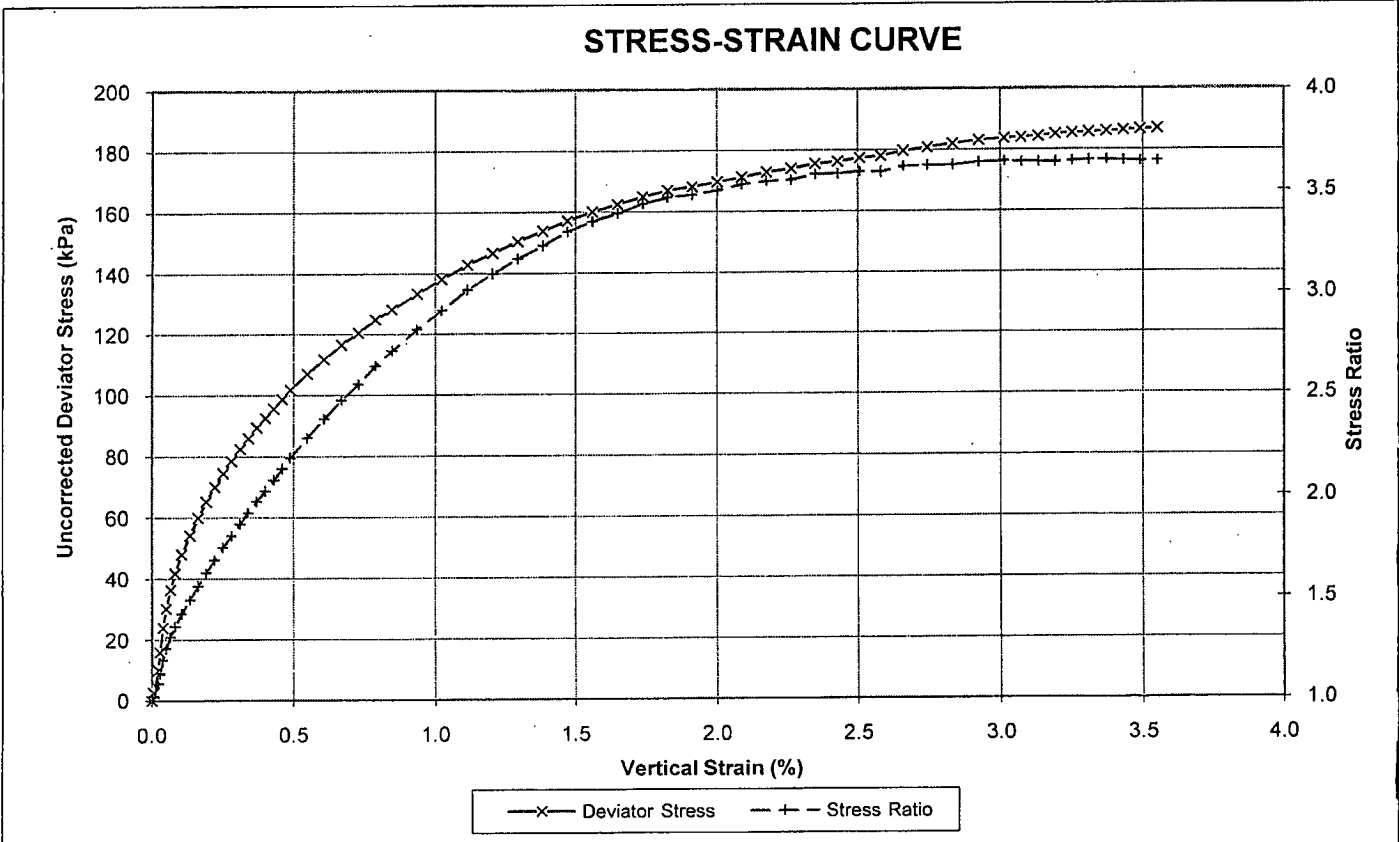
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STAGE 1 GRAPHS

CONSOLIDATION



STRESS-STRAIN CURVE



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Plate No.:

Page of

Site: Huia Watercare Plant, Your Ref No.: 27064.001

Job No.: 615300.001

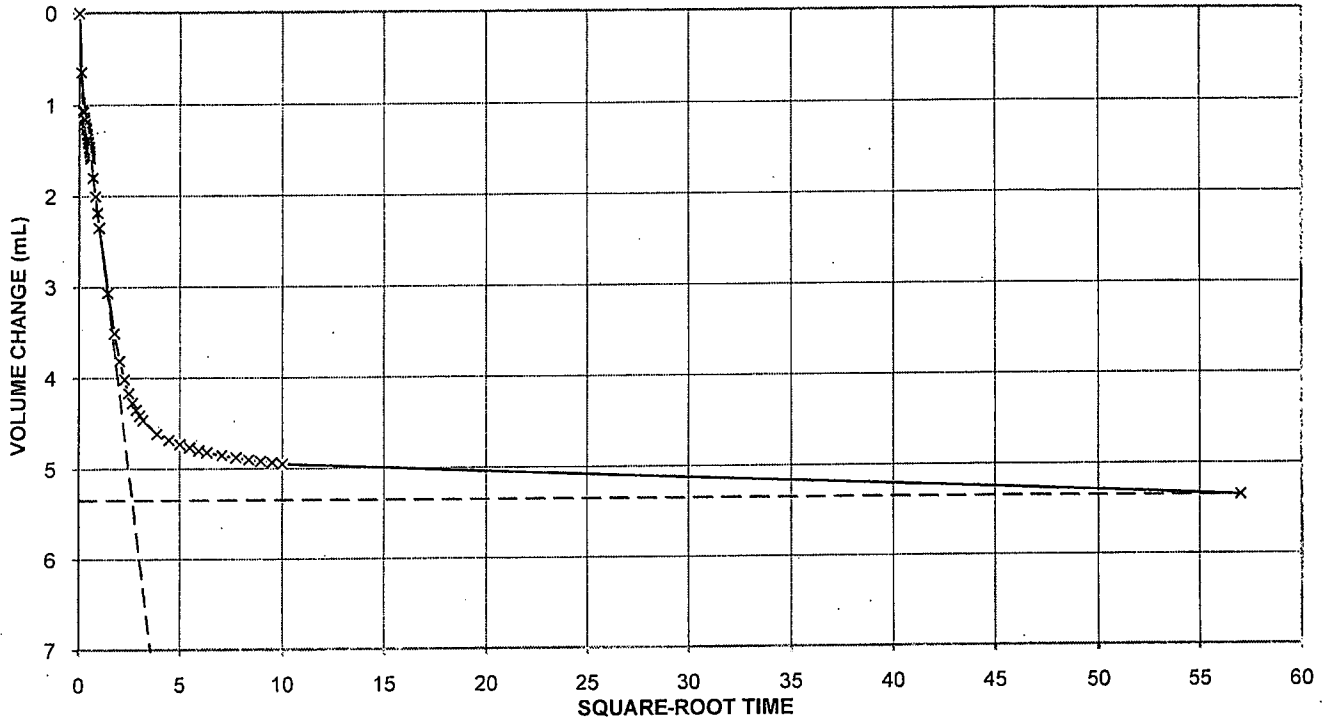
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Sample No.: PT1

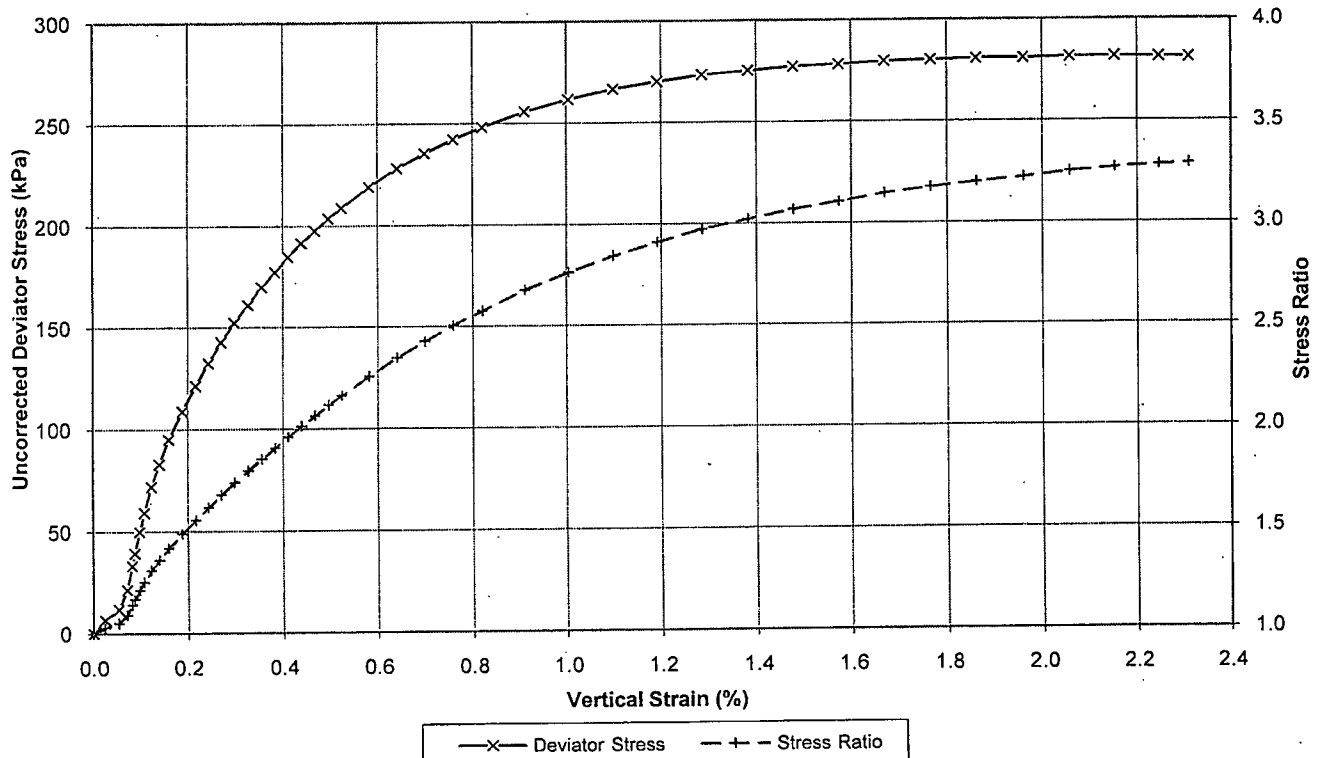
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STAGE 2 GRAPHS

CONSOLIDATION



STRESS-STRAIN CURVE



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Checked by: *Qbt*

Date: 28/05/10



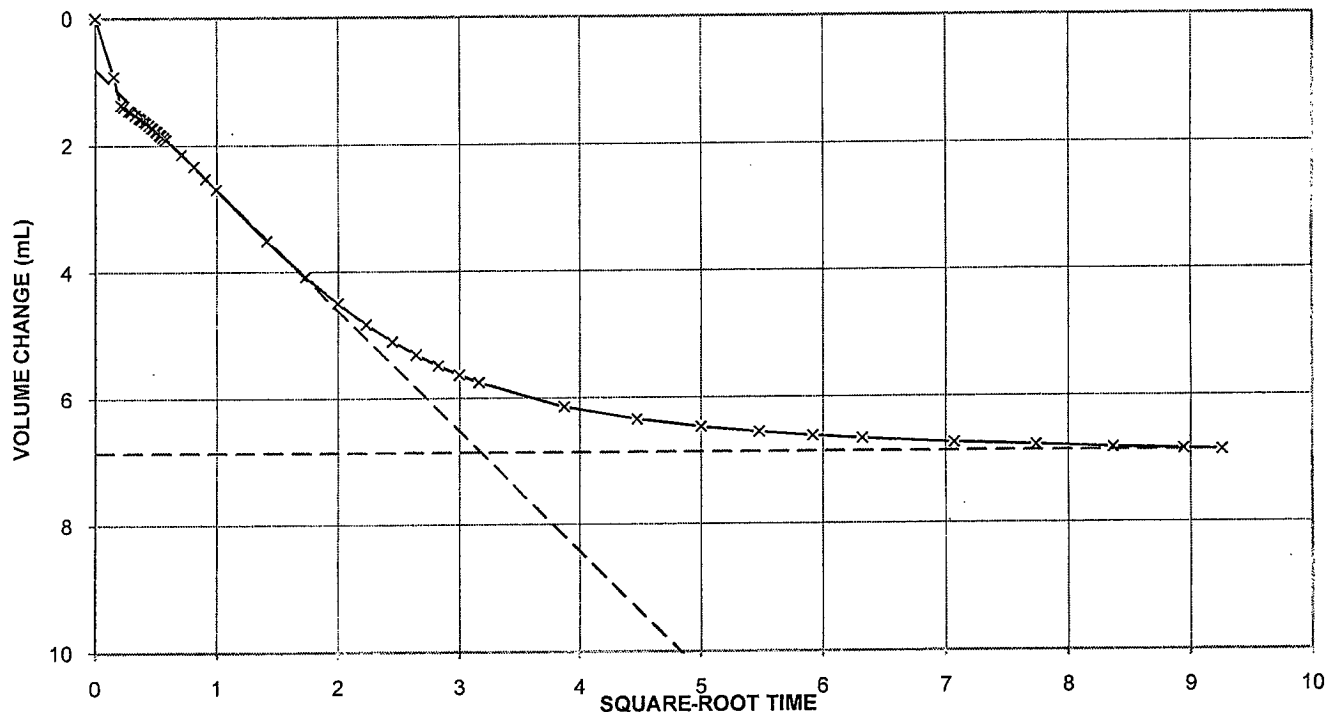
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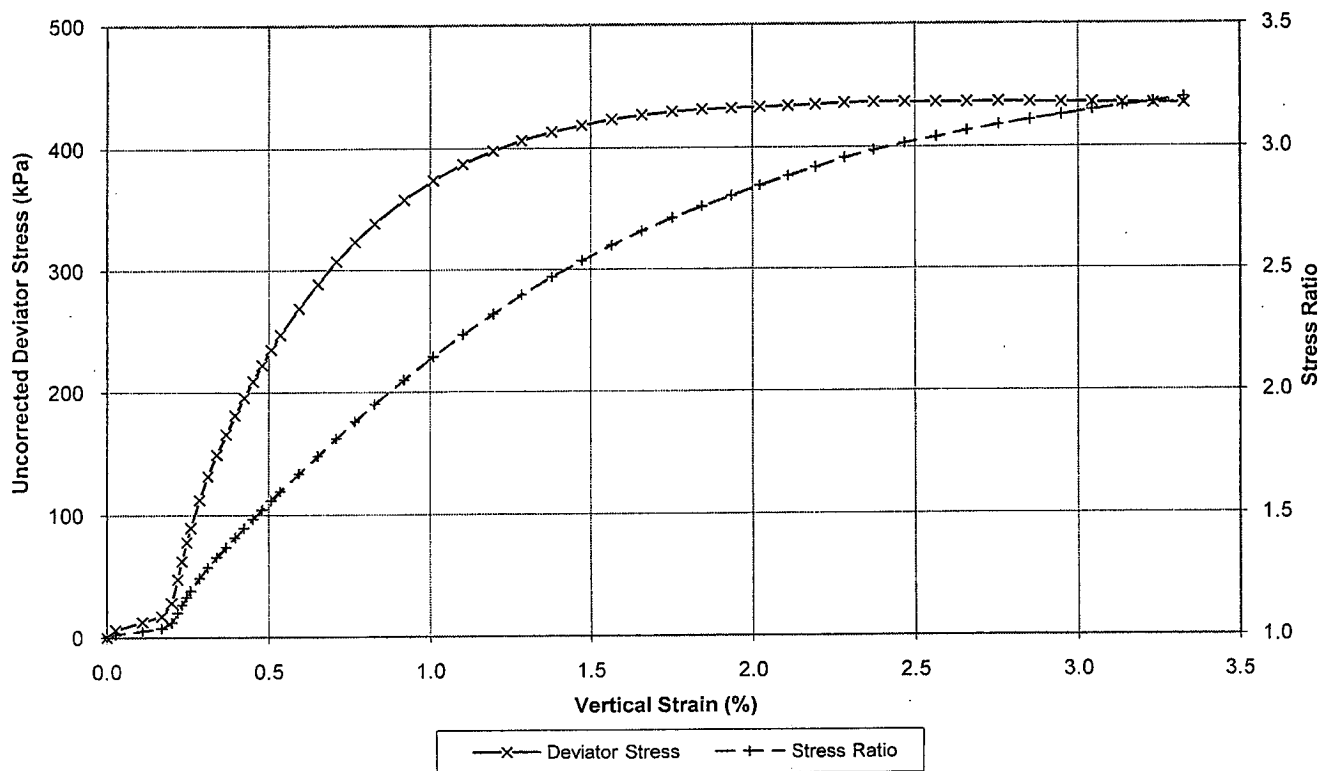
Plate No.:
Site: Huia Watercare Plant, Your Ref No.: 27064.001
Test pit/Bh No.: BH1 Sample No.: PT1

Page of
Job No.: 615300.001
Depth: 6.25 -- 6.37 (m)

STAGE 3 GRAPHS CONSOLIDATION



STRESS-STRAIN CURVE



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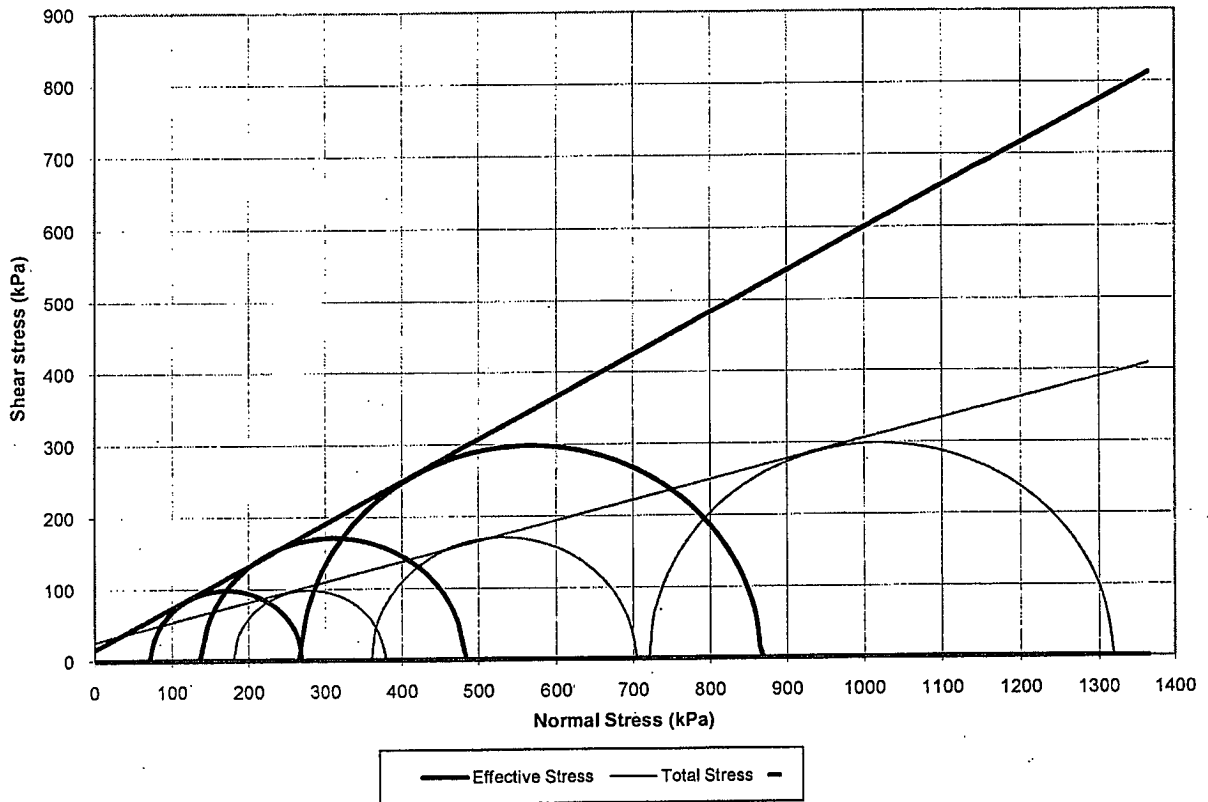


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Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Titirangi Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH1 Sample No.: PT2 Depth: 9.36 -- 9.47 (m)
 Test method used: BS1377:Part 8:1990:Clause 5 Saturation BS1377:Part 8:1990:Clause 6 Consolidation
 BS1377:Part 8:1990:Clause 7 Consolidated-undrained triaxial compression test with pore pressure measurement

CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST (3 STAGES) MOHR CIRCLES OF TOTAL AND EFFECTIVE STRESSES



Initial Sample Height:	112.80	mm	Initial Water Content:	45.7	%
Initial Sample Diameter:	53.55	mm	Initial Bulk Density:	1.76	t/m ³
Initial B Value:	72	%	Initial Dry Density:	1.21	t/m ³
B Value before Consolidation:	98	%	Final Water Content:	36.5	%

	Consolidation Stage			Failure Values				
	Cell Pressure (kPa)	Back Pressure (kPa)	Eff. Consol. Stress	Deviator Stress (kPa)	Pore Pressure Change During Shearing δu (kPa)	Effective Principal Stress (kPa)		Vertical Strain (%)
						Major σ_1'	Minor σ_3'	
STAGE 1	480	300	180	197.37	107.8	269.57	72.20	6.93
STAGE 2	660	300	360	342.54	221.2	481.34	138.80	4.77
STAGE 3	1020	300	720	597.15	451.8	865.35	268.20	3.21

Angle of Frictional Resistance:	$\phi =$	16	°	$\phi' =$	30	°
Cohesion:	$c =$	27	kPa	$c' =$	16	kPa
Linear Regression Coefficient:	$r =$	0.999		$r =$	1.000	

Sample History: Undisturbed core trimmed at natural water content.

Soil description: SILT, sandy, with minor clay, firm, brown with orange and black, low to medium plasticity, dilatant.

Failure Mode: Planar / Plastic Test Speed: 0.038 (mm/min)

Test Remarks: The sample was saturated by increments of cell pressure and back pressure. Failure for each stage was determined by either the maximum effective stress ratio or the maximum deviator stress. Strength parameters have been derived by using a linear regression fitting method.

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Site: Huia Watercare Plant, Your Ref No.: 27064.001

Job No.: 615300.001

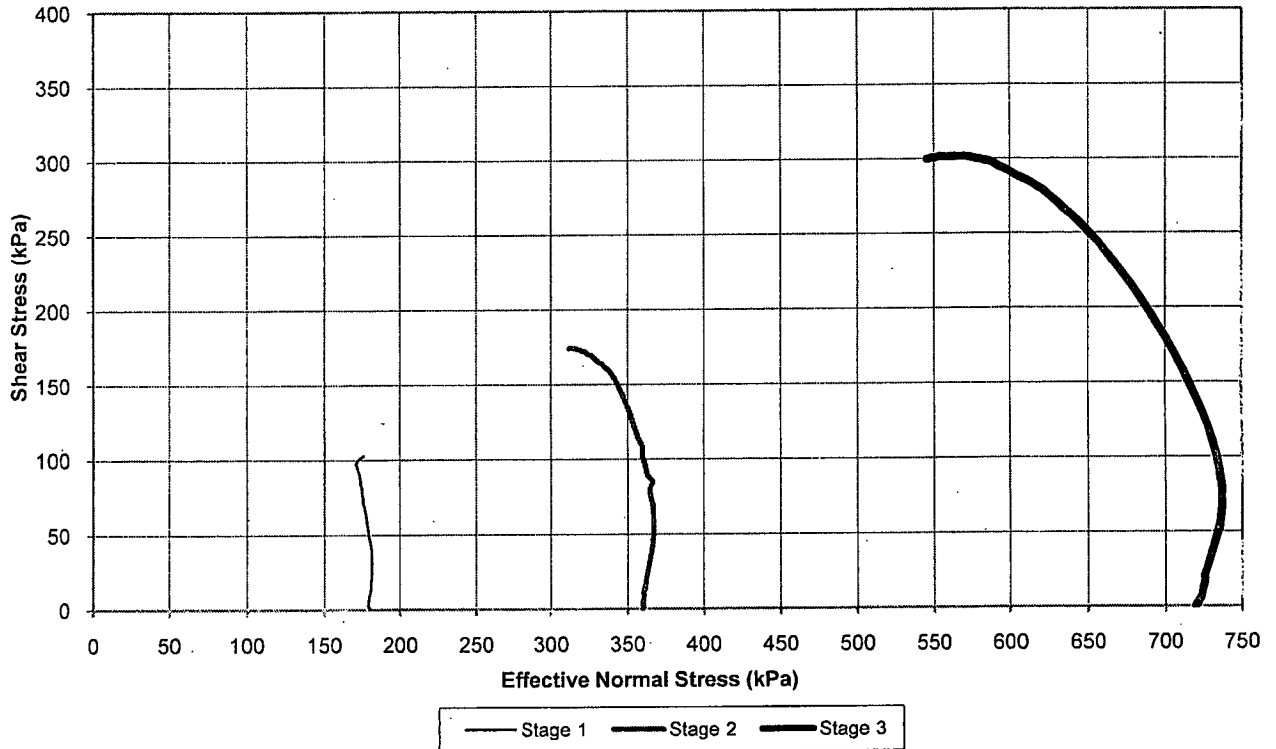
Test pit/Bh No.: BH1

Sample No.: PT2

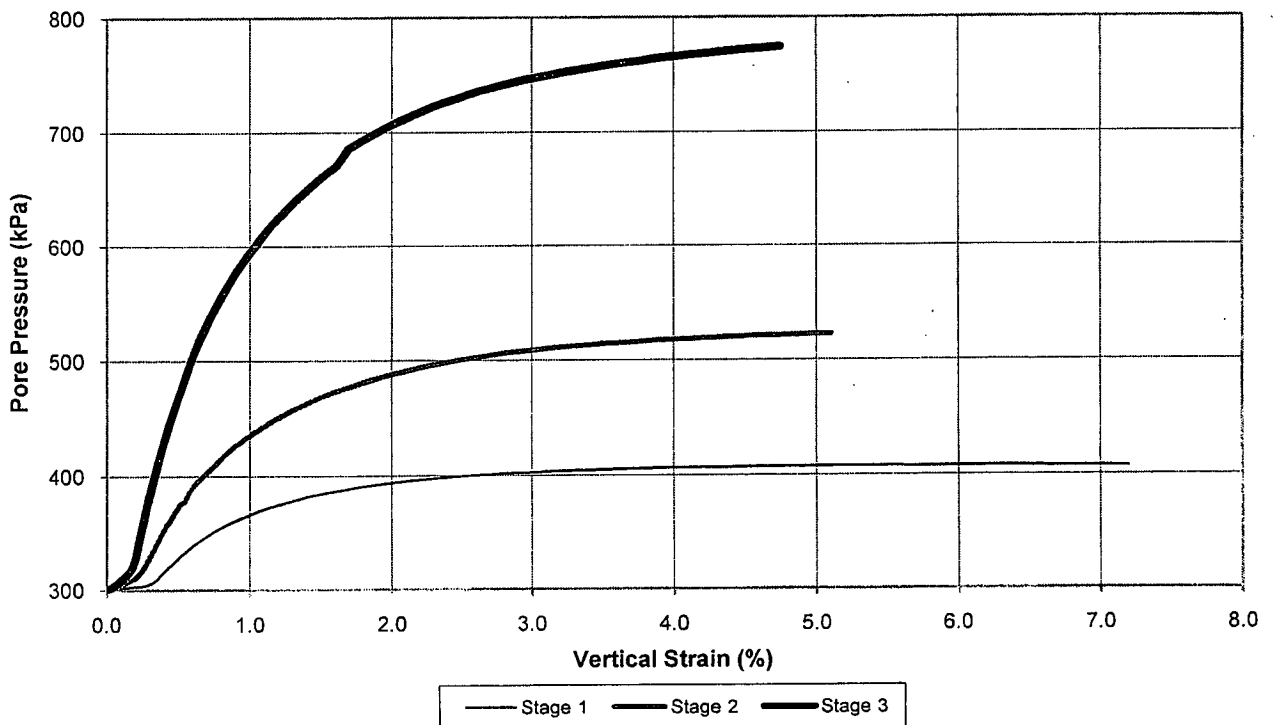
Depth: 9.36 -- 9.47 (m)

GRAPHS

STRESS PATH



PORE PRESSURE Vs VERTICAL STRAIN



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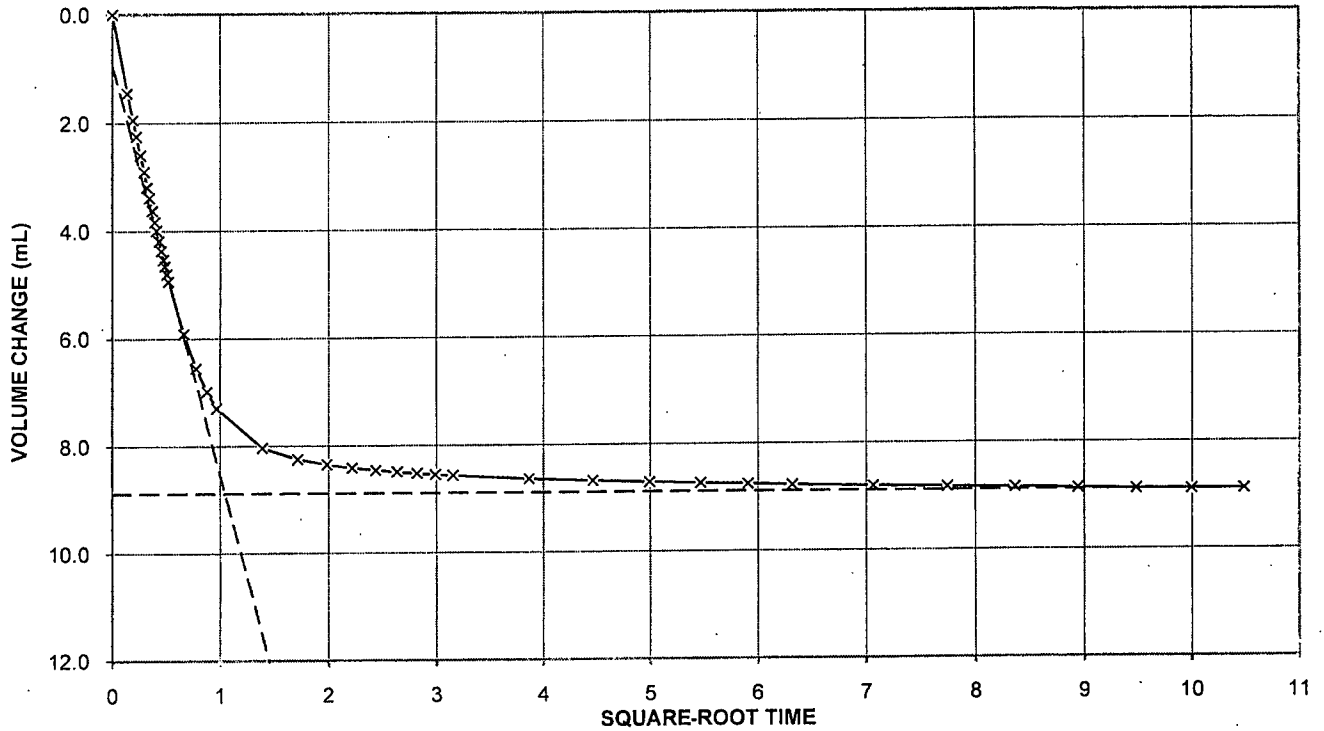
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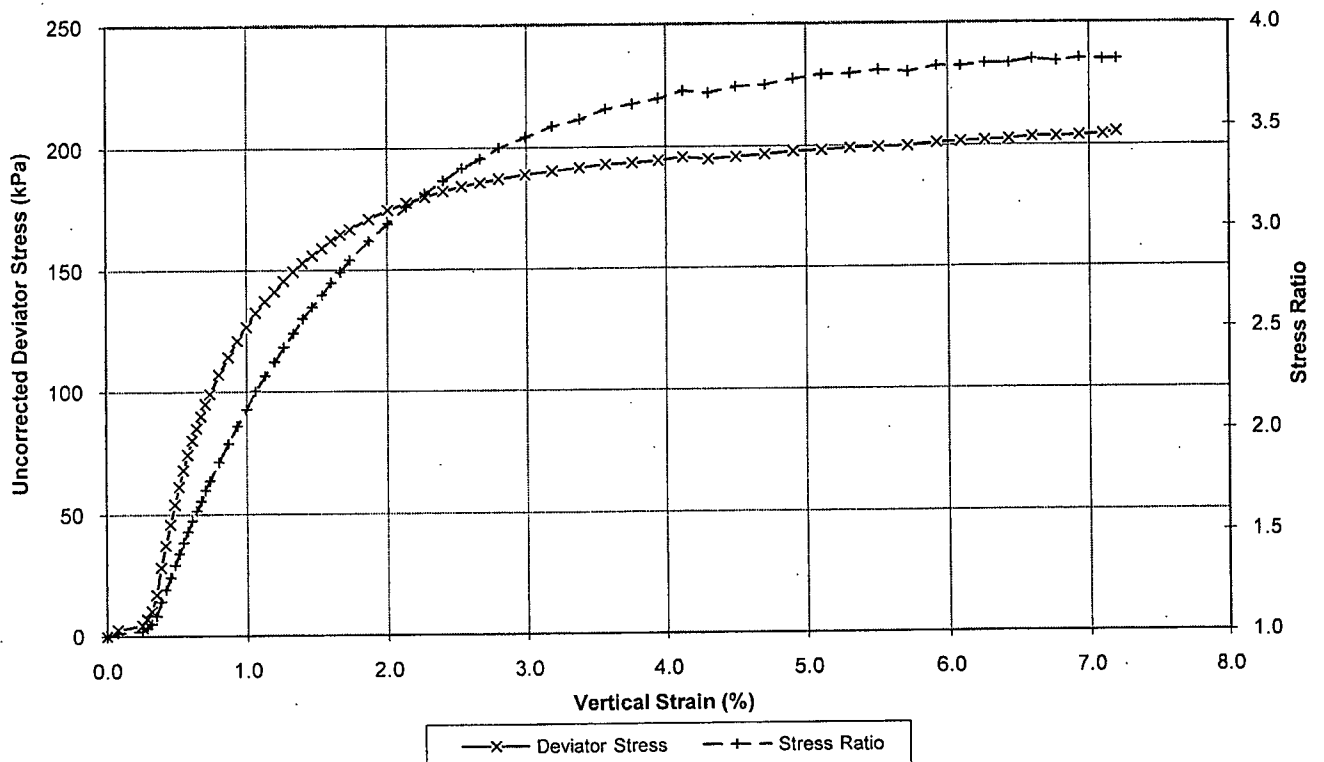
Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH1 Sample No.: PT2 Depth: 9.36 -- 9.47 (m)

STAGE 1 GRAPHS

CONSOLIDATION



STRESS-STRAIN CURVE



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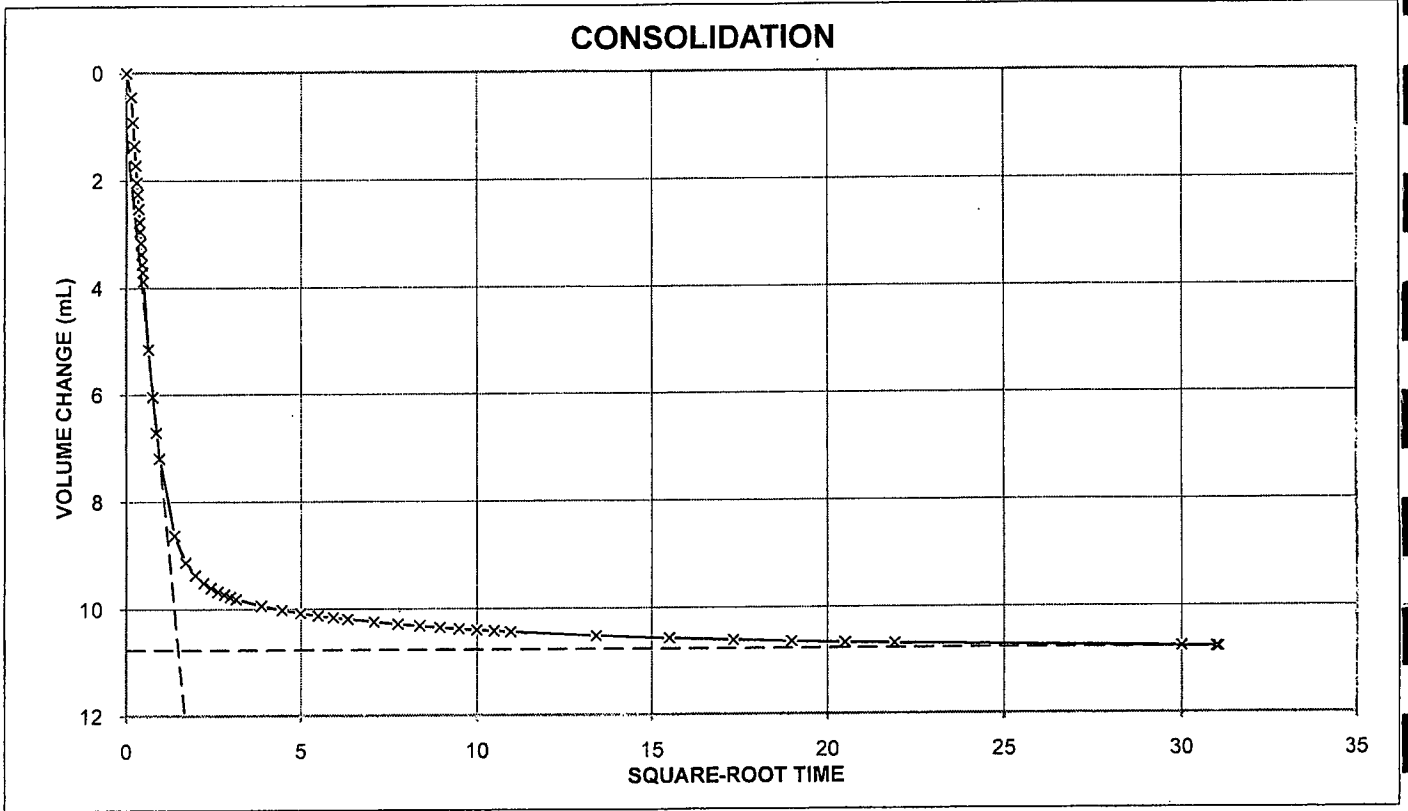
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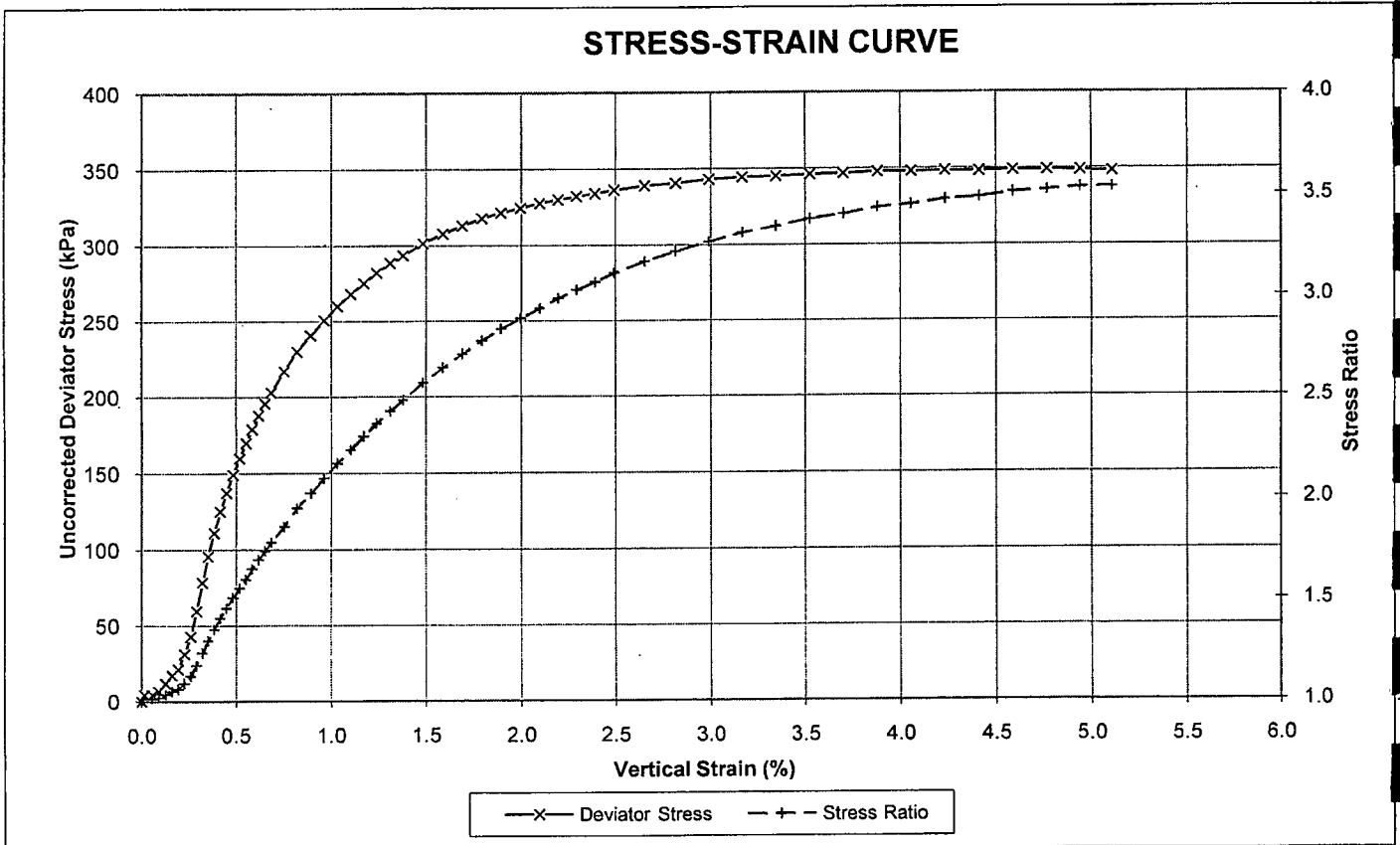
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Form Date:	July 2003
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Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH1 Sample No.: PT2 Depth: 9.36 -- 9.47 (m)

STAGE 2 GRAPHS CONSOLIDATION



STRESS-STRAIN CURVE



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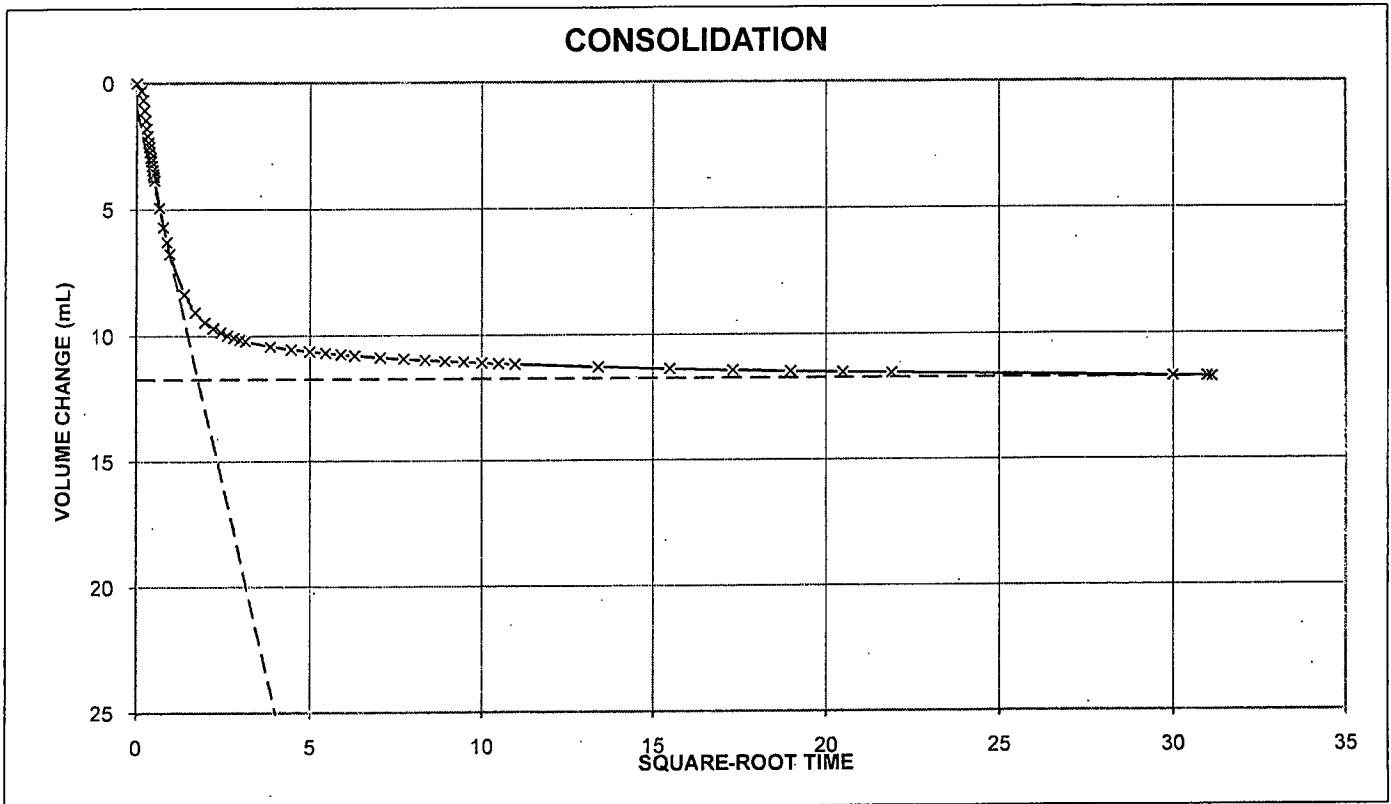


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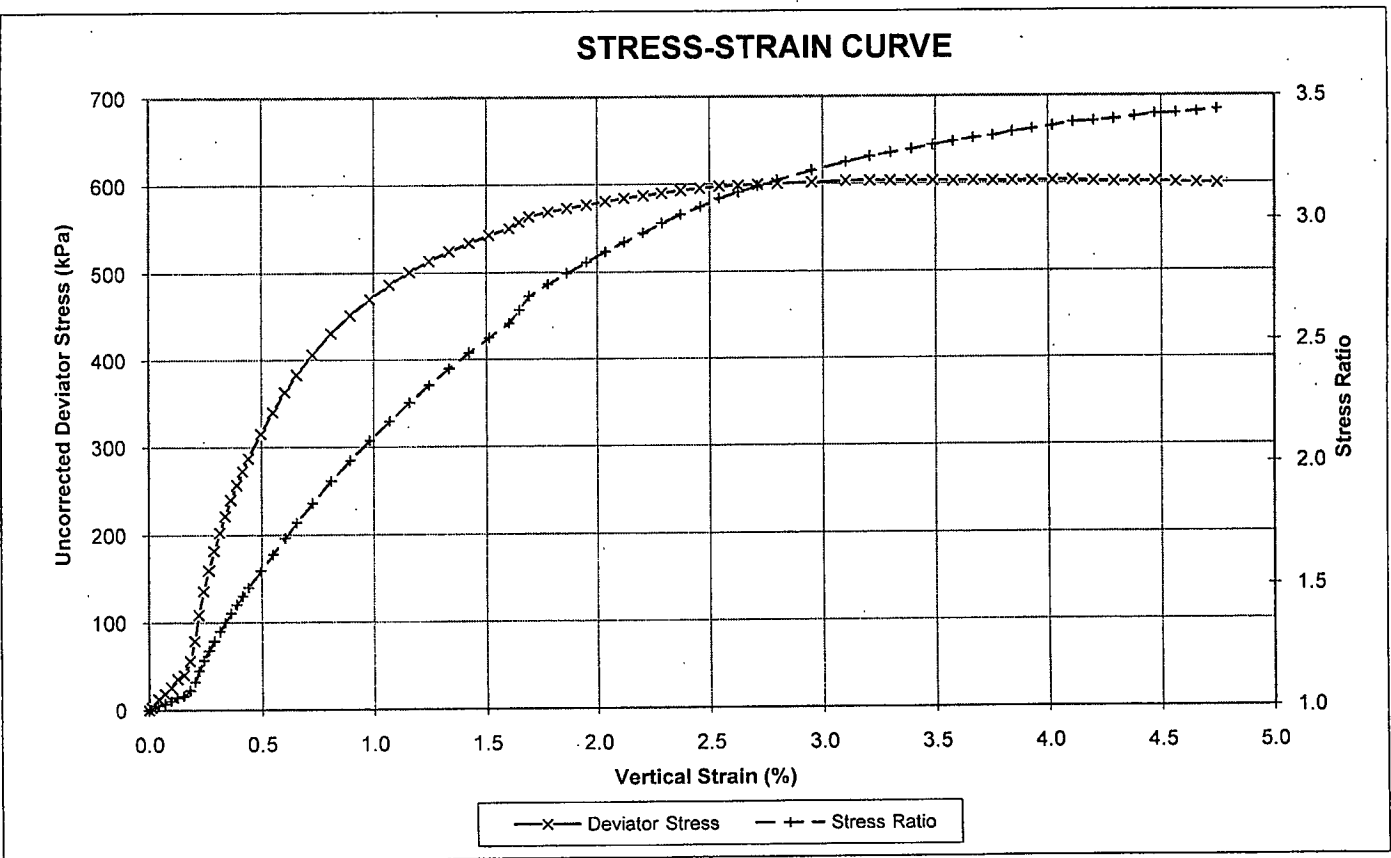
Form No.:	TG1-3
Form Date:	July 2003
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Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH1 Sample No.: PT2 Depth: 9.36 -- 9.47 (m)

STAGE 3 GRAPHS CONSOLIDATION



STRESS-STRAIN CURVE



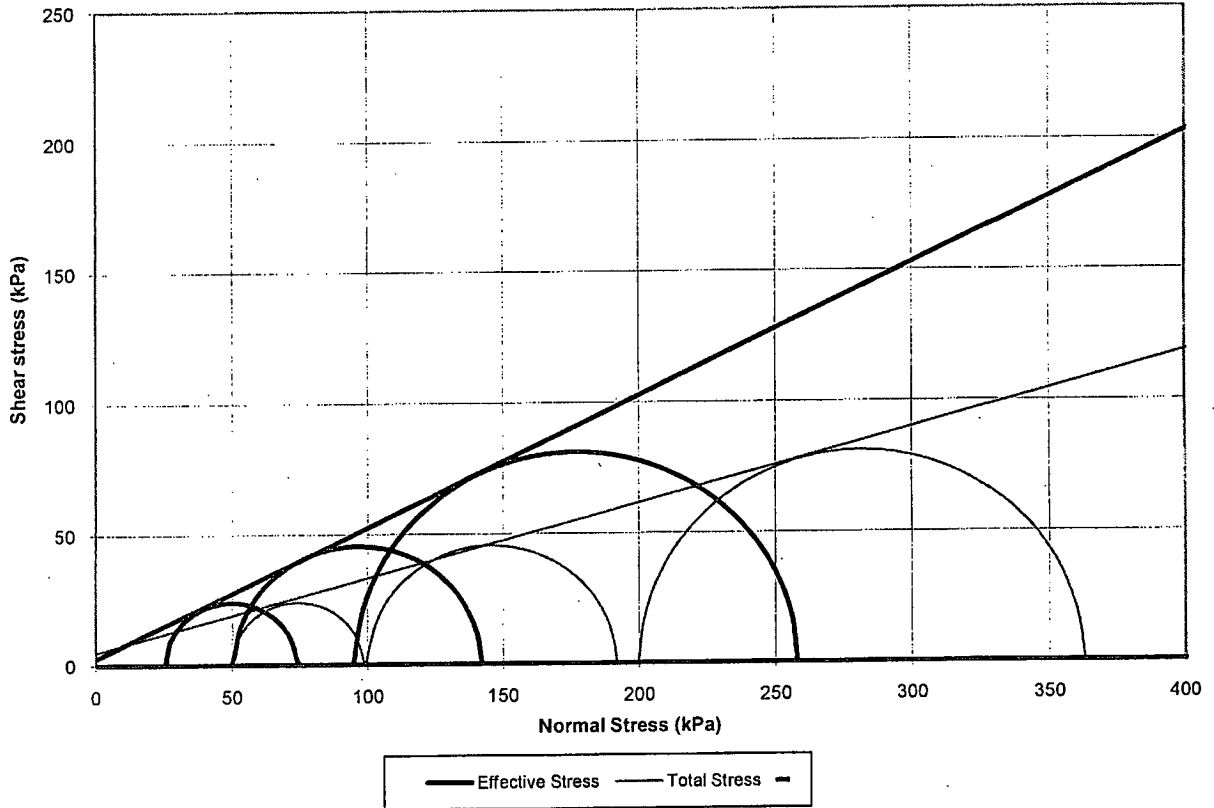


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Form Date:	July 2003
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Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Titirangi Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH4 Sample No.: PT1 Depth: 2.75 -- 2.86 (m)
 Test method used: BS1377:Part 8:1990:Clause 5 Saturation BS1377:Part 8:1990:Clause 6 Consolidation
 BS1377:Part 8:1990:Clause 7 Consolidated-undrained triaxial compression test with pore pressure measurement

CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST (3 STAGES) MOHR CIRCLES OF TOTAL AND EFFECTIVE STRESSES



Initial Sample Height:	111.11	mm	Initial Water Content:	61.2	%
Initial Sample Diameter:	53.85	mm	Initial Bulk Density:	1.61	t/m ³
Initial B Value:	60	%	Initial Dry Density:	1.00	t/m ³
B Value before Consolidation:	96	%	Final Water Content:	52.5	%

	Consolidation Stage			Failure Values				
	Cell Pressure (kPa)	Back Pressure (kPa)	Eff. Consol. Stress	Deviator Stress (kPa)	Pore Pressure Change During Shearing Δu (kPa)	Effective Principal Stress (kPa)		Vertical Strain (%)
						Major σ_1'	Minor σ_3'	
STAGE 1	350	300	50	48.06	24.4	73.66	25.60	4.46
STAGE 2	400	300	100	91.34	49.3	142.04	50.70	4.99
STAGE 3	500	300	200	162.41	104.6	257.81	95.40	6.06

Angle of Frictional Resistance:	$\phi =$	16	°	$\phi' =$	27	°
Cohesion:	$c =$	5	kPa	$c' =$	3	kPa
Linear Regression Coefficient:	$r =$	0.999		$r =$	1.000	

Sample History: Undisturbed core trimmed at natural water content.

Soil description: SILT, with some clay and minor sand, soft, grey, medium to high plasticity, dilatant.

Failure Mode: Planar / Plastic Test Speed: 0.018 (mm/min)

Test Remarks: The sample was saturated by increments of cell pressure and back pressure. Failure for each stage was determined by the maximum deviator stress. Strength parameters have been derived by using a linear regression fitting method.

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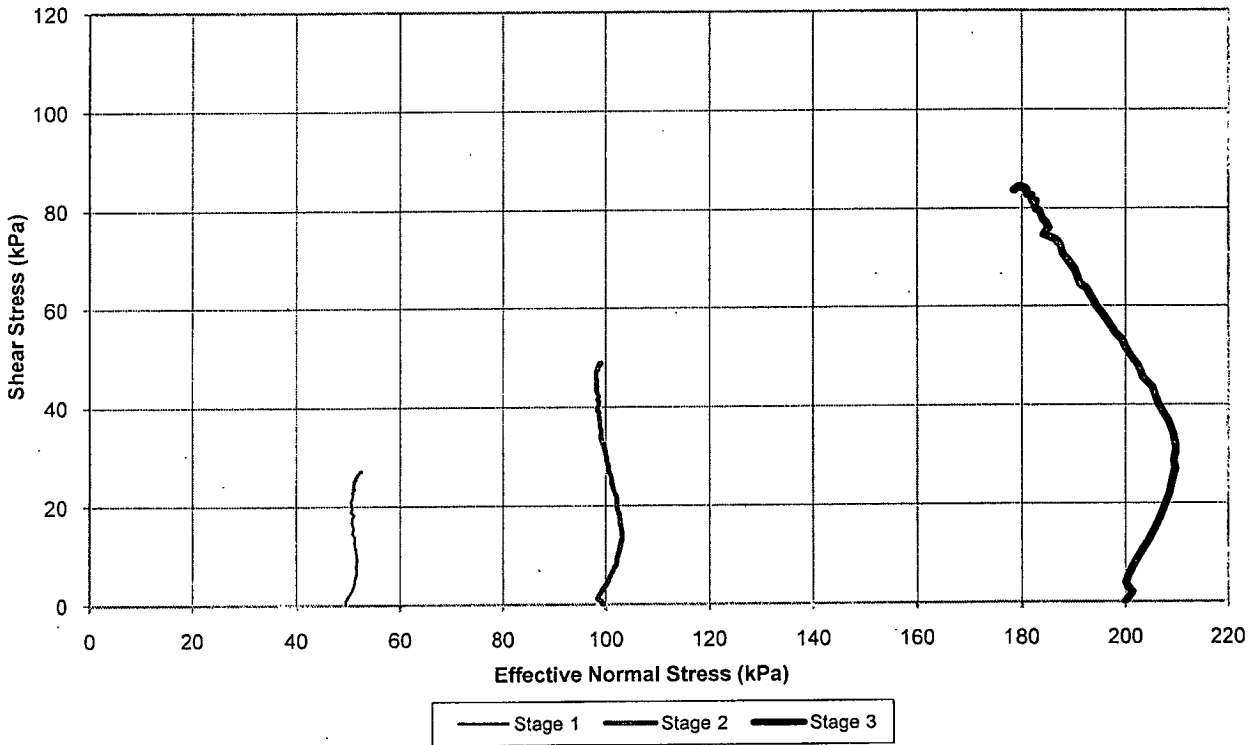
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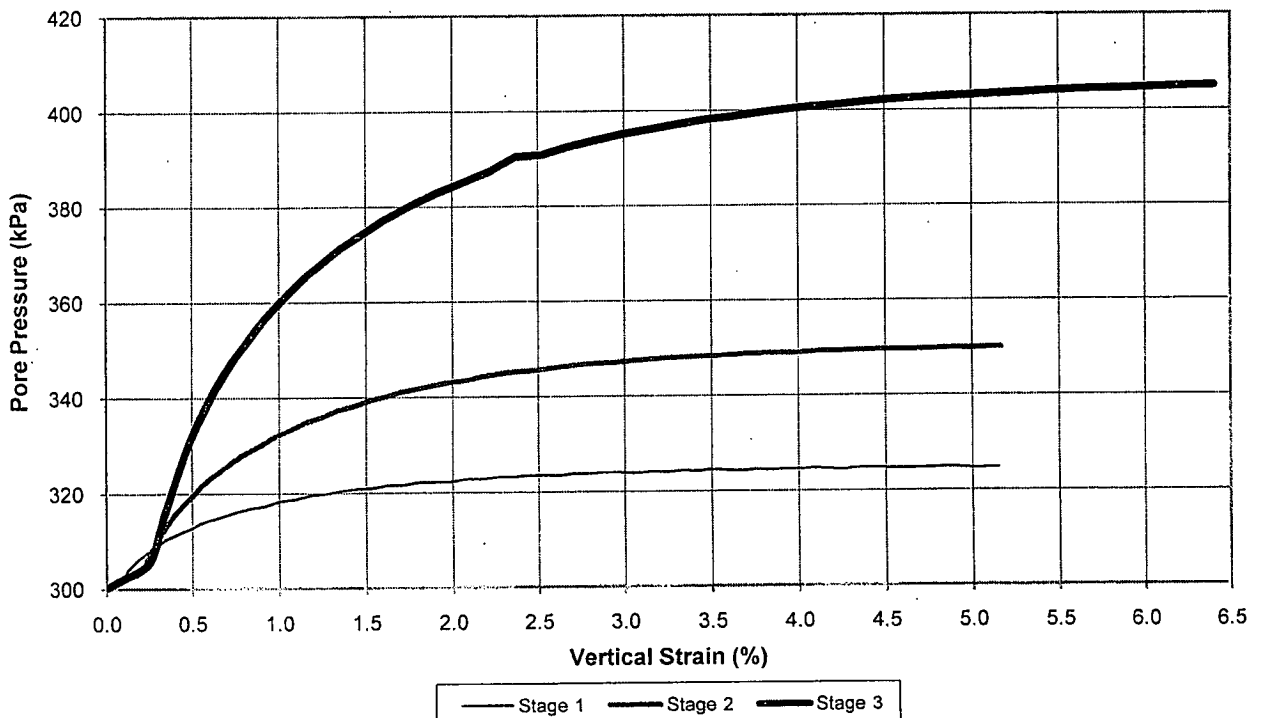
Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH4 Sample No.: PT1 Depth: 2.75 -- 2.86 (m)

GRAPHS

STRESS PATH



PORE PRESSURE Vs VERTICAL STRAIN



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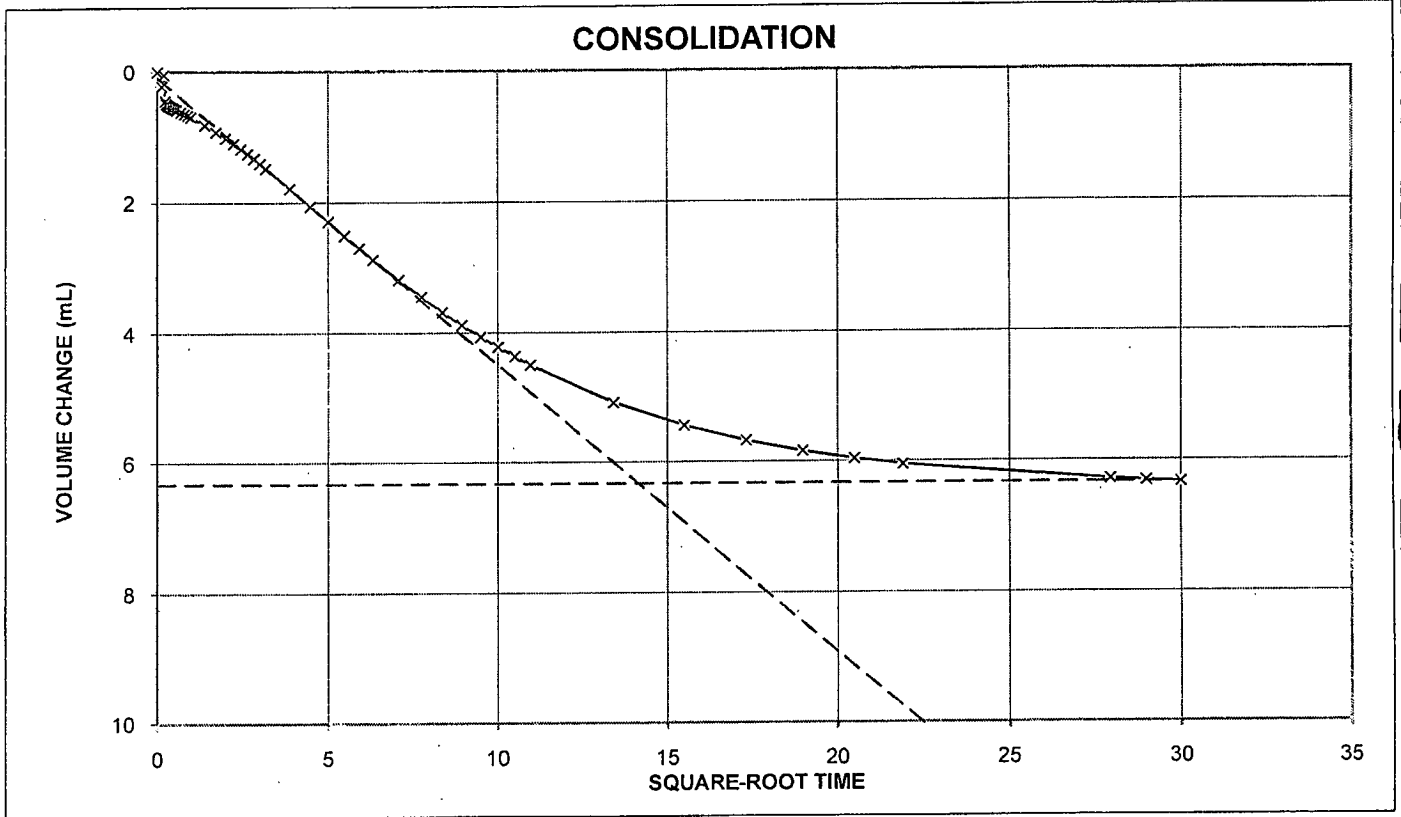
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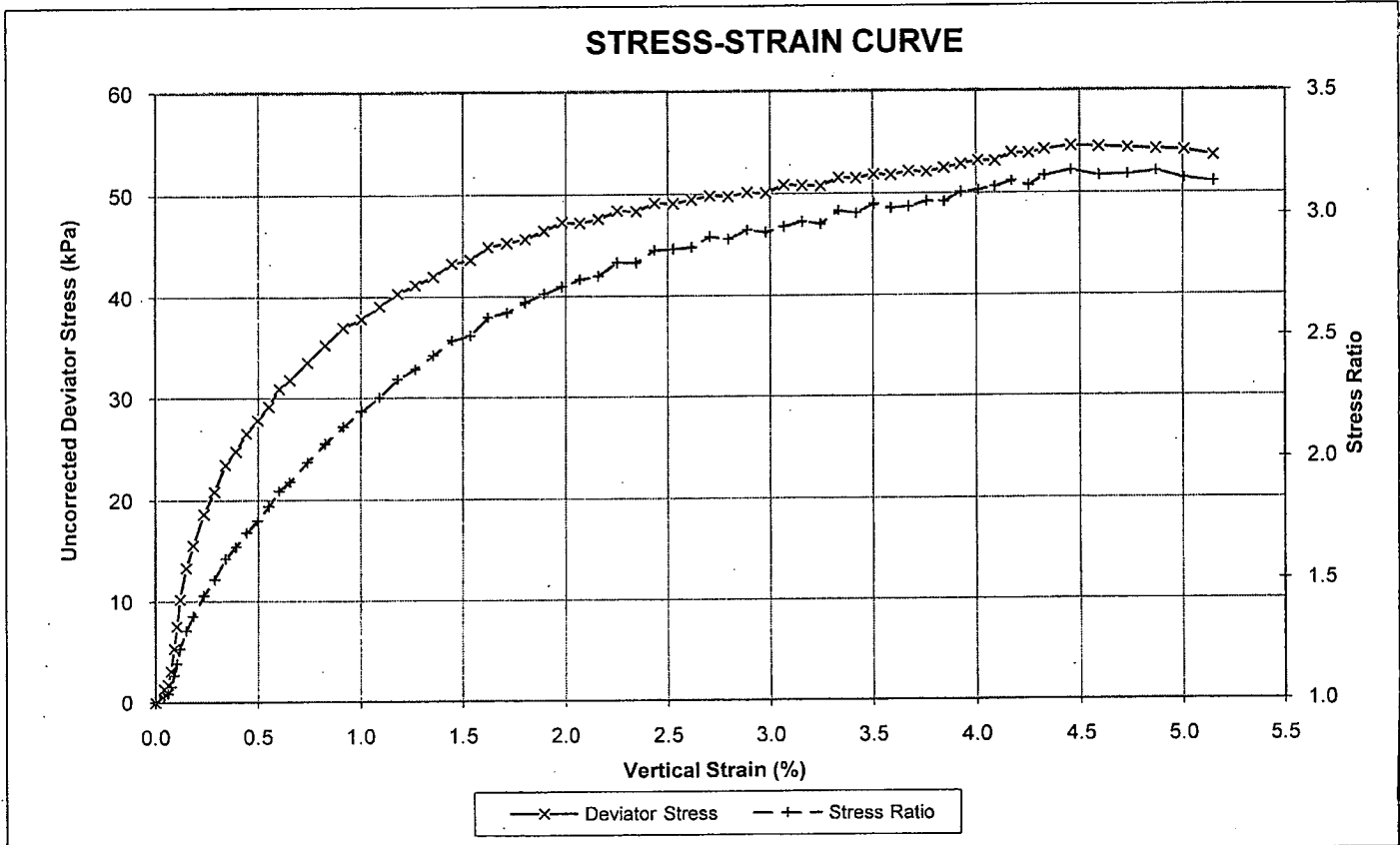
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 Site: Huia Watercare Plant, Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH4 Sample No.: PT1 Depth: 2.75 -- 2.86 (m)

STAGE 1 GRAPHS

CONSOLIDATION



STRESS-STRAIN CURVE



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Site: Huia Watercare Plant, Your Ref No.: 27064.001

Job No.: 615300.001

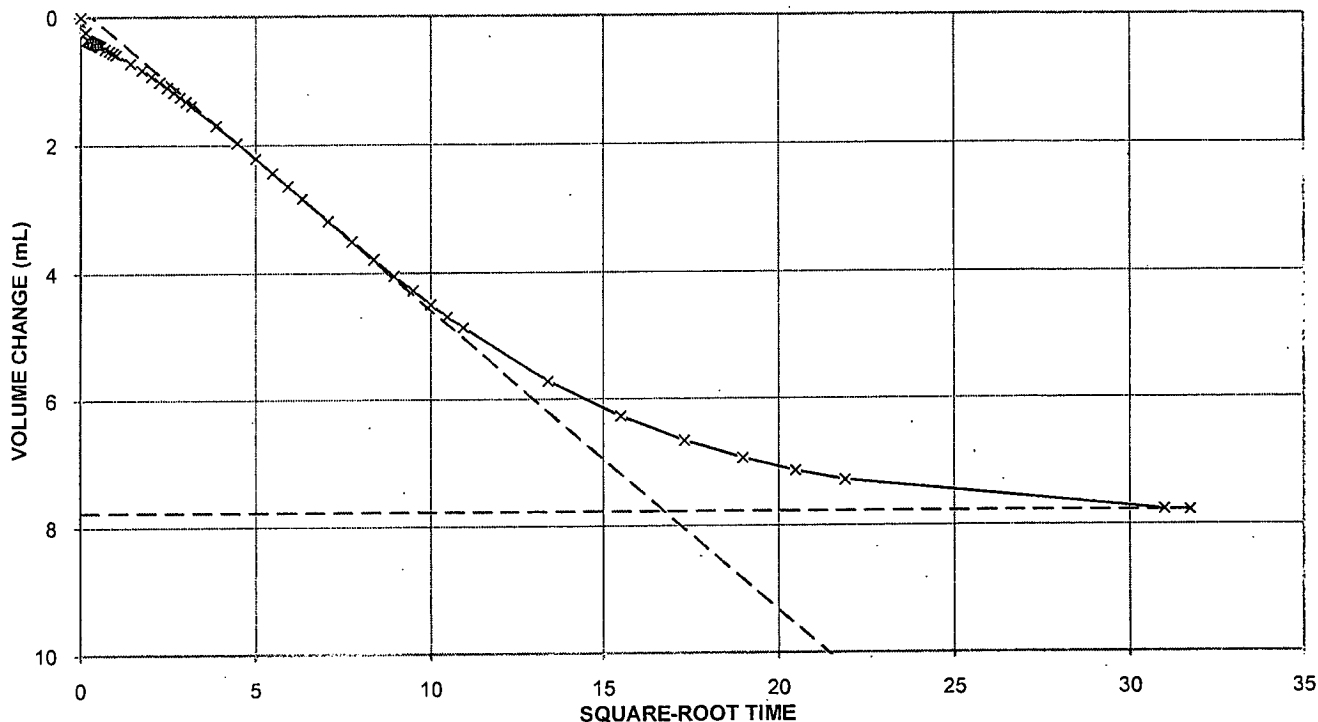
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Sample No.: PT1

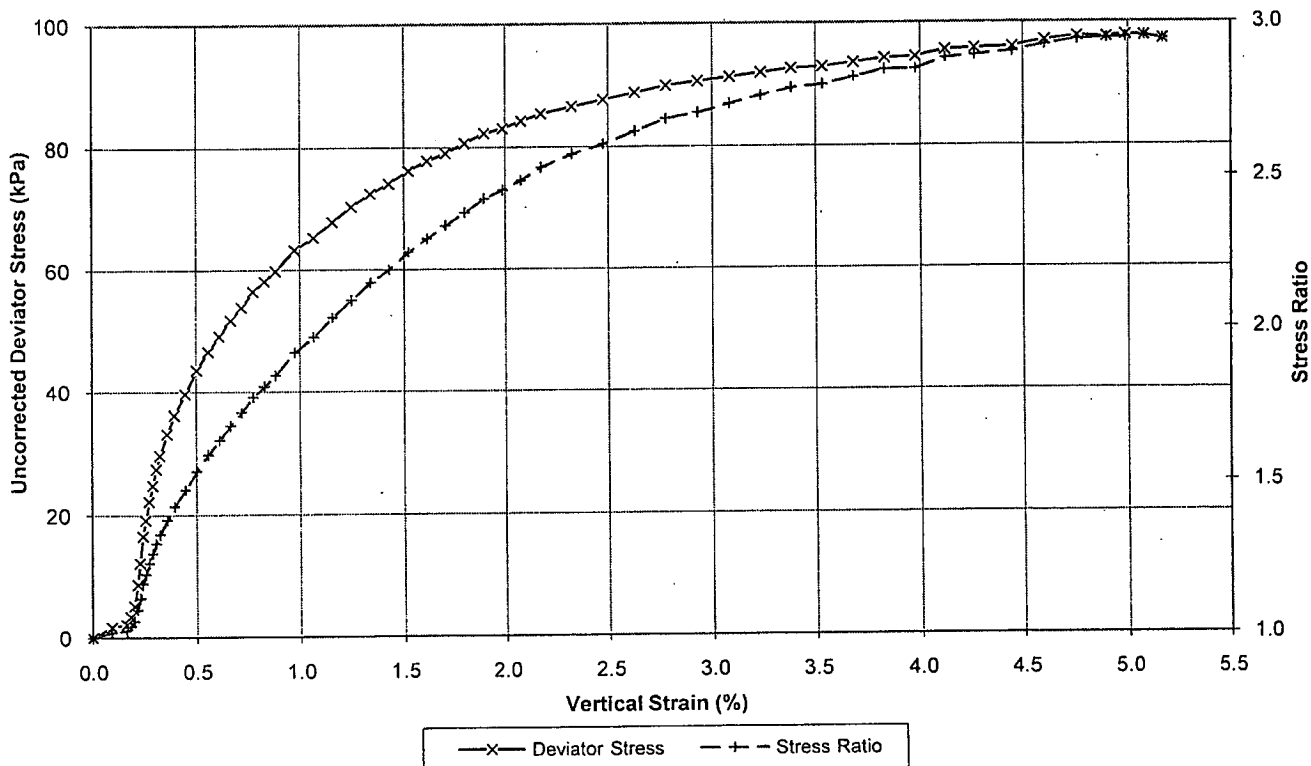
Depth: 2.75 -- 2.86 (m)

STAGE 2 GRAPHS

CONSOLIDATION



STRESS-STRAIN CURVE



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8/06/10

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Date:

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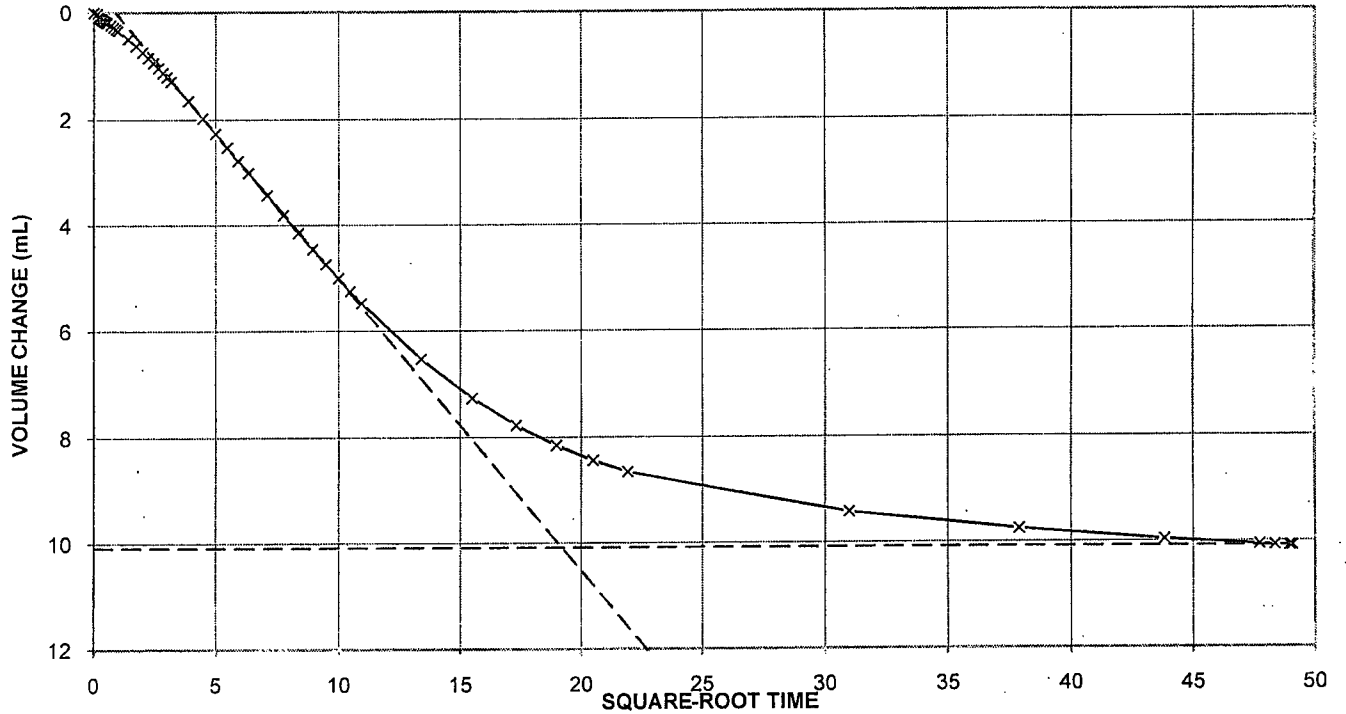
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Form Date:	July 2003
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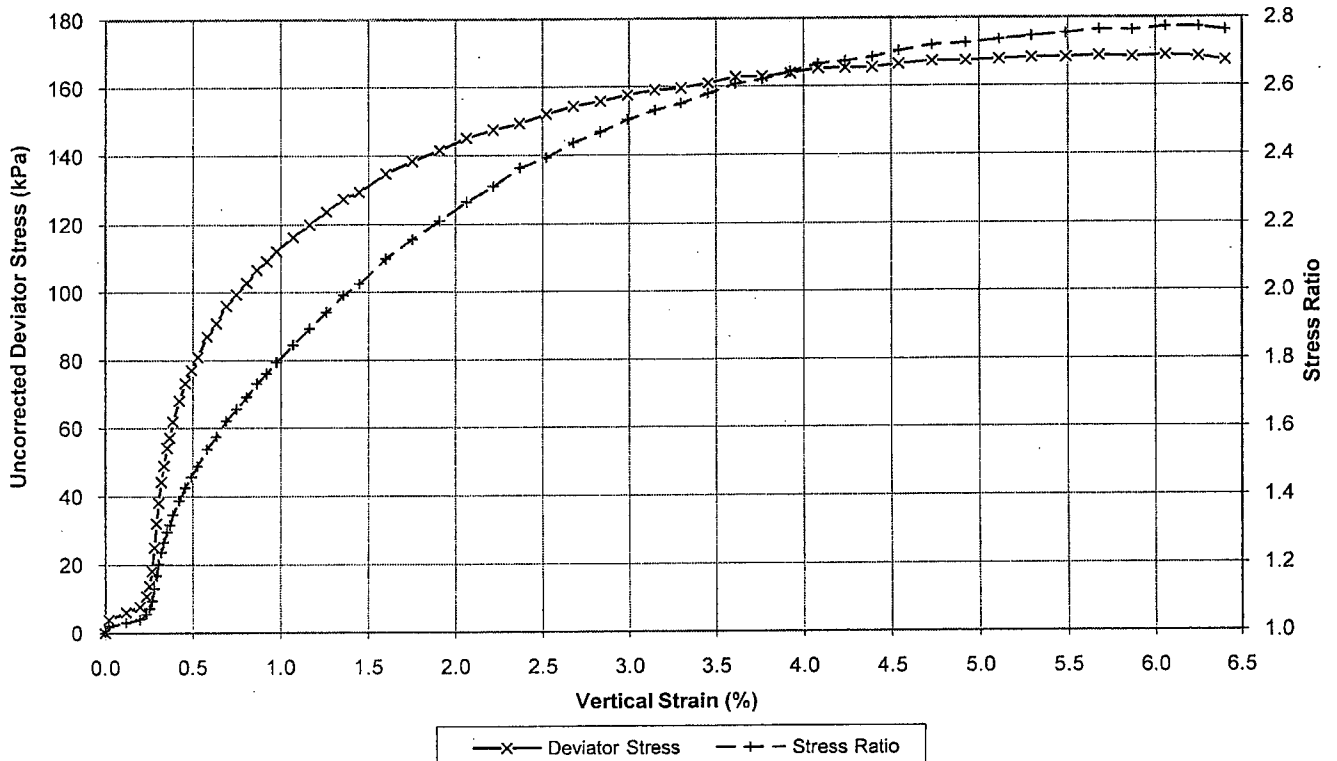
Plate No.:
Site: Huia Watercare Plant, Your Ref No.: 27064.001
Test pit/Bh No.: BH4 Sample No.: PT1

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Job No.: 615300.001
Depth: 2.75 -- 2.86 (m)

STAGE 3 GRAPHS CONSOLIDATION



STRESS-STRAIN CURVE



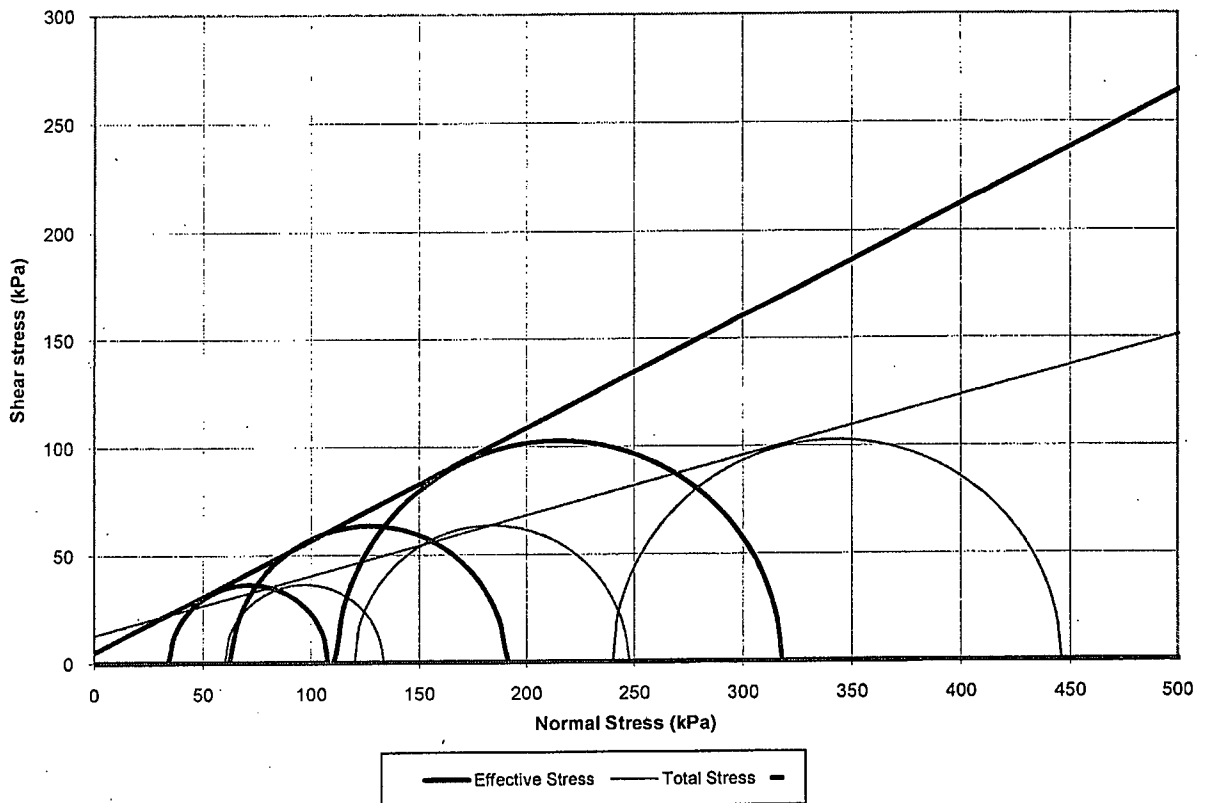


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Plate No.:		Page	of
Site:	Huia Watercare Plant, Titirangi	Your Ref No.:	27064.001
Test pit/Bh No.:	BH6	Sample No.:	PT3
Test method used:	BS1377:Part 8:1990:Clause 5 Saturation	BS1377:Part 8:1990:Clause 6 Consolidation	
	BS1377:Part 8:1990:Clause 7 Consolidated-undrained triaxial compression test with pore pressure measurement		

CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST (3 STAGES) MOHR CIRCLES OF TOTAL AND EFFECTIVE STRESSES



Initial Sample Height:	110.04	mm	Initial Water Content:	62.3	%
Initial Sample Diameter:	53.94	mm	Initial Bulk Density:	1.60	t/m ³
Initial B Value:	38	%	Initial Dry Density:	0.99	t/m ³
B Value before Consolidation:	98	%	Final Water Content:	60.1	%

	Consolidation Stage			Failure Values				
	Cell Pressure (kPa)	Back Pressure (kPa)	Eff. Consol. Stress	Deviator Stress (kPa)	Pore Pressure Change During Shearing Δu (kPa)	Effective Principal Stress (kPa)		Vertical Strain (%)
						Major σ_1'	Minor σ_3'	
STAGE 1	360	300	60	73.33	25.5	107.83	34.50	3.52
STAGE 2	420	300	120	127.10	56.8	190.30	63.20	2.77
STAGE 3	540	300	240	205.58	128.2	317.38	111.80	3.42

Angle of Frictional Resistance:	$\phi = 15^\circ$	Total	$\phi' = 27^\circ$	Effective
Cohesion:	$c = 13$ kPa		$c' = 5$ kPa	
Linear Regression Coefficient:	$r = 0.996$		$r = 1.000$	

Sample History: Undisturbed core trimmed at natural water content.

Soil description: SILT, with some clay and minor sand, soft, grey with orange brown, medium to high plasticity, dilatant.

Failure Mode: Planar / Plastic Test Speed: 0.02 (mm/min)

Test Remarks: The sample was saturated by increments of cell pressure and back pressure. Failure for each stage was determined by either the maximum effective stress ratio or the maximum deviator stress. Strength parameters have been derived by using a linear regression fitting method.

Entered by: *UW* Date: 8/06/10 Checked by: *SDG* Date: 15/6/10



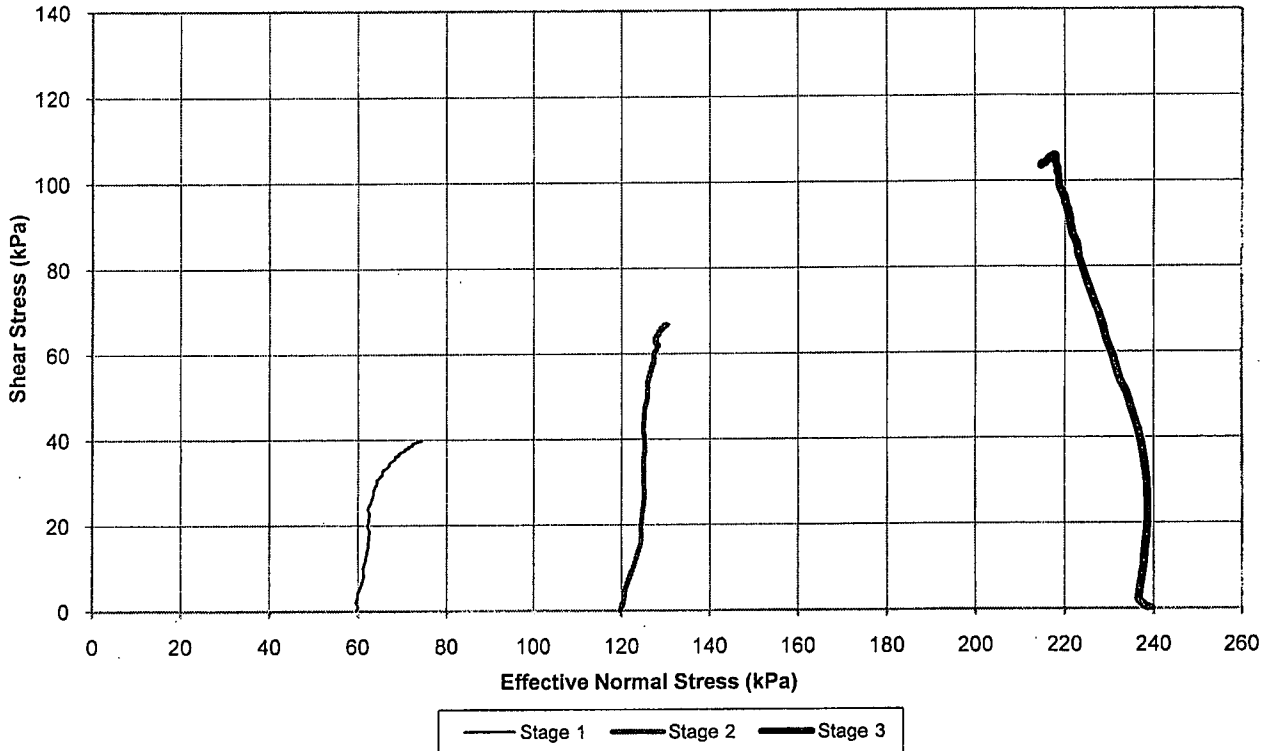
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Form Date:	July 2003
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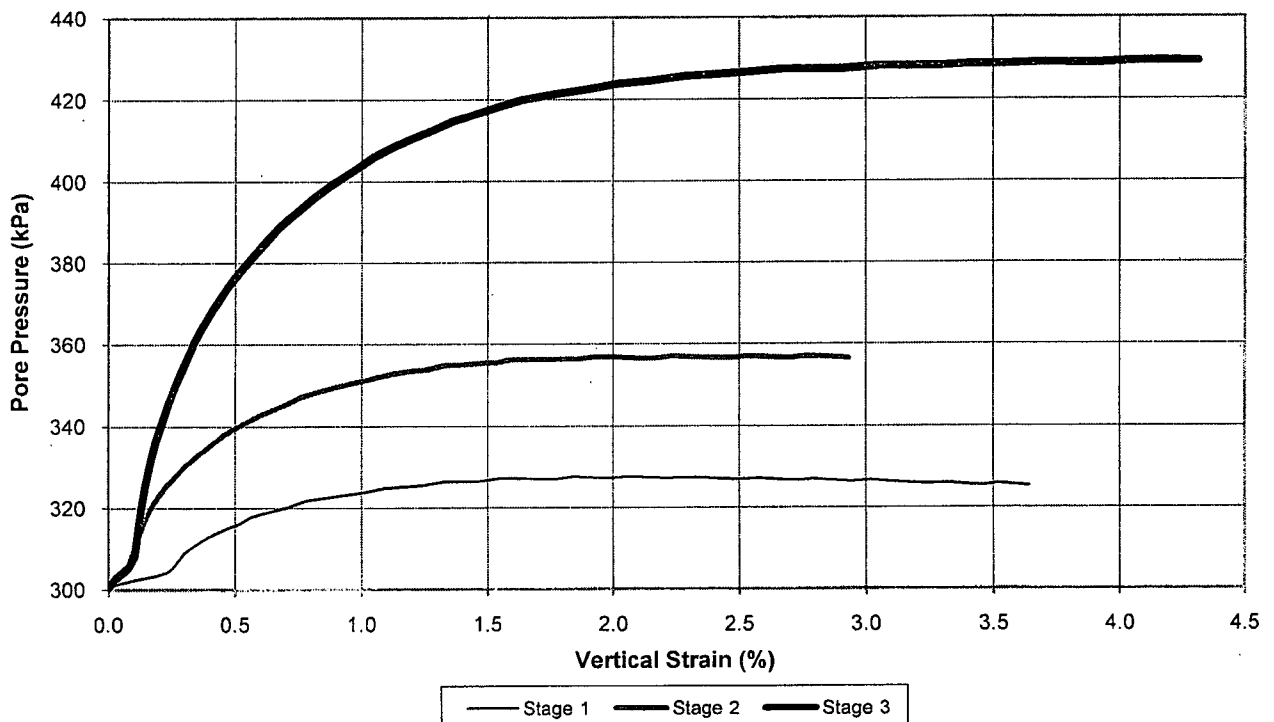
Plate No.: _____ Page of _____
Site: Huia Watercare Plant, Your Ref No.: 27064.001 Job No.: 615300.001
Test pit/Bh No.: BH6 Sample No.: PT3 Depth: 3.21 -- 3.32 (m)

GRAPHS

STRESS PATH



PORE PRESSURE Vs VERTICAL STRAIN



Entered by: *lm* Date: *8/6/10* Checked by: *SDG* Date: *15/6/10*



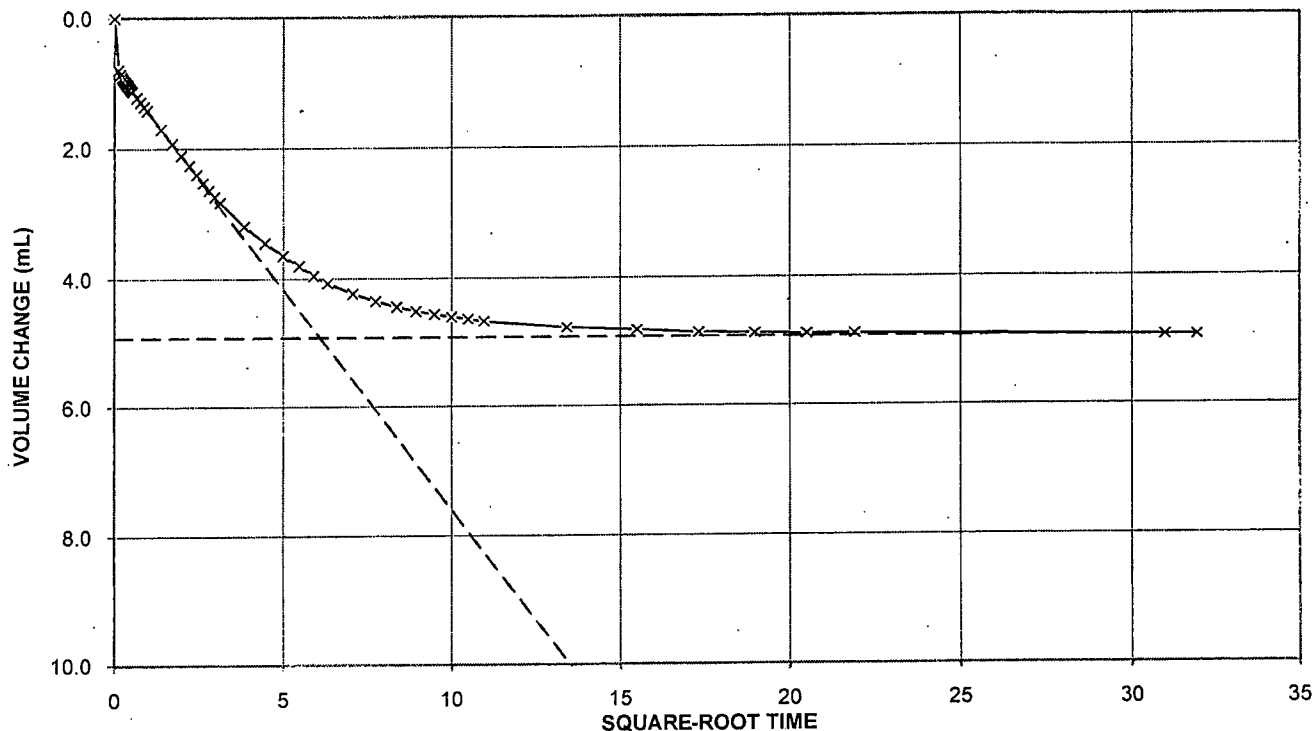
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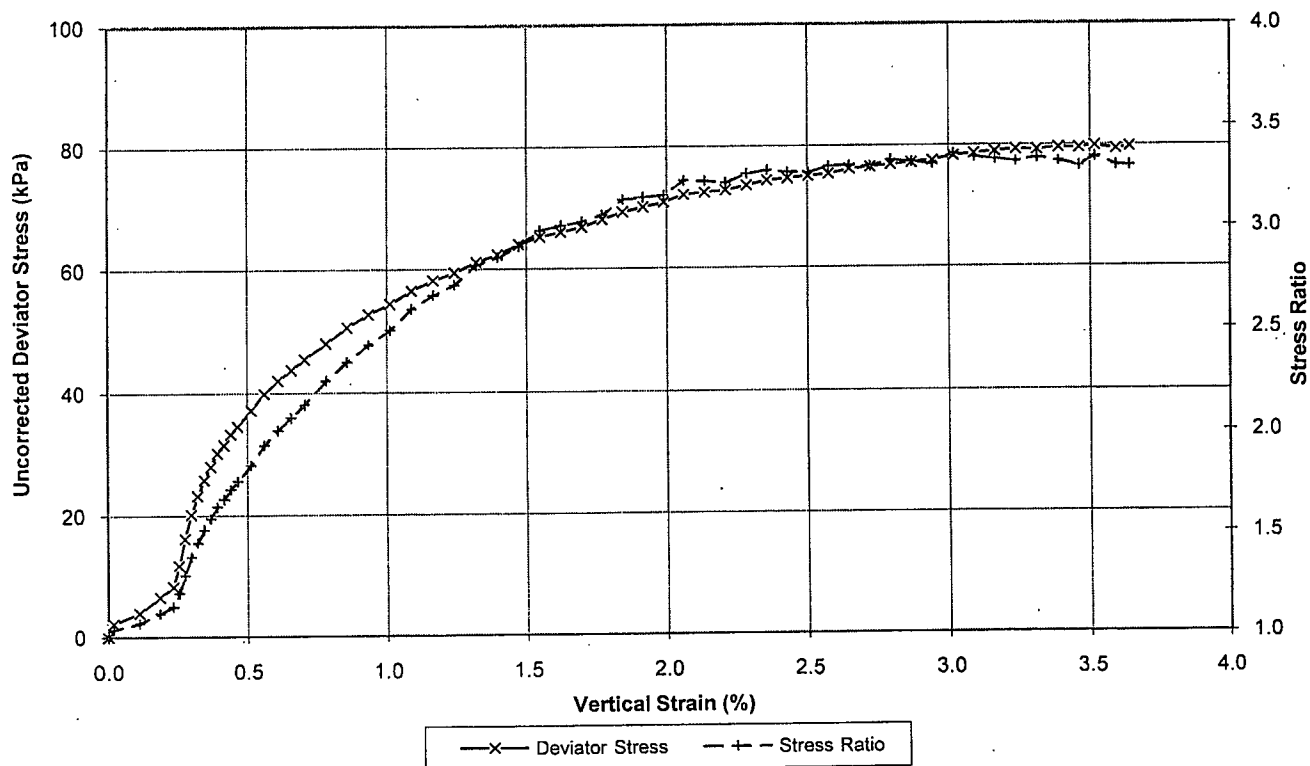
Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH6 Sample No.: PT3 Depth: 3.21 -- 3.32 (m)

STAGE 1 GRAPHS

CONSOLIDATION



STRESS-STRAIN CURVE



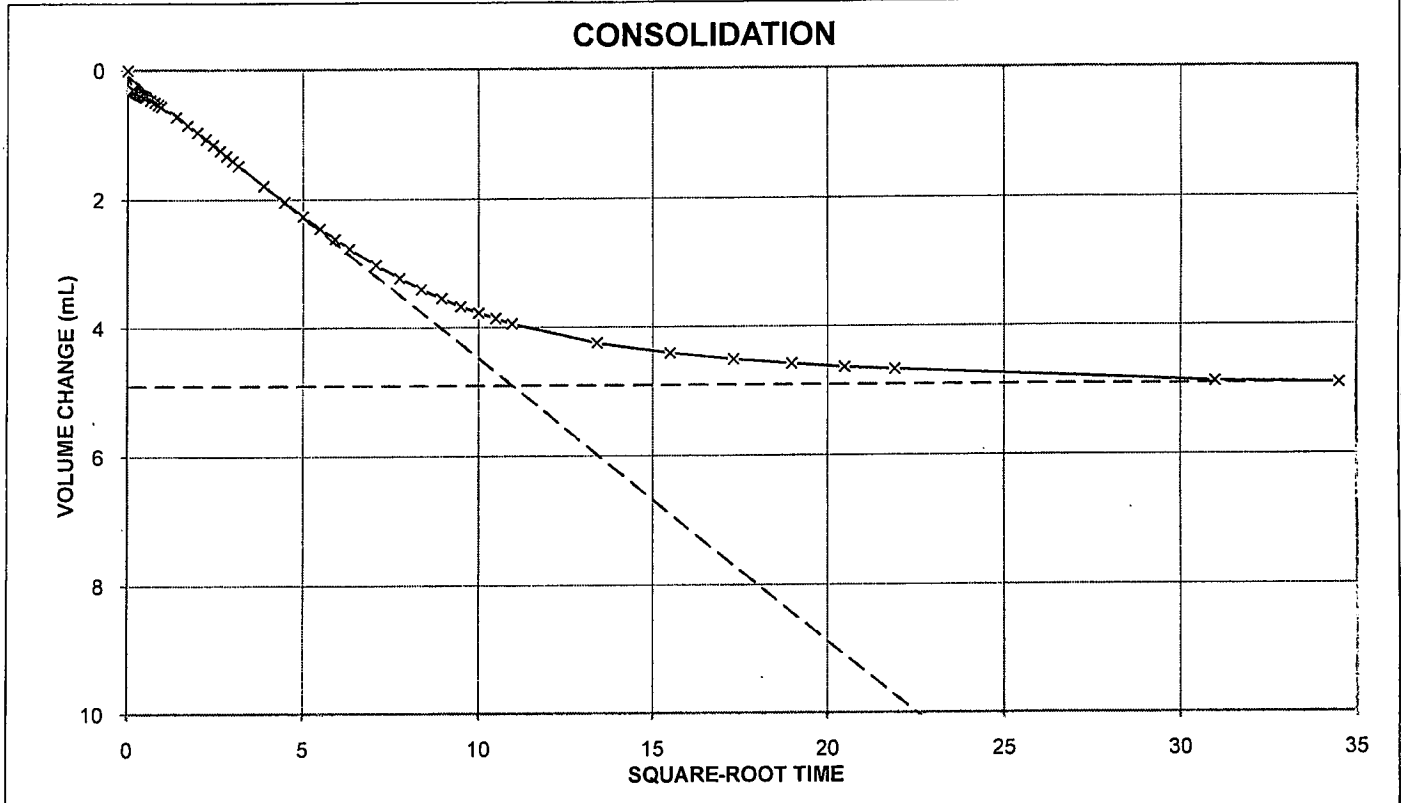


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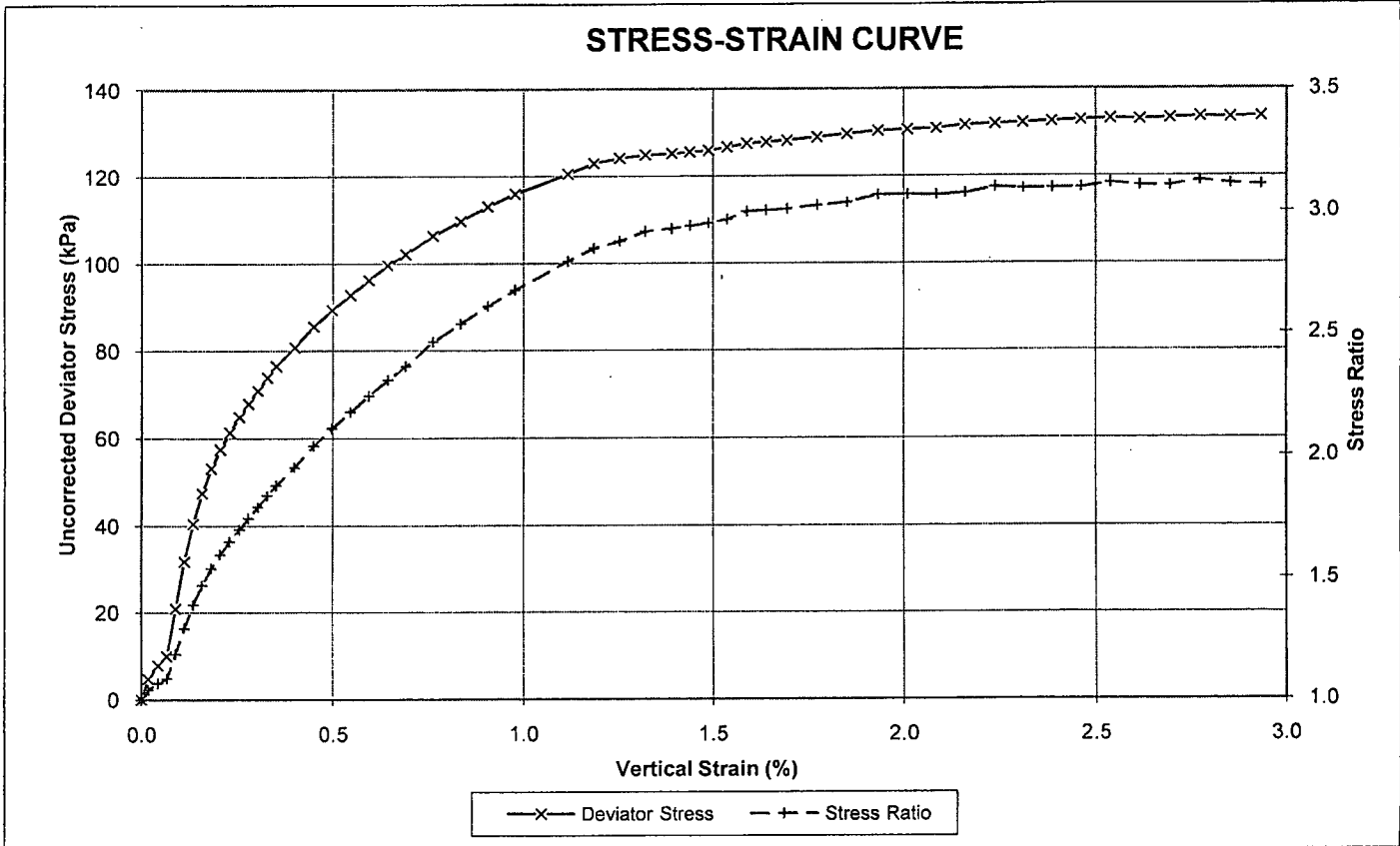
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Form Date:	July 2003
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Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH6 Sample No.: PT3 Depth: 3.21 -- 3.32 (m)

STAGE 2 GRAPHS CONSOLIDATION



STRESS-STRAIN CURVE



Entered by: *lm* Date: 8/06/00 Checked by: *SDG* Date: 15/6/10

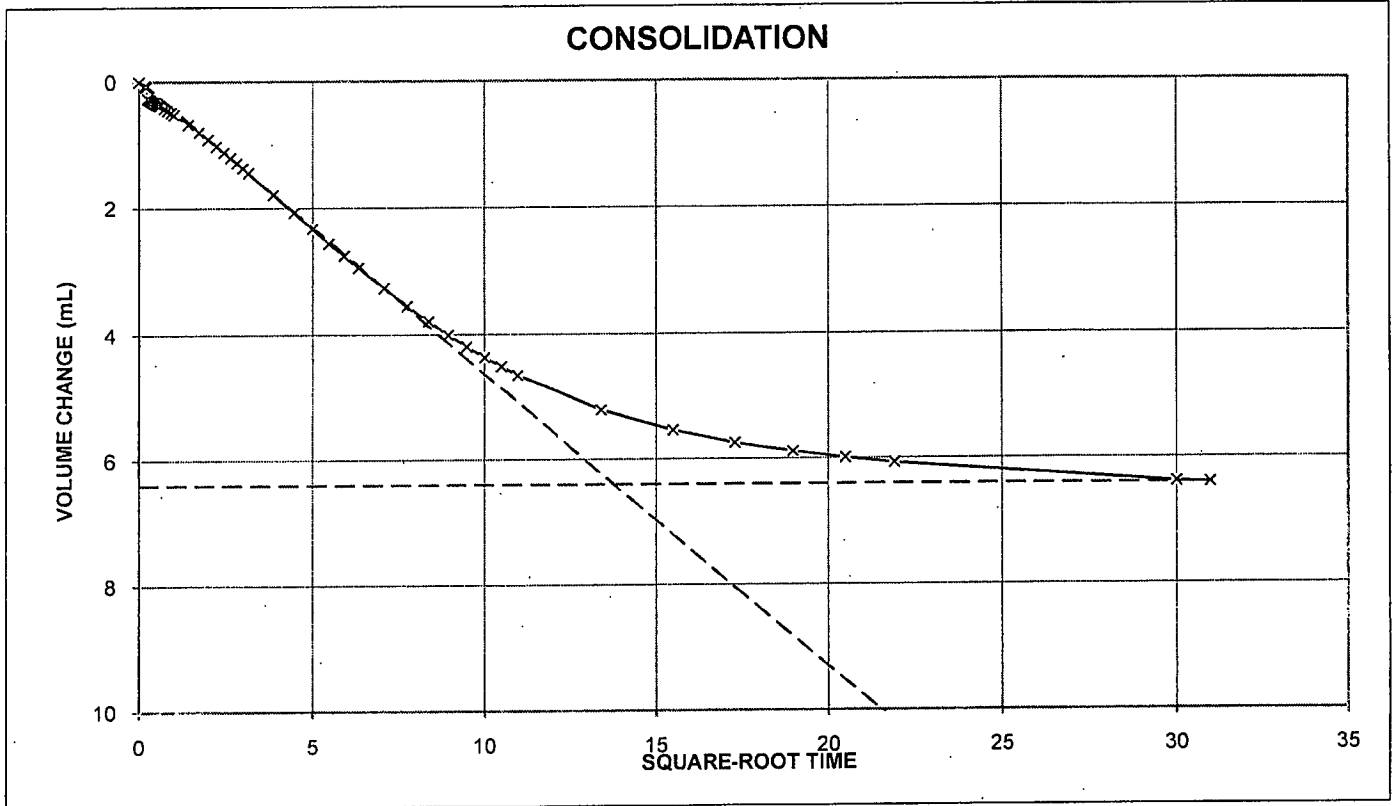


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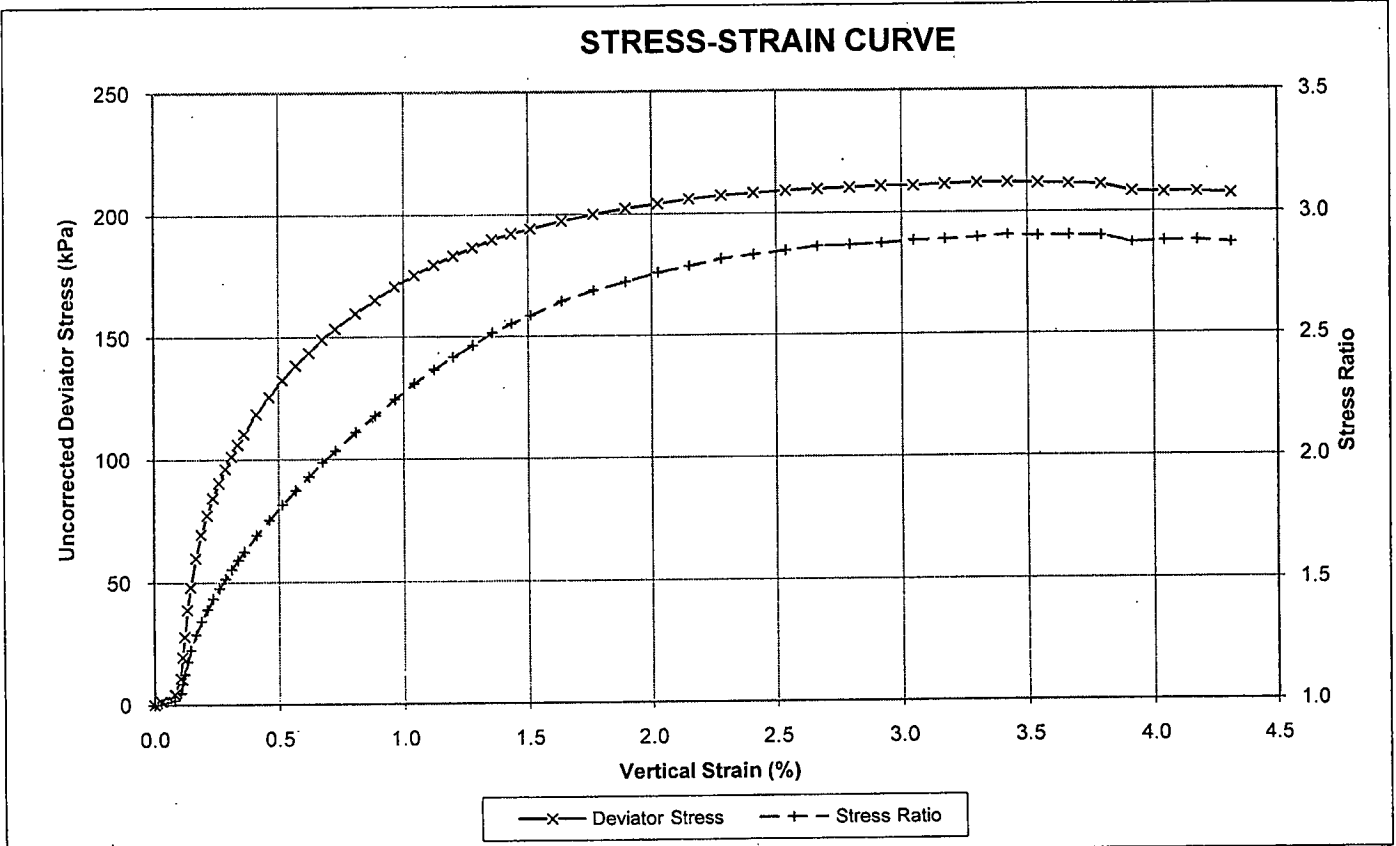
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Form Date:	July 2003
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Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH6 Sample No.: PT3 Depth: 3.21 -- 3.32 (m)

STAGE 3 GRAPHS CONSOLIDATION



STRESS-STRAIN CURVE



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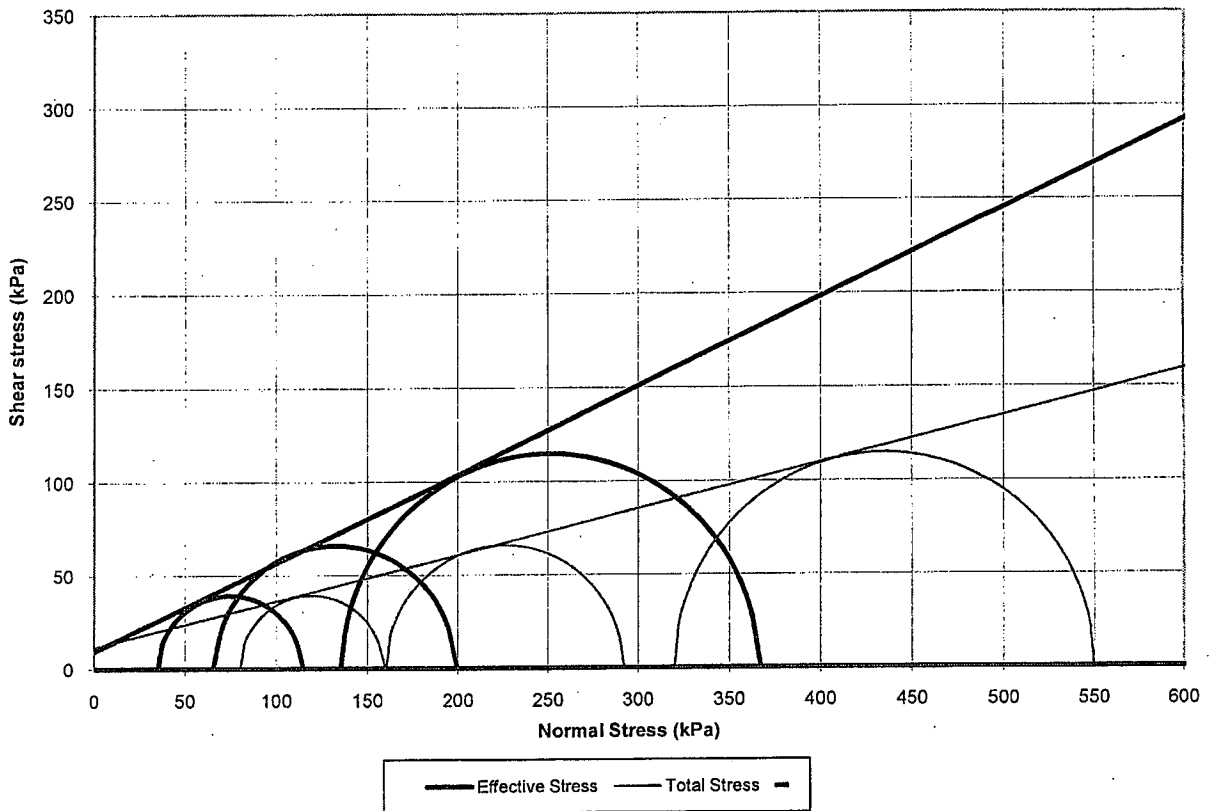


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Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Titirangi Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH6 Sample No.: PT4 Depth: 4.60 -- 4.71 (m)
 Test method used: BS1377:Part 8:1990:Clause 5 Saturation BS1377:Part 8:1990:Clause 6 Consolidation
 BS1377:Part 8:1990:Clause 7 Consolidated-undrained triaxial compression test with pore pressure measurement

CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST (3 STAGES) MOHR CIRCLES OF TOTAL AND EFFECTIVE STRESSES



Initial Sample Height:	116.22	mm	Initial Water Content:	70.1	%
Initial Sample Diameter:	53.89	mm	Initial Bulk Density:	1.57	t/m ³
Initial B Value:	40	%	Initial Dry Density:	0.92	t/m ³
B Value before Consolidation:	96	%	Final Water Content:	64.6	%

	Consolidation Stage			Failure Values				
	Cell Pressure (kPa)	Back Pressure (kPa)	Eff. Consol. Stress	Deviator Stress (kPa)	Pore Pressure Change During Shearing Δu (kPa)	Effective Principal Stress (kPa)		Vertical Strain (%)
						Major σ_1'	Minor σ_3'	
STAGE 1	380	300	80	78.53	44.8	113.73	35.20	3.24
STAGE 2	460	300	160	131.66	93.6	198.06	66.40	2.65
STAGE 3	620	300	320	229.75	184	365.75	136.00	2.78

Angle of Frictional Resistance:	$\phi = 14^\circ$	Total	$\phi' = 25^\circ$	Effective
Cohesion:	$c = 12$ kPa		$c' = 9$ kPa	
Linear Regression Coefficient:	$r = 1.000$		$r = 0.999$	

Sample History: Undisturbed core trimmed at natural water content.

Soil description: SILT, with some clay, firm, light grey with grey / black and orange brown, medium plasticity, dilatant.

Failure Mode: Planar / Plastic Test Speed: 0.038 (mm/min)

Test Remarks: The sample was saturated by increments of cell pressure and back pressure. Failure for each stage was determined by the maximum deviator stress. Strength parameters have been derived by using a linear regression fitting method.

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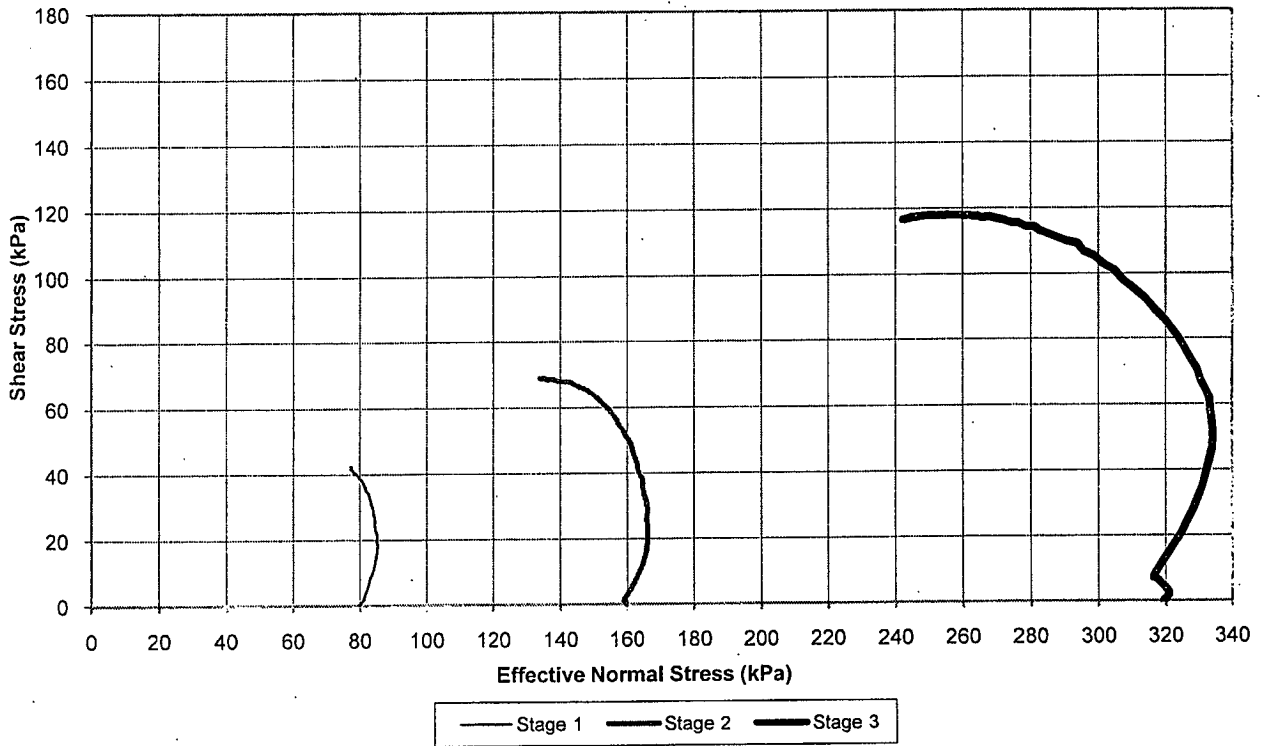
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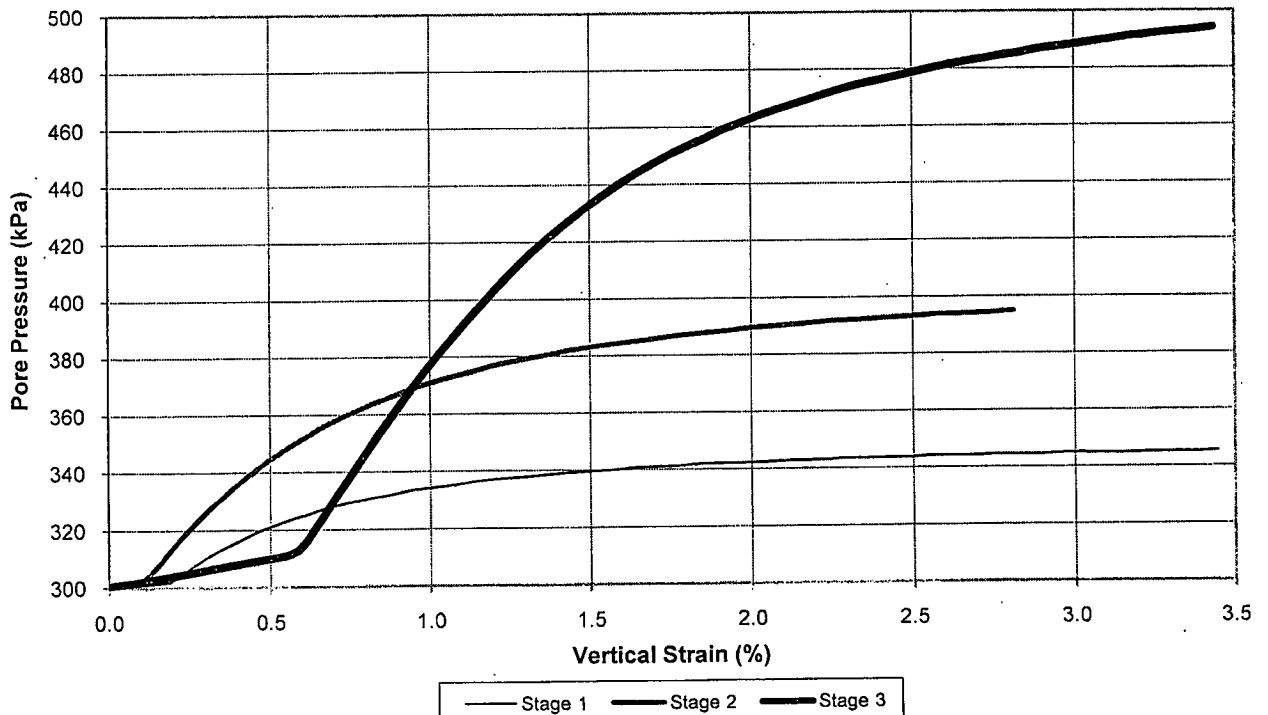
Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH6 Sample No.: PT4 Depth: 4.60 -- 4.71 (m)

GRAPHS

STRESS PATH



PORE PRESSURE Vs VERTICAL STRAIN



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Page of

Site: Huia Watercare Plant, Your Ref No.: 27064.001

Job No.: 615300.001

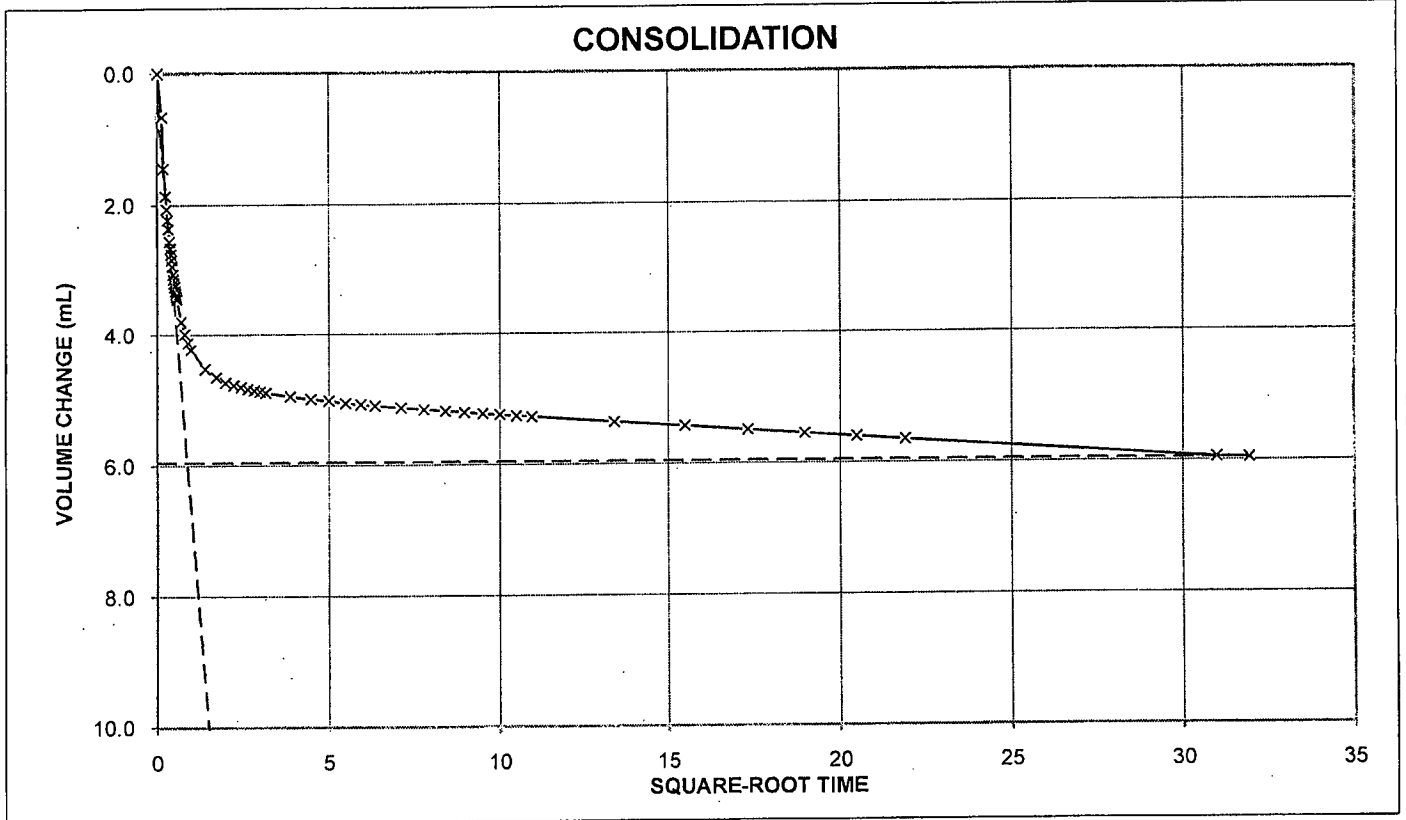
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Sample No.: PT4

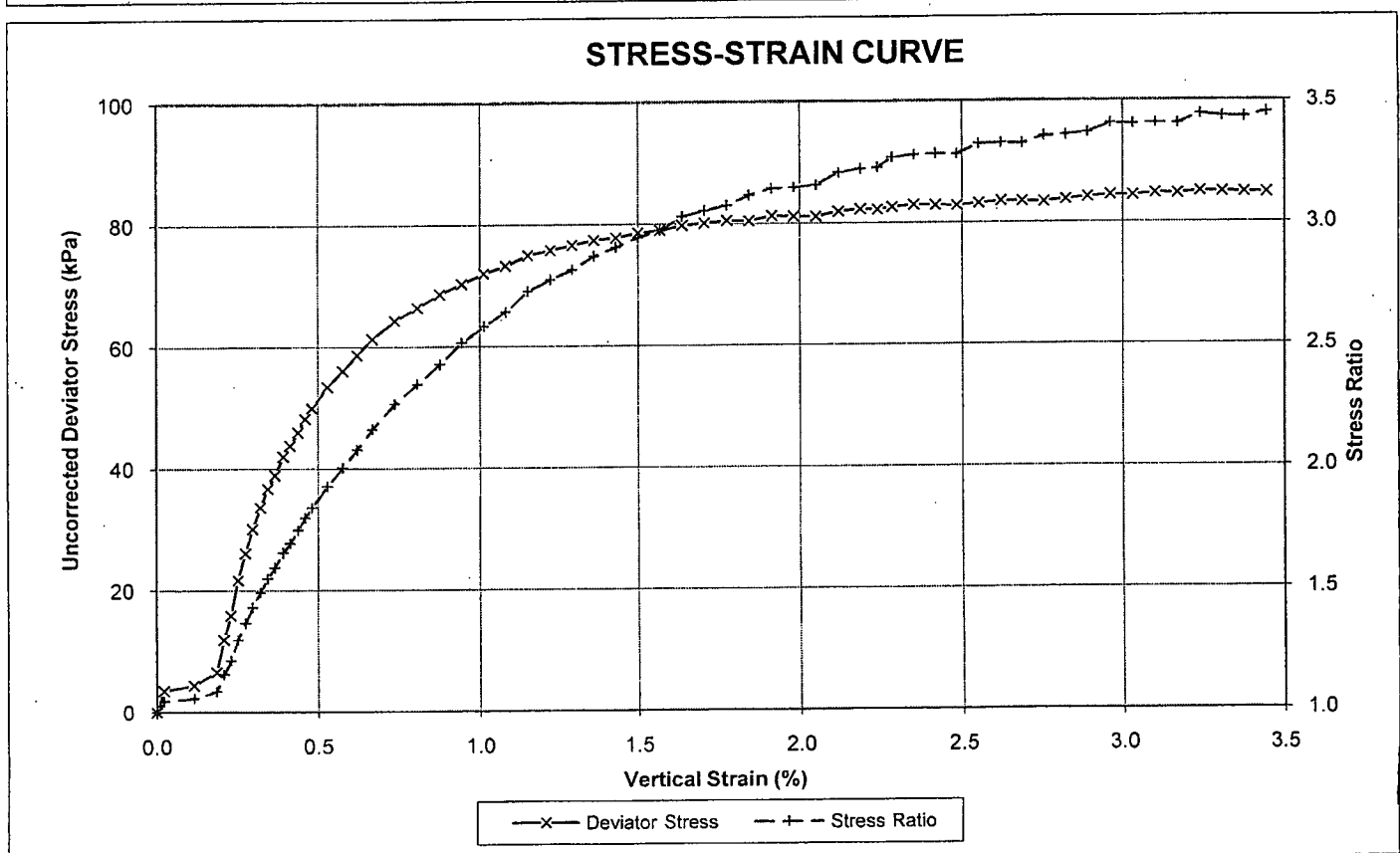
Depth: 4.60 -- 4.71 (m)

STAGE 1 GRAPHS

CONSOLIDATION



STRESS-STRAIN CURVE



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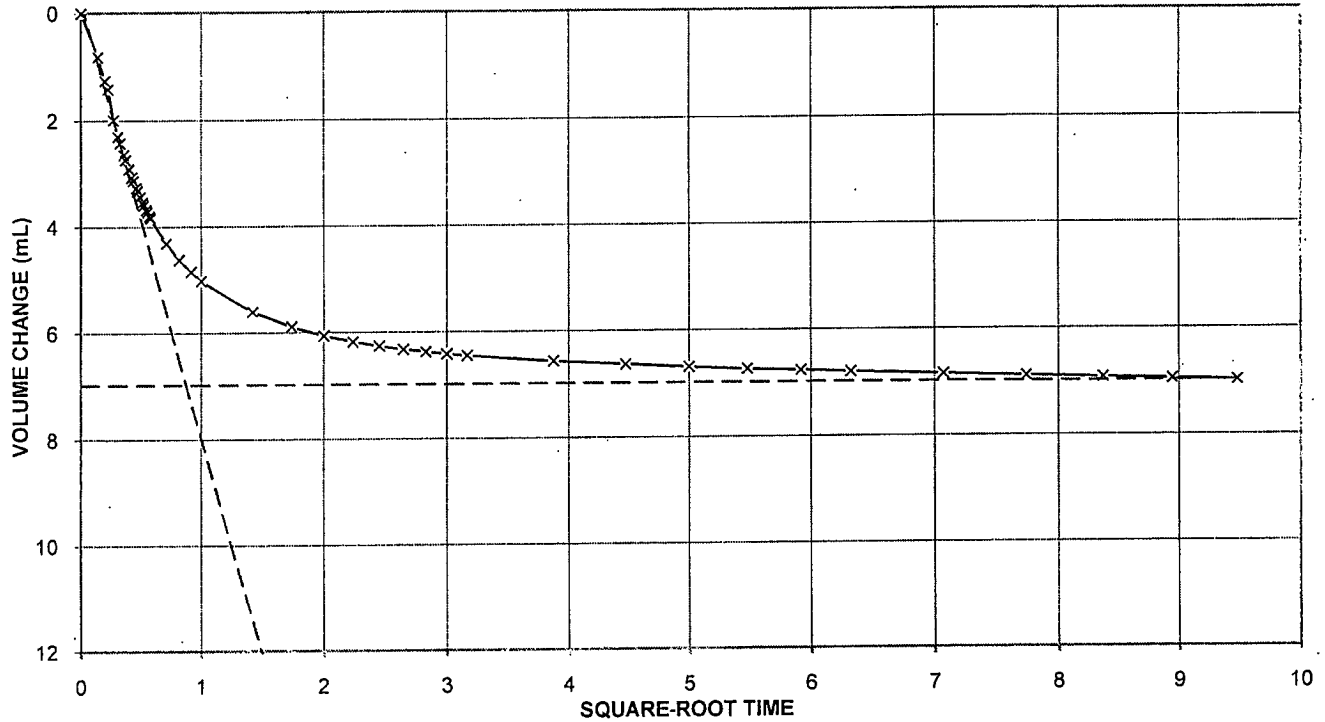
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Test pit/Bh No.: BH6 Sample No.: PT4

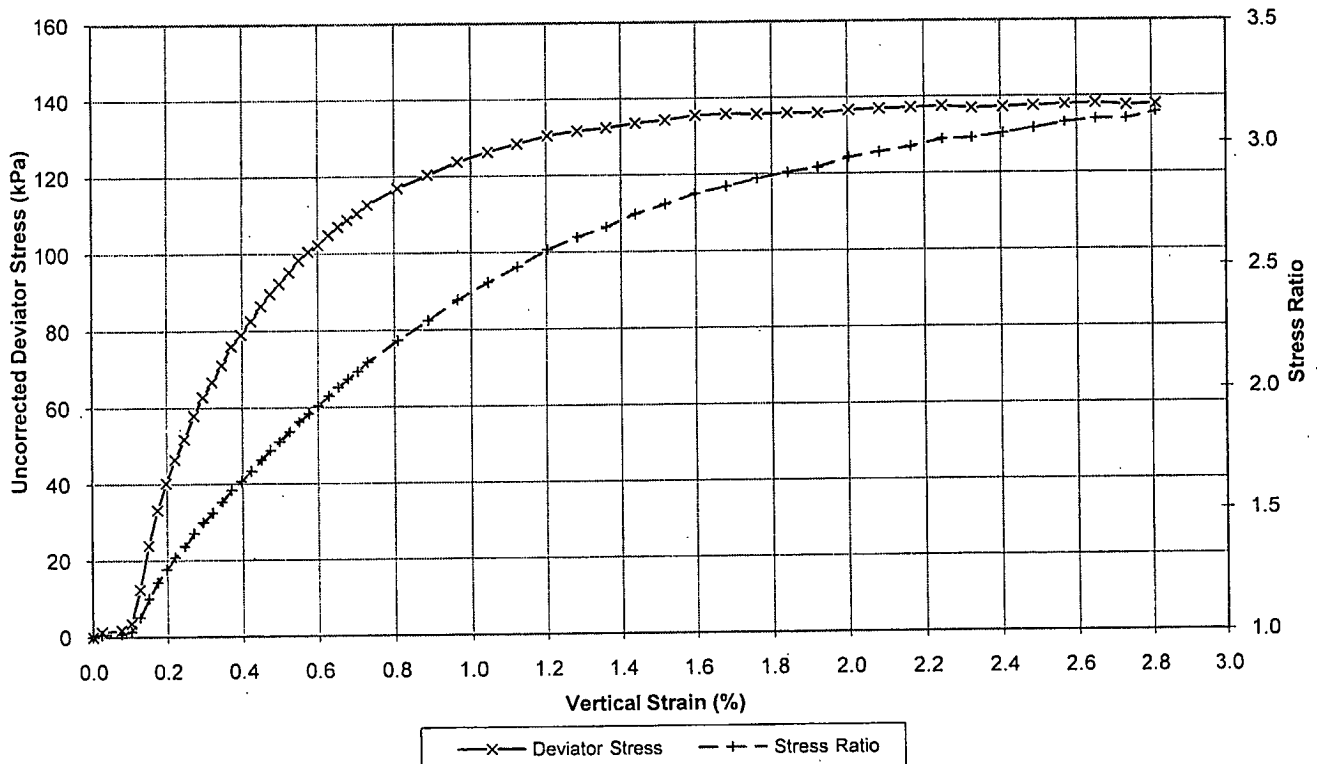
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Job No.: 615300.001
Depth: 4.60 -- 4.71 (m)

STAGE 2 GRAPHS

CONSOLIDATION



STRESS-STRAIN CURVE



Entered by: *Wm*

Date: 8/06/10

Checked by: SDG

Date: 17/6/10

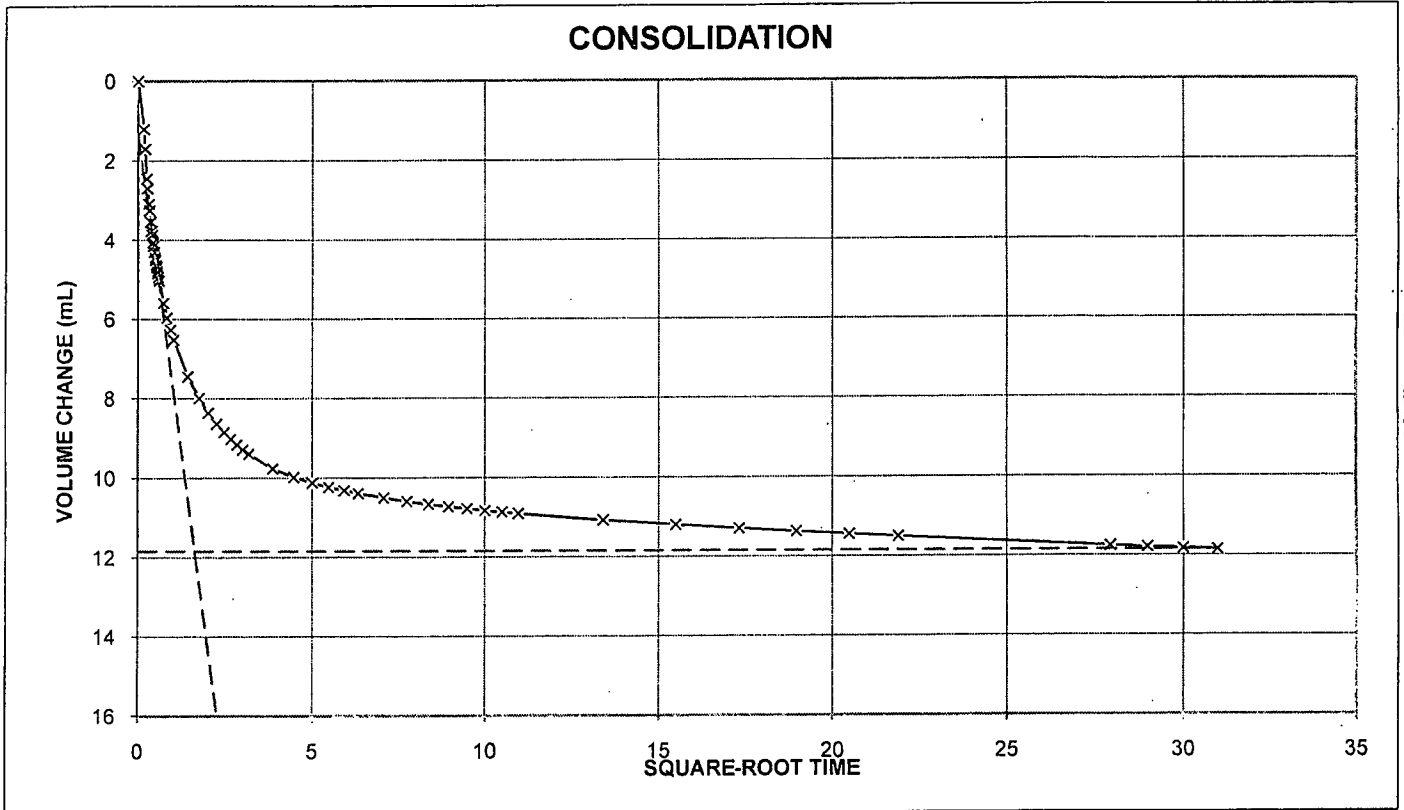


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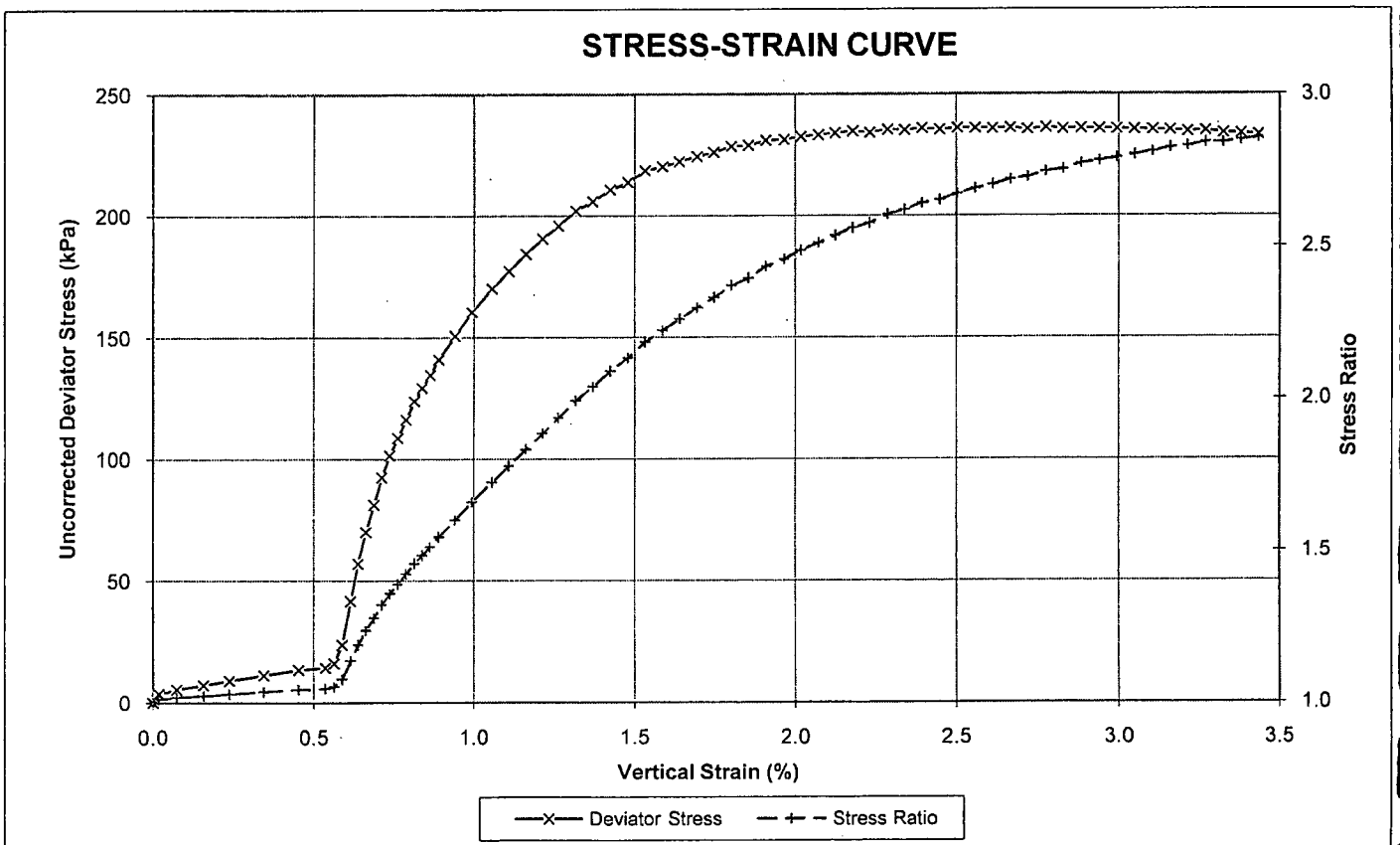
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Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH6 Sample No.: PT4 Depth: 4.60 -- 4.71 (m)

STAGE 3 GRAPHS CONSOLIDATION



STRESS-STRAIN CURVE



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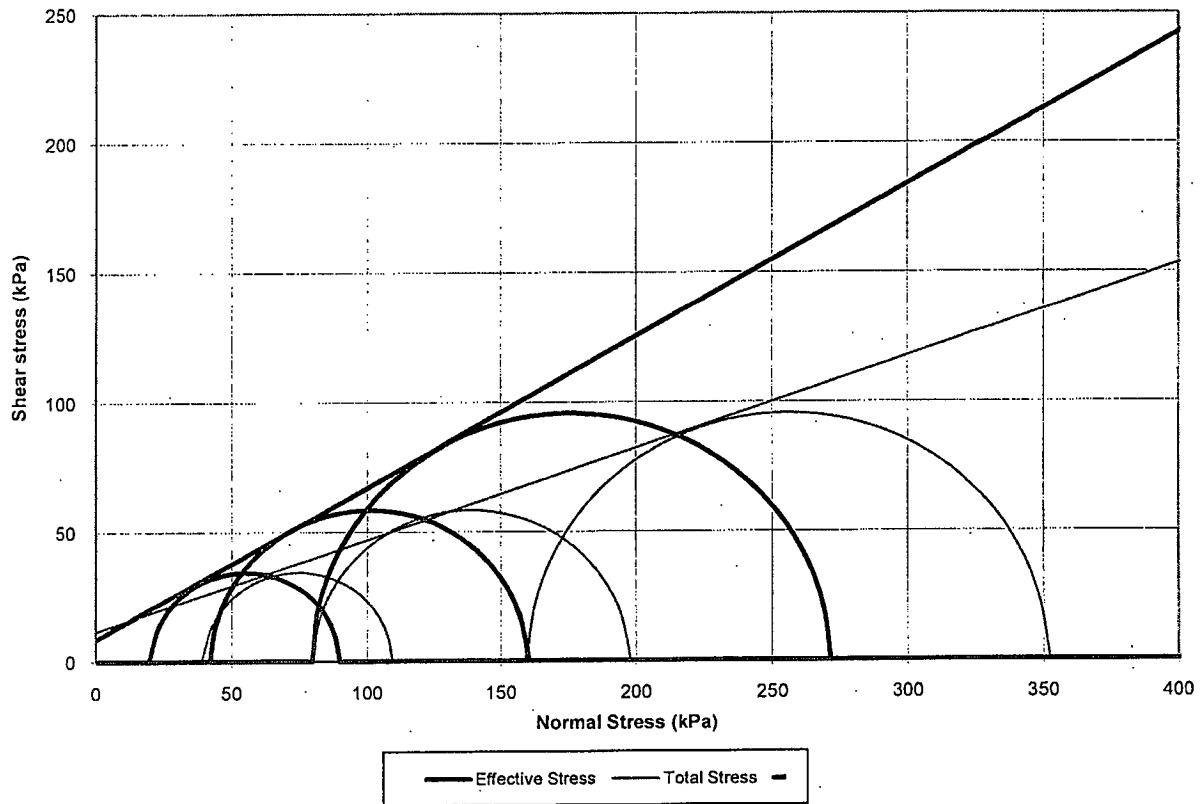
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Form Date:	July 2003

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Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Titirangi Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH8 Sample No.: PT1 Depth: 2.02 -- 2.14 (m)
 Test method used: BS1377:Part 8:1990:Clause 5 Saturation BS1377:Part 8:1990:Clause 6 Consolidation
 BS1377:Part 8:1990:Clause 7 Consolidated-undrained triaxial compression test with pore pressure measurement

CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST (3 STAGES) MOHR CIRCLES OF TOTAL AND EFFECTIVE STRESSES



Initial Sample Height:	118.76	mm	Initial Water Content:	53.1	%
Initial Sample Diameter:	60.32	mm	Initial Bulk Density:	1.63	t/m ³
Initial B Value:	22	%	Initial Dry Density:	1.06	t/m ³
B Value before Consolidation:	96	%	Final Water Content:	53.2	%

	Consolidation Stage			Failure Values				
	Cell Pressure (kPa)	Back Pressure (kPa)	Eff. Consol. Stress	Deviator Stress (kPa)	Pore Pressure Change During Shearing Δu (kPa)	Effective Principal Stress (kPa)		Vertical Strain (%)
						Major σ_1'	Minor σ_3'	
STAGE 1	490	450	40	68.97	19.5	89.47	20.50	3.55
STAGE 2	530	450	80	117.11	37.5	159.61	42.50	2.44
STAGE 3	610	450	160	191.47	80.5	270.97	79.50	3.21

Angle of Frictional Resistance:	$\phi = 19^\circ$	Total	$\phi' = 30^\circ$	Effective
Cohesion:	$c = 12$ kPa		$c' = 9$ kPa	
Linear Regression Coefficient:	$r = 0.998$		$r = 1.000$	

Sample History: Undisturbed core trimmed at natural water content.

Soil description: SILT, clayey, with some sand, soft to firm, orange brown with black, medium to high plasticity, dilatant.

Failure Mode: Planar / Plastic Test Speed: 0.03 (mm/min)

Test Remarks: The sample was saturated by increments of cell pressure and back pressure. Failure for each stage was determined by the maximum effective stress ratio. Strength parameters have been derived by using a linear regression fitting method.

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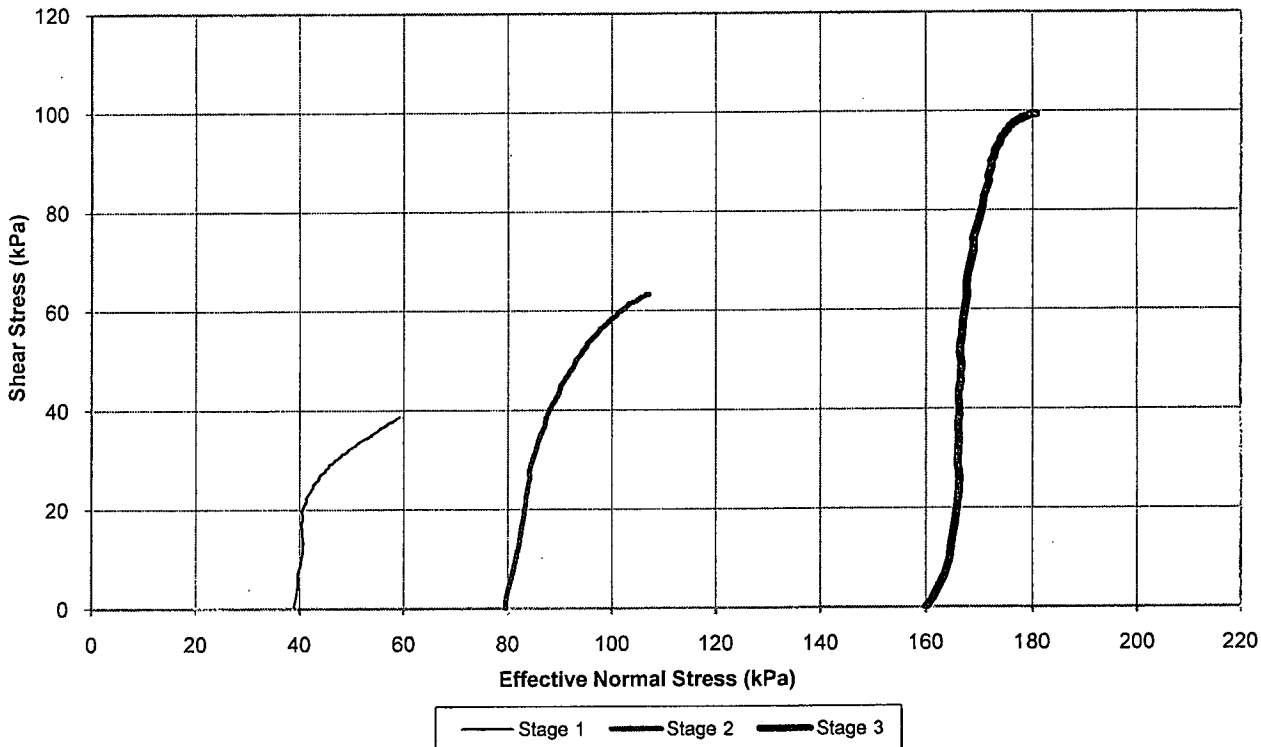
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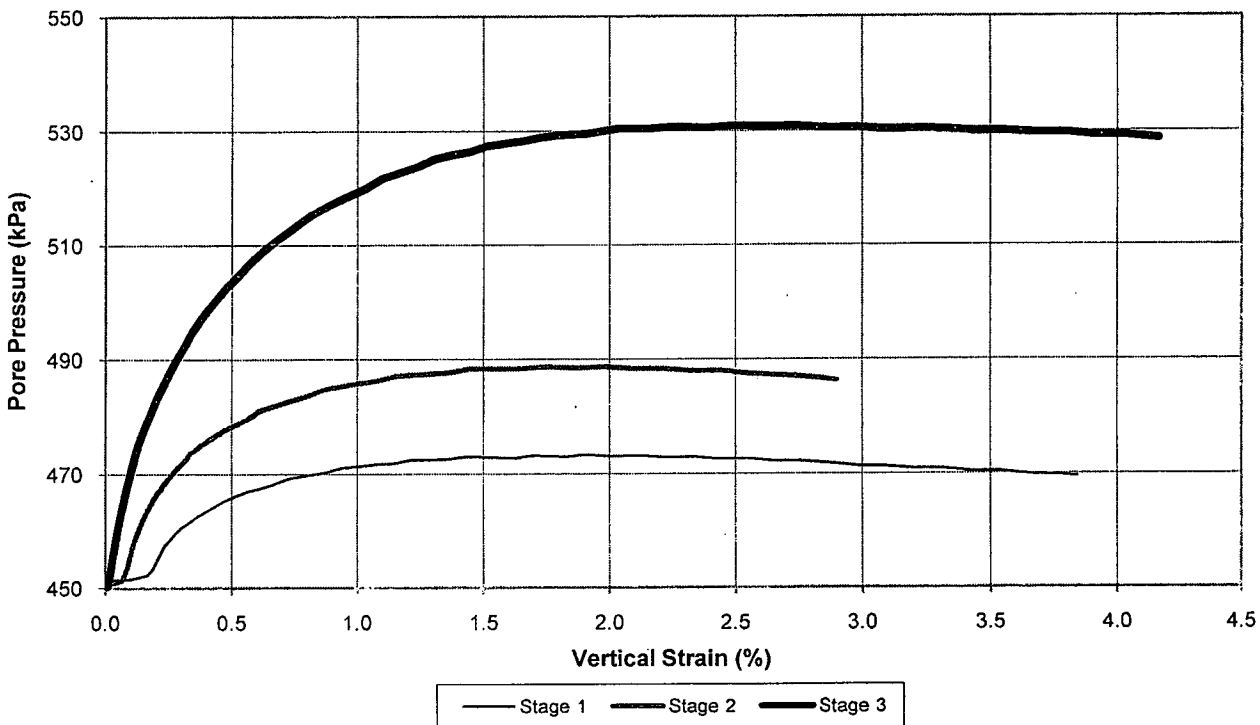
Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH8 Sample No.: PT1 Depth: 2.02 -- 2.14 (m)

GRAPHS

STRESS PATH



PORE PRESSURE Vs VERTICAL STRAIN



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Plate No.:

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Site: Huia Watercare Plant, Your Ref No.: 27064.001

Job No.: 615300.001

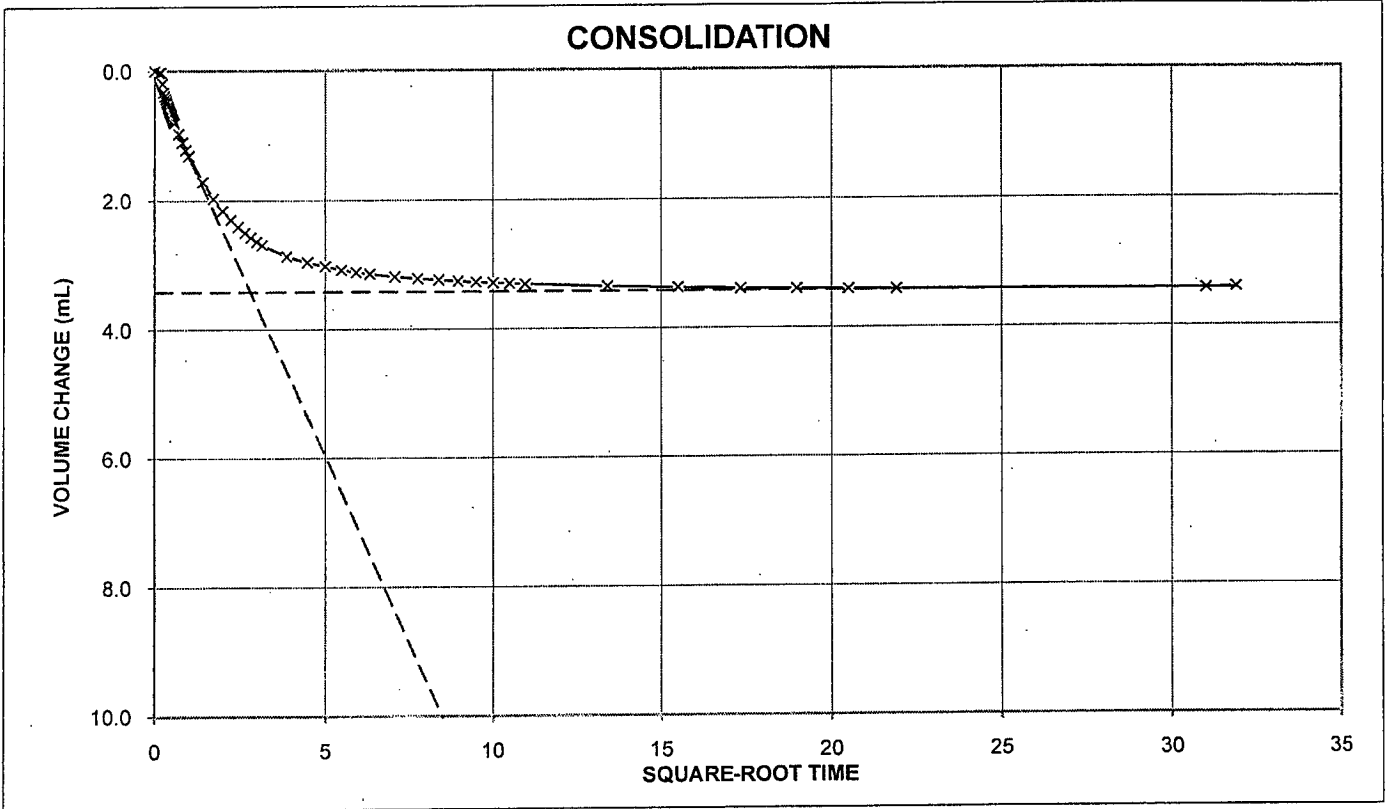
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Sample No.: PT1

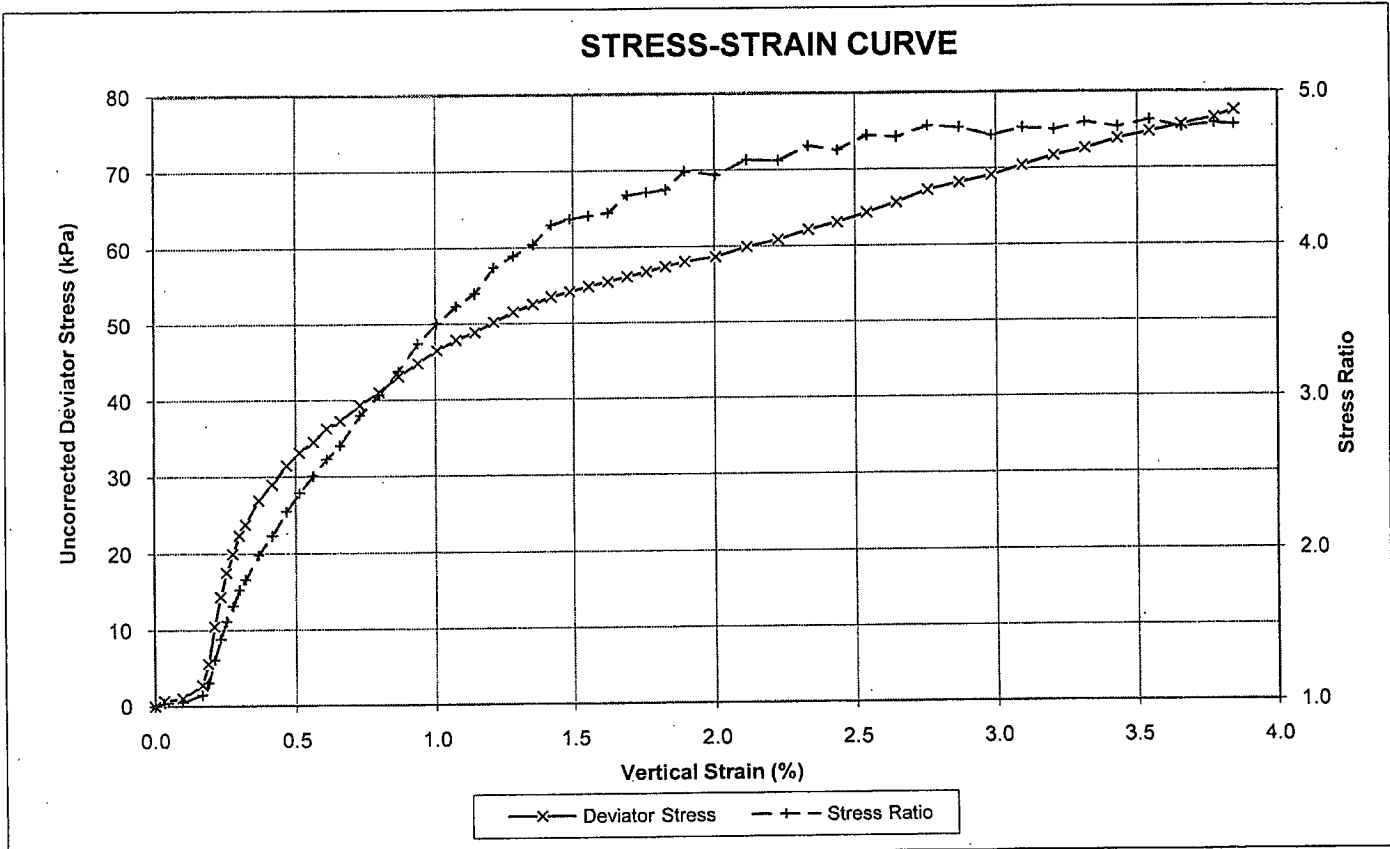
Depth: 2.02 -- 2.14 (m)

STAGE 1 GRAPHS

CONSOLIDATION



STRESS-STRAIN CURVE



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Date: 8/06/10

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Date: 15/6/10

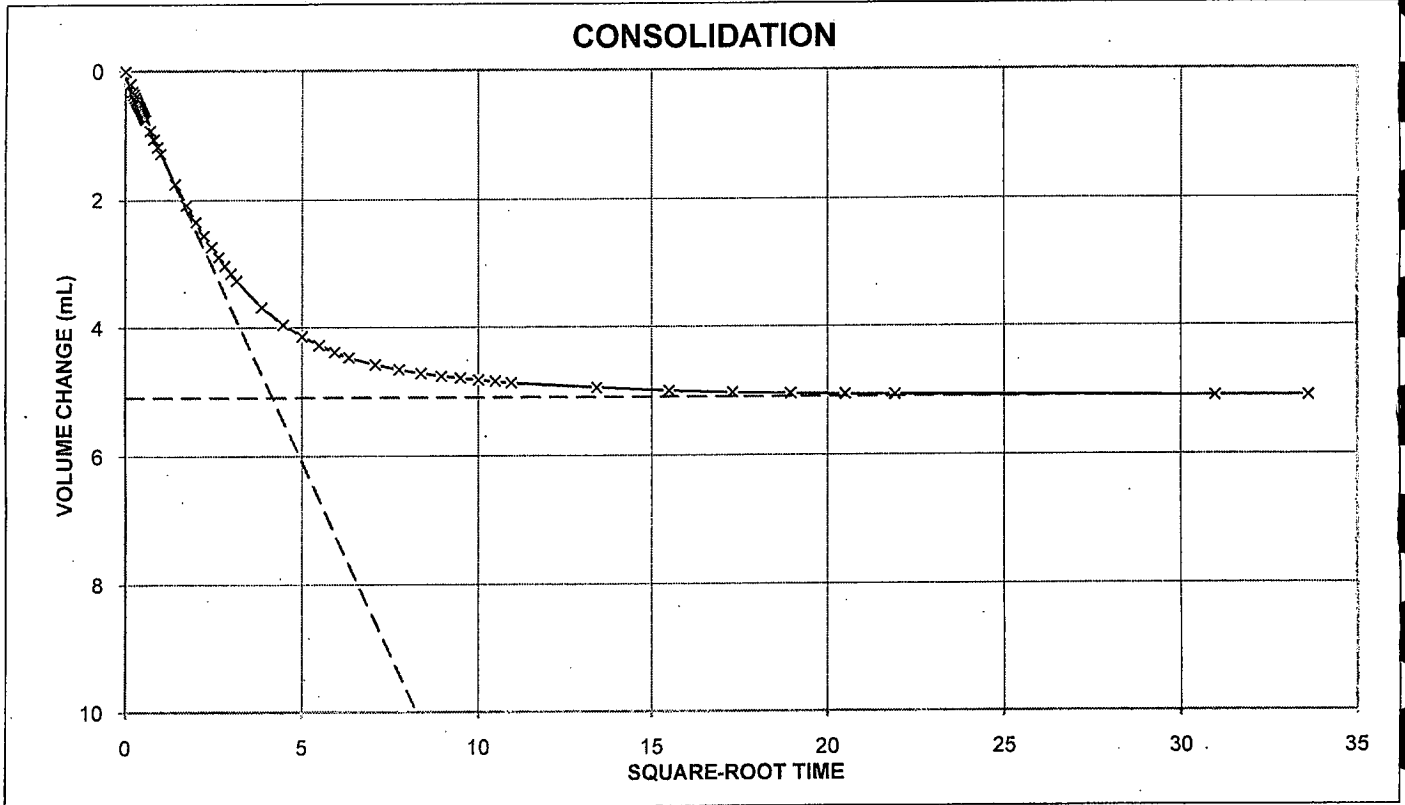


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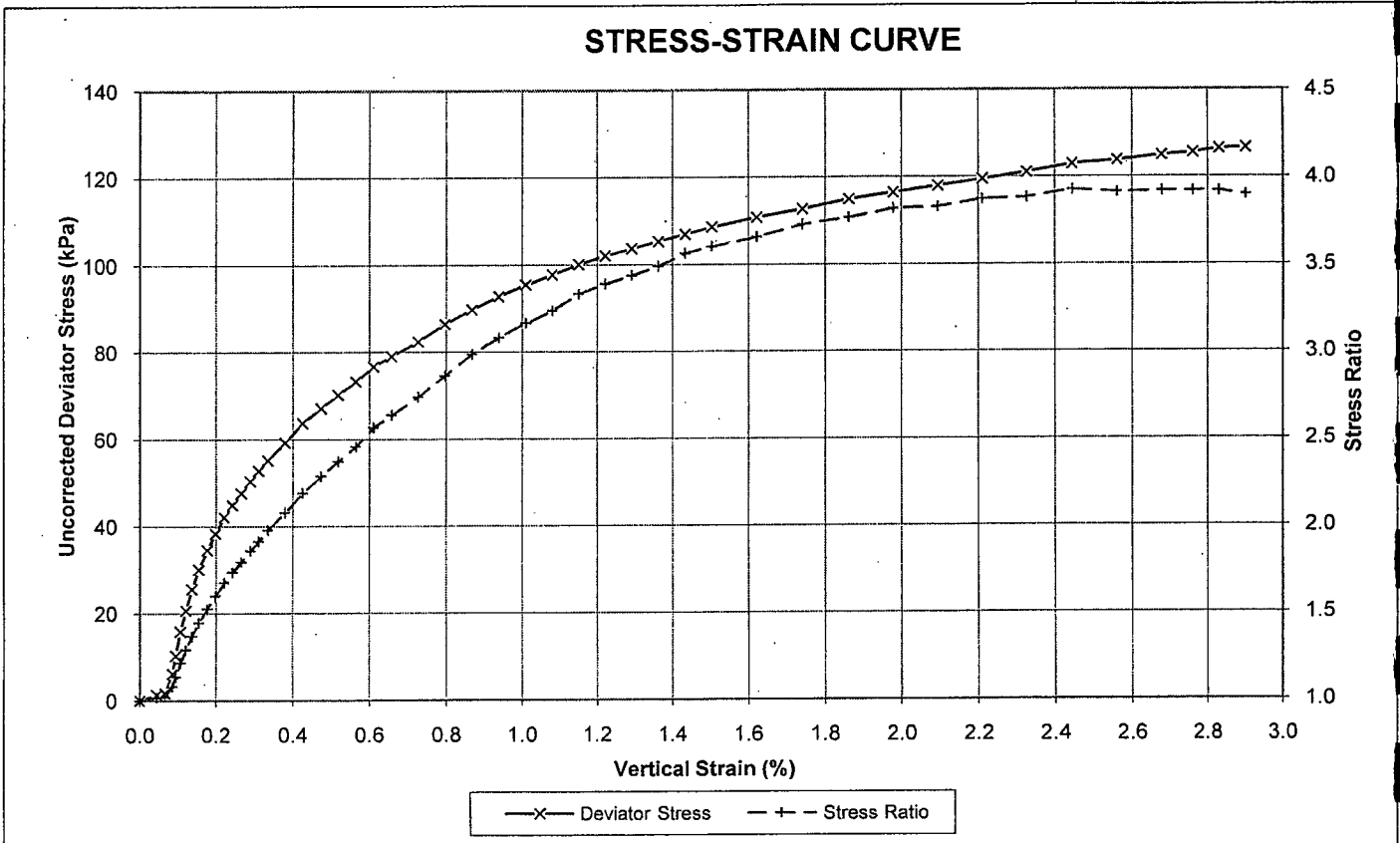
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Plate No.: _____ Page _____ of _____
 Site: Huia Watercare Plant, Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH8 Sample No.: PT1 Depth: 2.02 -- 2.14 (m)

STAGE 2 GRAPHS CONSOLIDATION



STRESS-STRAIN CURVE





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Site: Huia Watercare Plant, Your Ref No.: 27064.001

Job No.: 615300.001

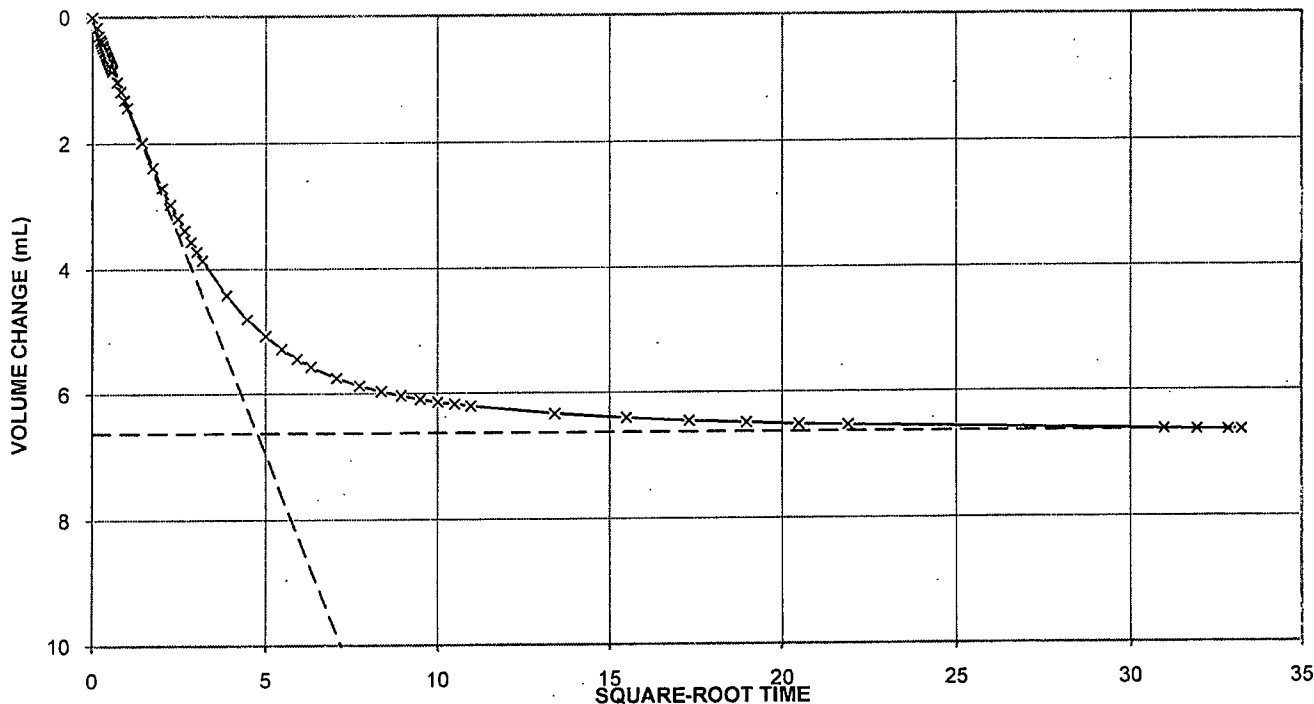
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Sample No.: PT1

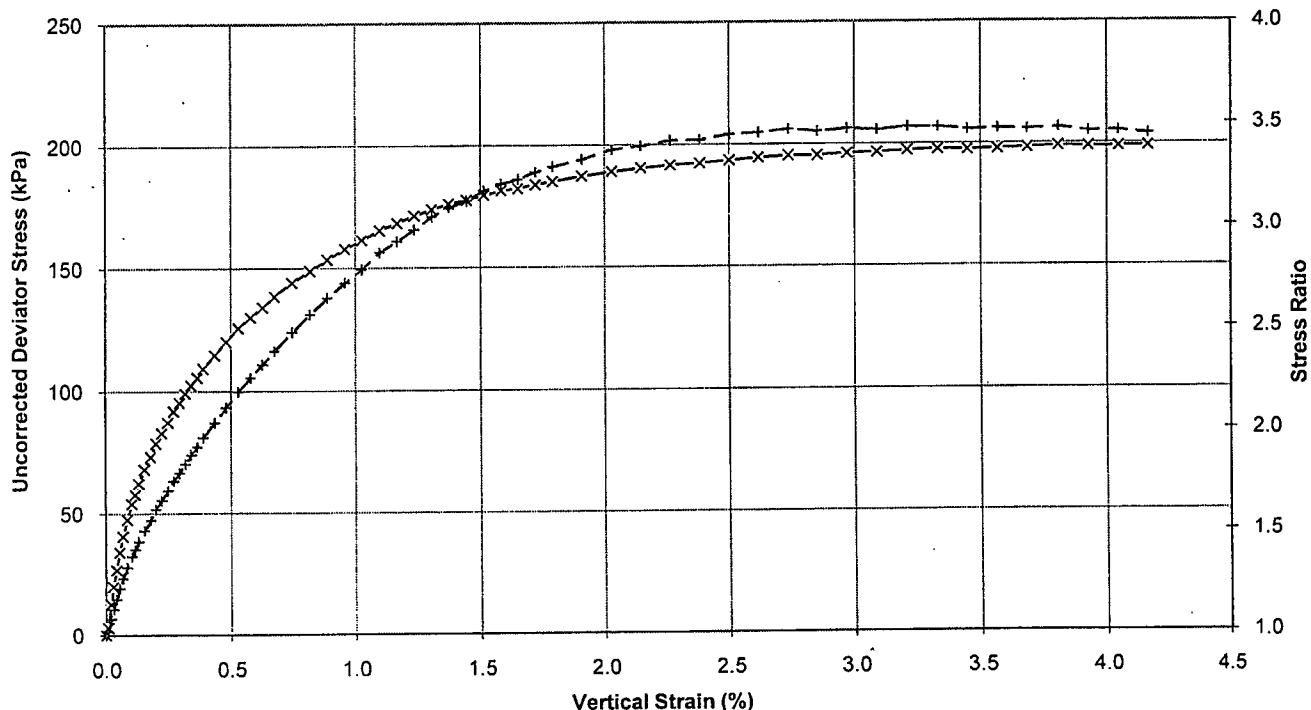
Depth: 2.02 -- 2.14 (m)

STAGE 3 GRAPHS

CONSOLIDATION



STRESS-STRAIN CURVE



Entered by: *lm*

Date: 8/06/10

Checked by: SDG

Date: 15/6/10

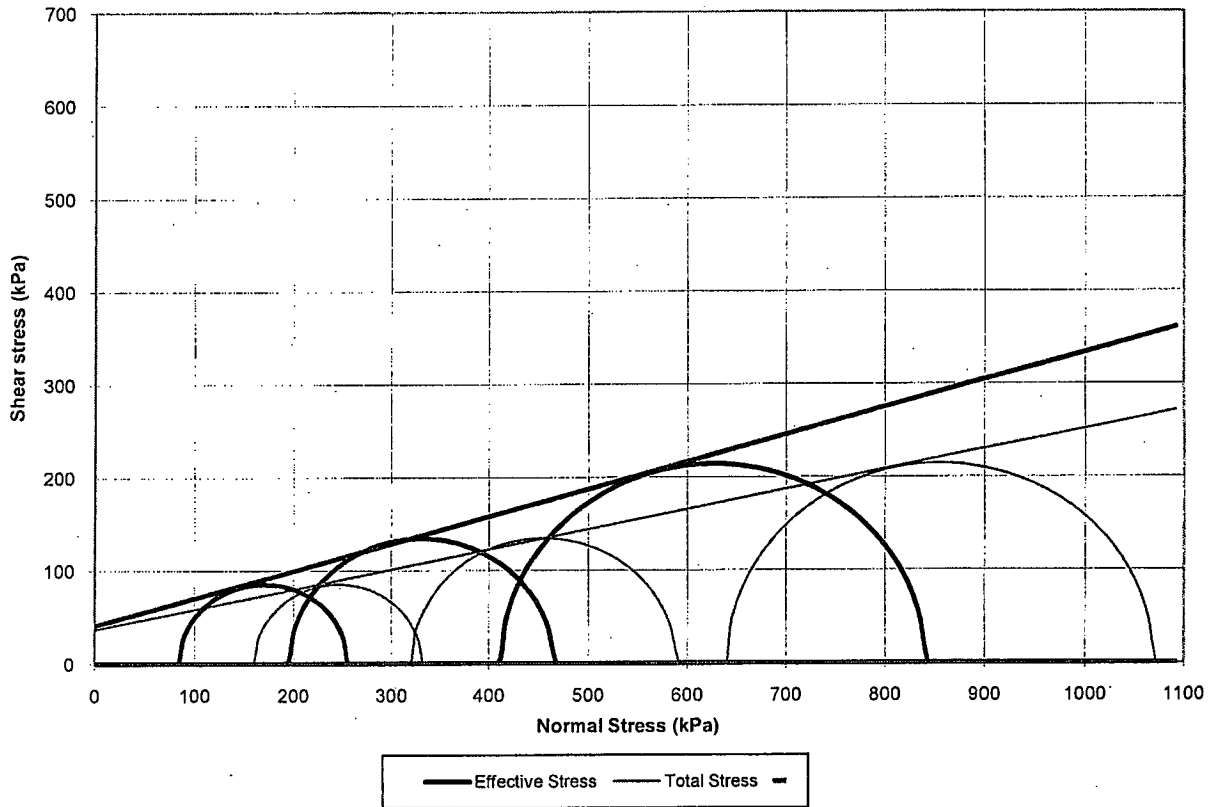


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Plate No.:		Page	of
Site:	Huia Watercare Plant, Titirangi	Your Ref No.:	27064.001
Test pit/Bh No.:	BH6	Sample No.:	SS2
Test method used:	BS1377:Part 8:1990:Clause 5 Saturation	BS1377:Part 8:1990:Clause 6 Consolidation	
	BS1377:Part 8:1990:Clause 7 Consolidated-undrained triaxial compression test with pore pressure measurement		

CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST (3 STAGES) MOHR CIRCLES OF TOTAL AND EFFECTIVE STRESSES



Initial Sample Height:	101.51	mm	Initial Water Content:	49.6	%
Initial Sample Diameter:	54.46	mm	Initial Bulk Density:	1.69	t/m ³
Initial B Value:	50	%	Initial Dry Density:	1.13	t/m ³
B Value before Consolidation:	100	%	Final Water Content:	43.6	%

	Consolidation Stage			Failure Values				
	Cell Pressure (kPa)	Back Pressure (kPa)	Eff. Consol. Stress	Deviator Stress (kPa)	Pore Pressure Change During Shearing δu (kPa)	Effective Principal Stress (kPa)		Vertical Strain (%)
						Major σ_1'	Minor σ_3'	
STAGE 1	460	300	160	171.17	75.6	255.57	84.40	2.24
STAGE 2	620	300	320	268.95	124.1	464.85	195.90	1.72
STAGE 3	940	300	640	428.91	228.1	840.81	411.90	1.83

	Total		Effective
Angle of Frictional Resistance:	$\phi = 12^\circ$		$\phi' = 16^\circ$
Cohesion:	$c = 37$ kPa		$c' = 41$ kPa
Linear Regression Coefficient:	$r = 0.998$		$r = 0.999$

Sample History: Undisturbed core trimmed at natural water content.

Soil description: SILT, with some sand and minor clay, firm, low to medium plasticity, dilatant.

Failure Mode: Planar Test Speed: 0.028 (mm/min)

Test Remarks: The sample was saturated by increments of cell pressure and back pressure. Failure for each stage was determined by either the maximum effective stress ratio or the maximum deviator stress. Strength parameters have been derived by using a linear regression fitting method.

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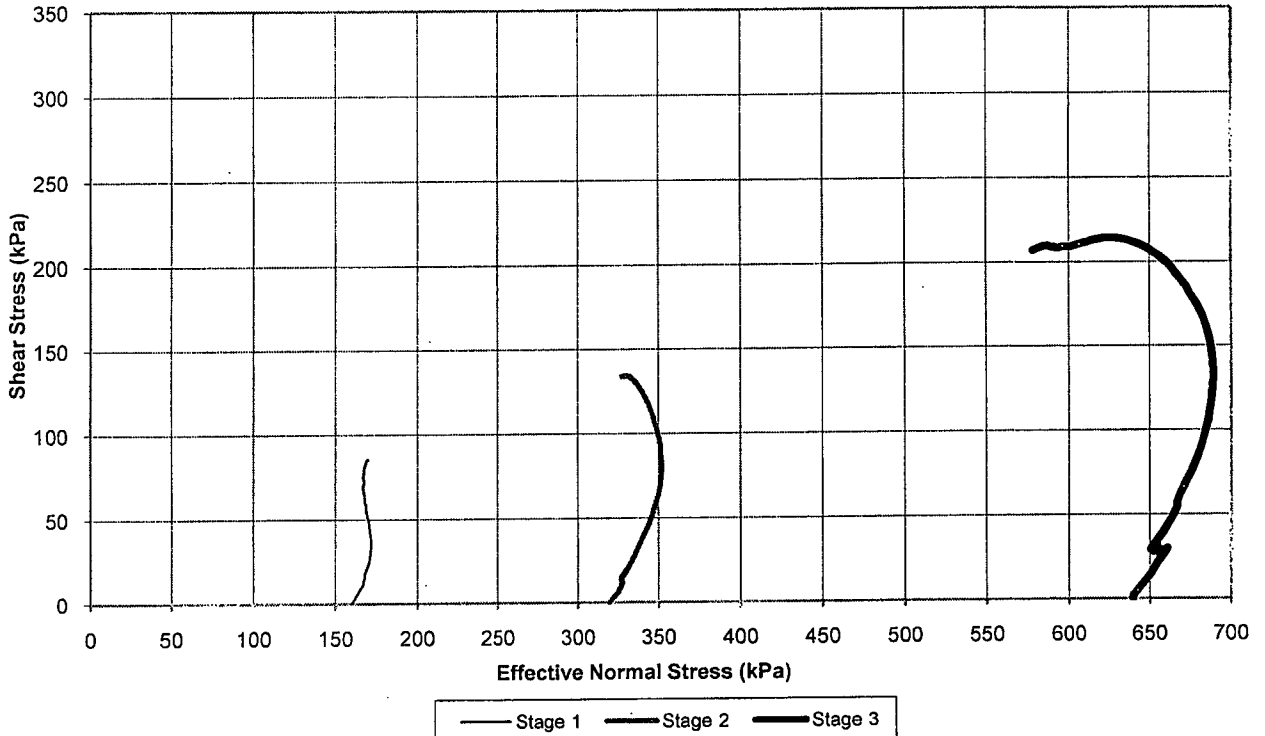
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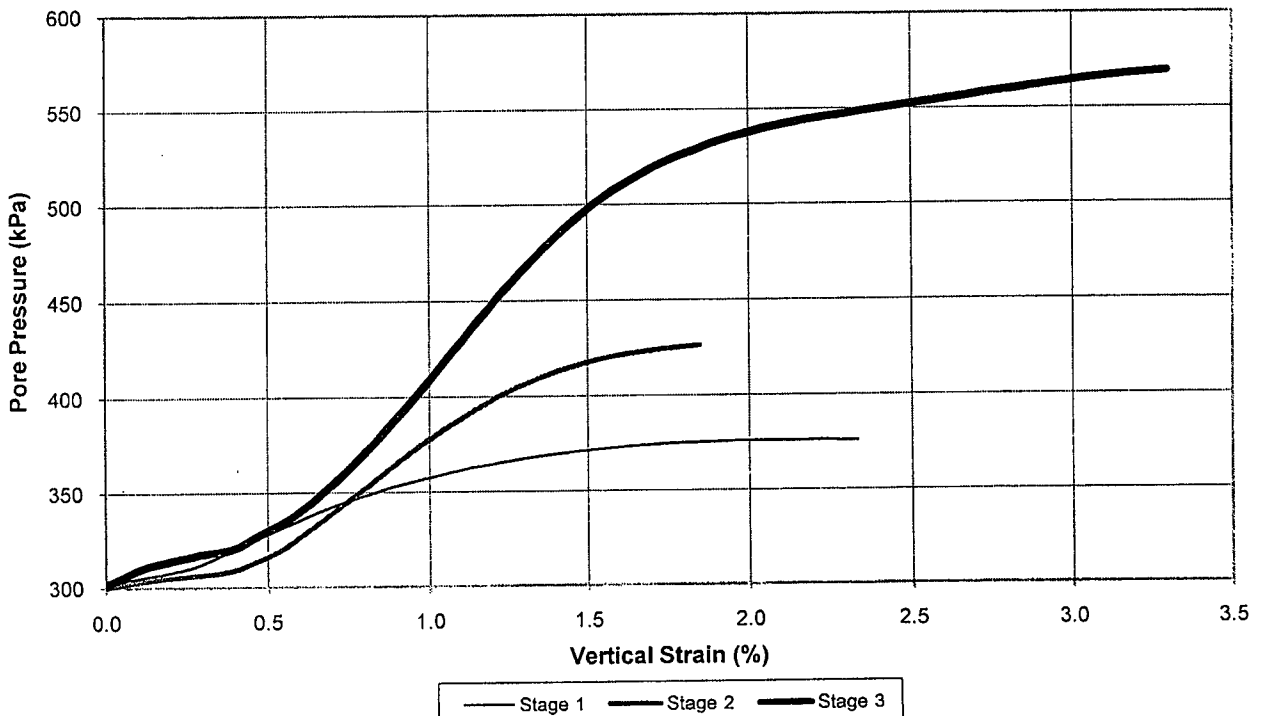
Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH6 Sample No.: SS2 Depth: 7.95 -- 8.05 (m)

GRAPHS

STRESS PATH



PORE PRESSURE Vs VERTICAL STRAIN



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Site: Huia Watercare Plant, Your Ref No.: 27064.001

Test pit/Bh No.: BH6

Sample No.: SS2

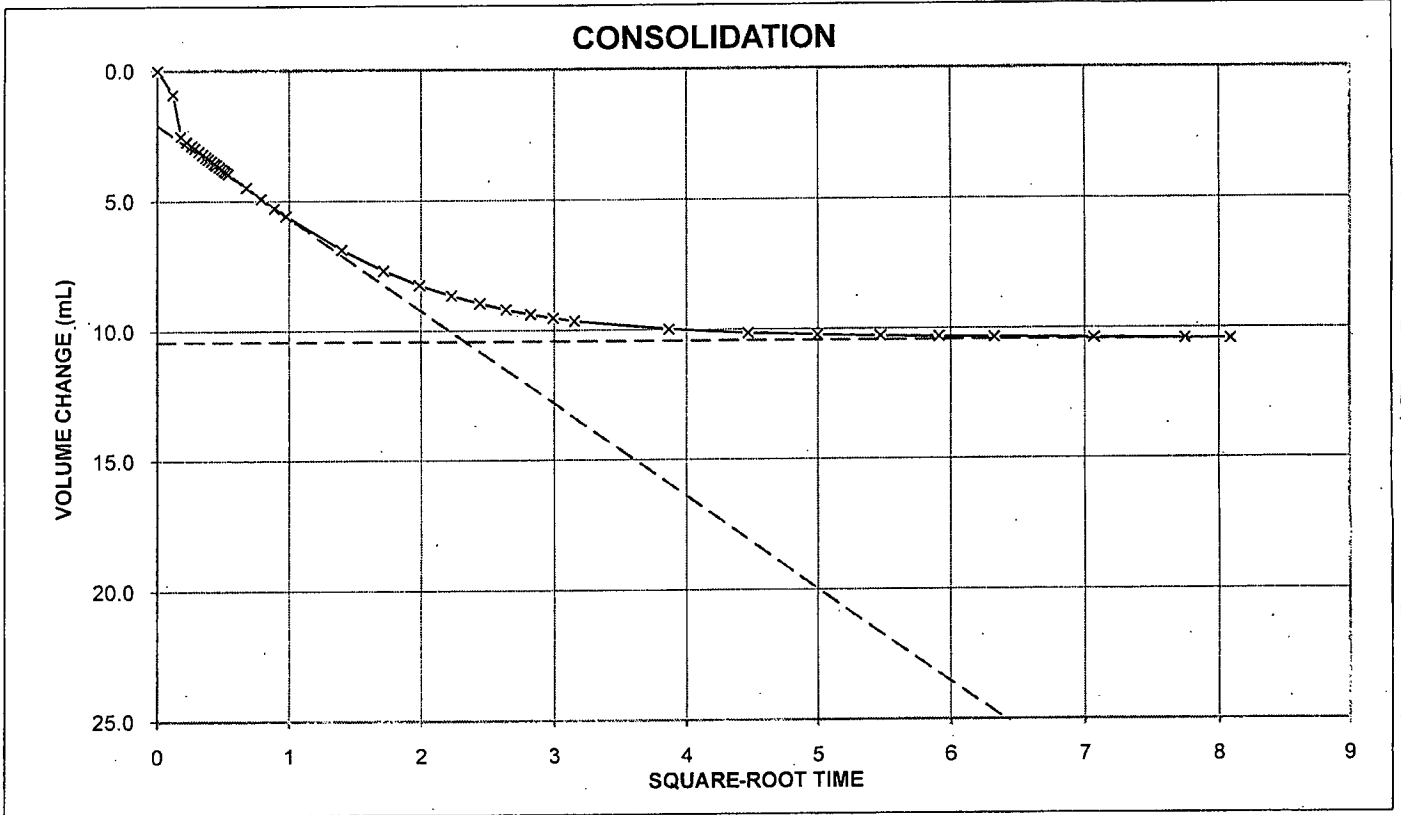
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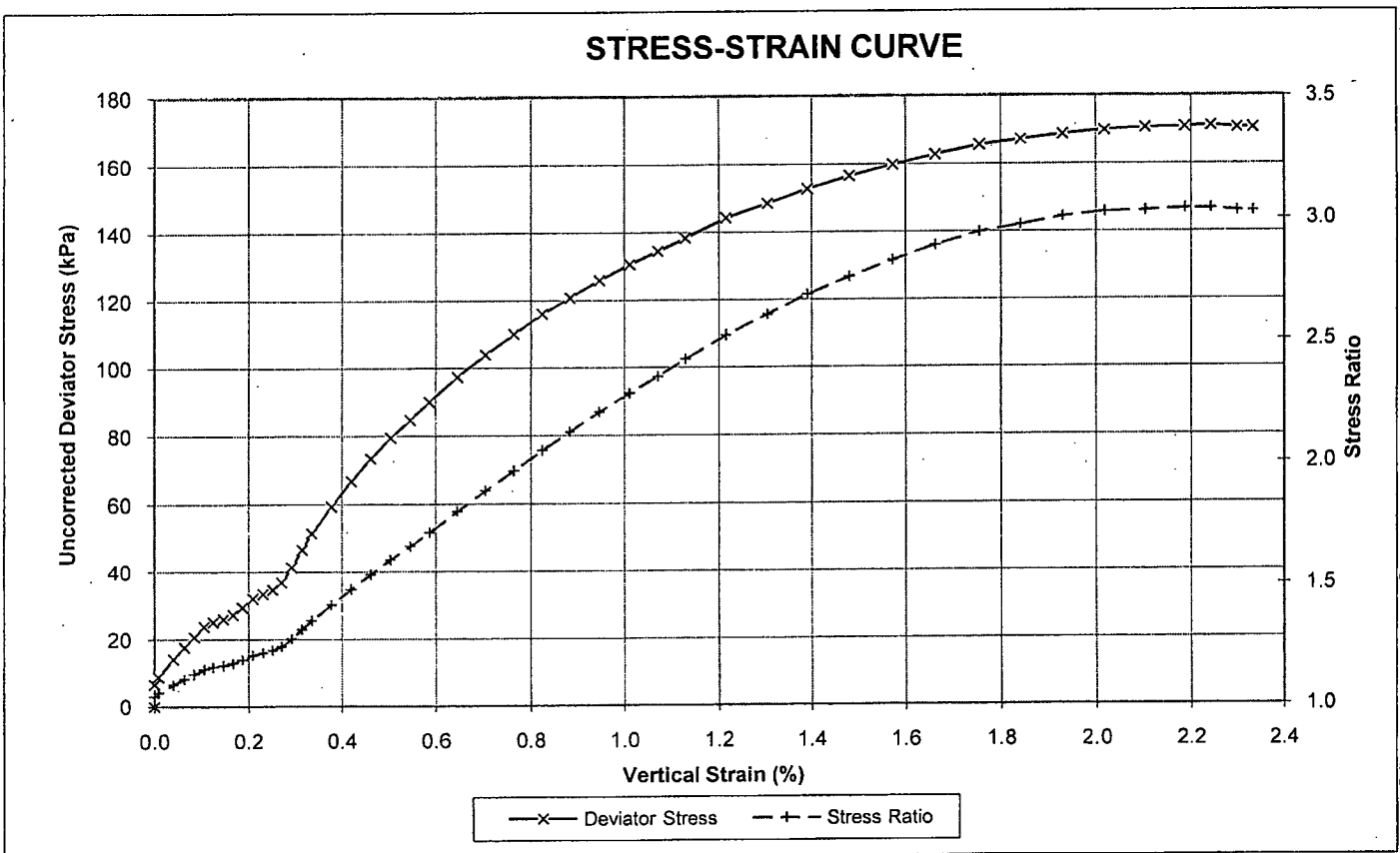
Depth: 7.95 -- 8.05 (m)

STAGE 1 GRAPHS

CONSOLIDATION



STRESS-STRAIN CURVE



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Date:

8/06/10

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SDG

Date:

15/16/10

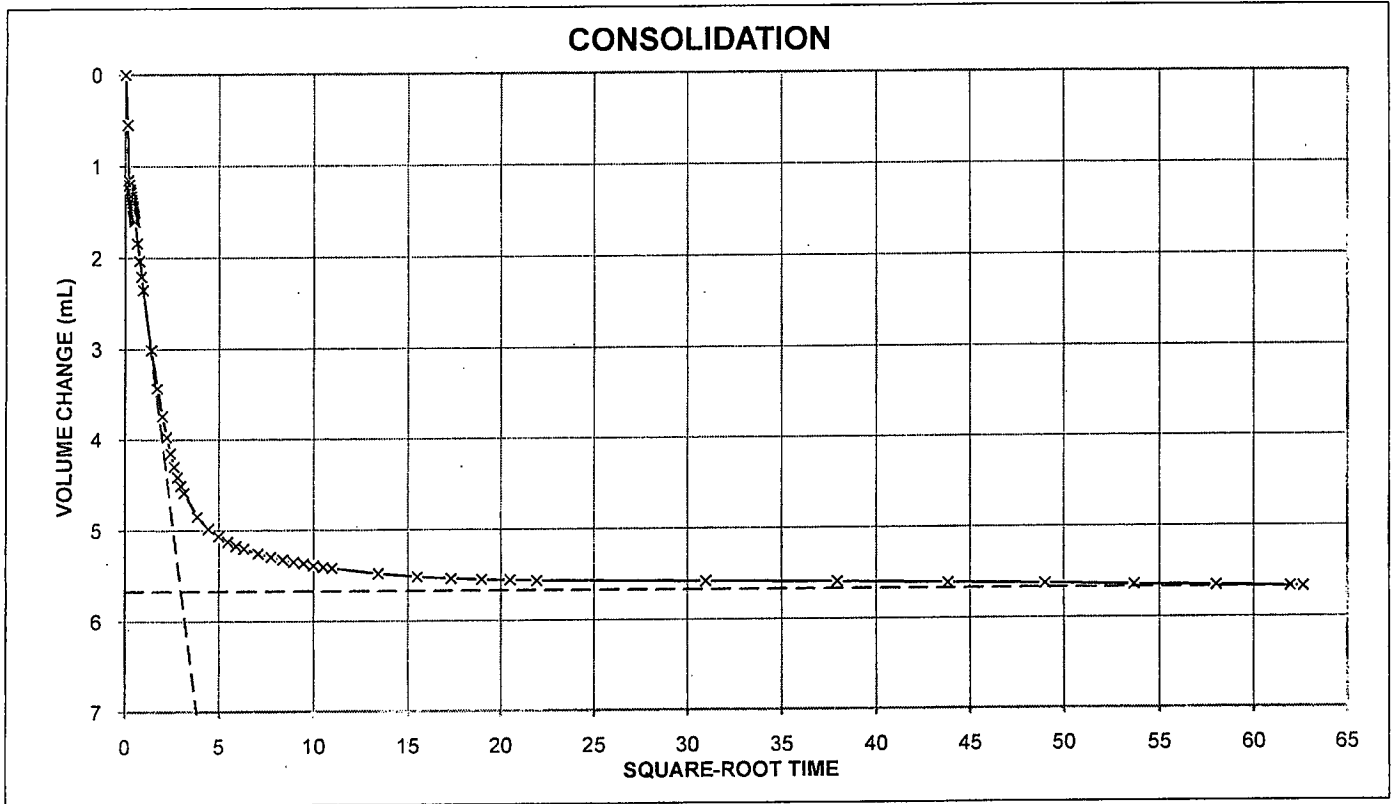


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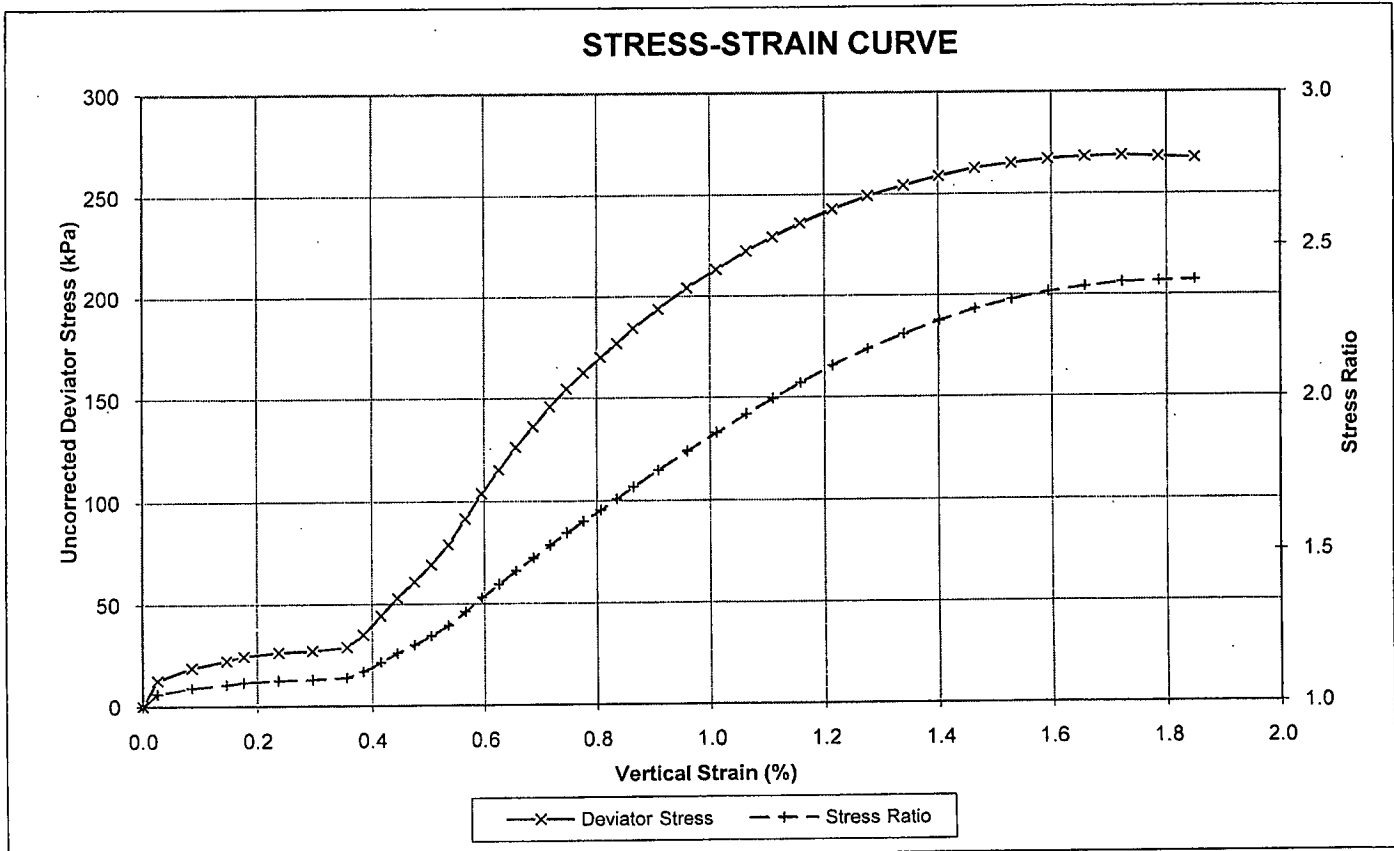
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Form Date:	July 2003
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Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH6 Sample No.: SS2 Depth: 7.95 -- 8.05 (m)

STAGE 2 GRAPHS CONSOLIDATION



STRESS-STRAIN CURVE



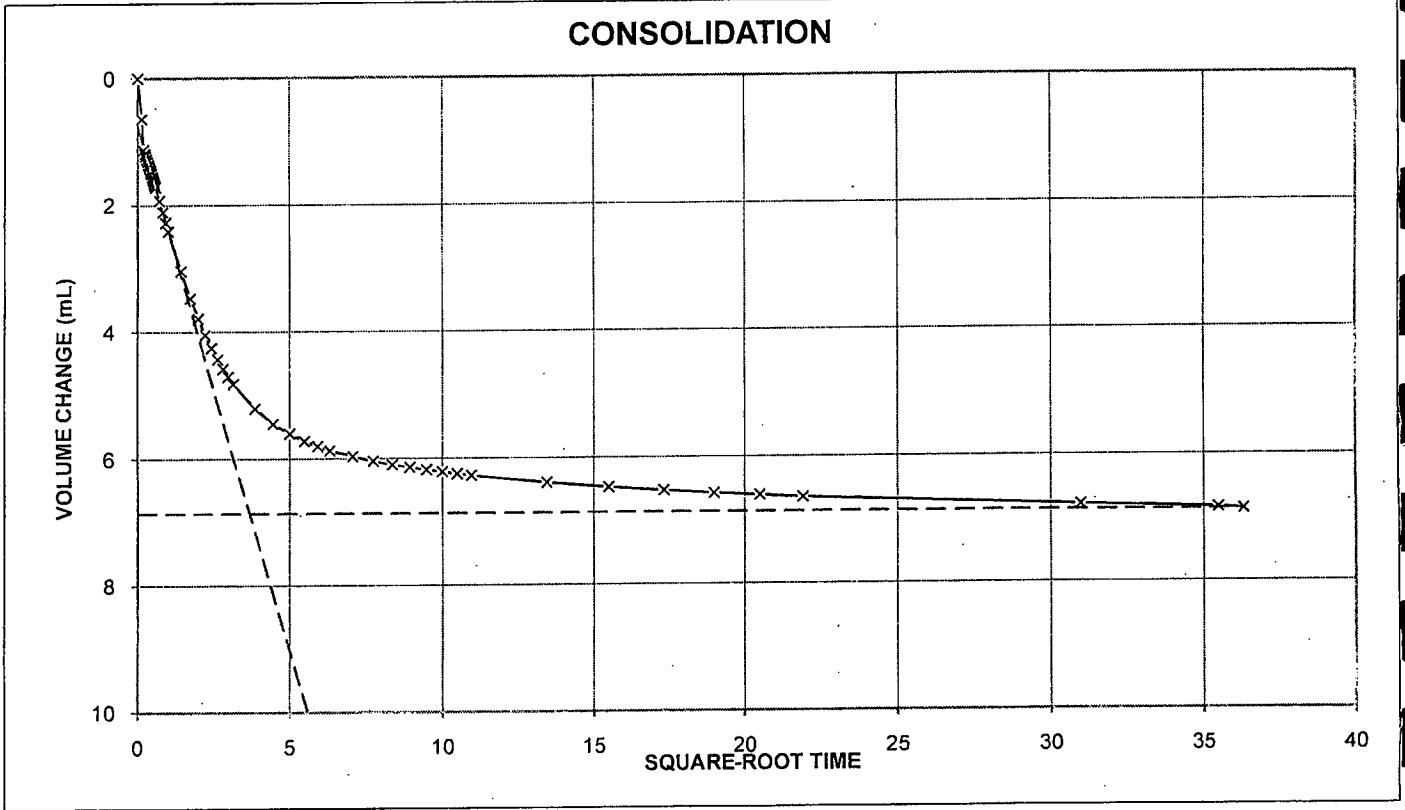


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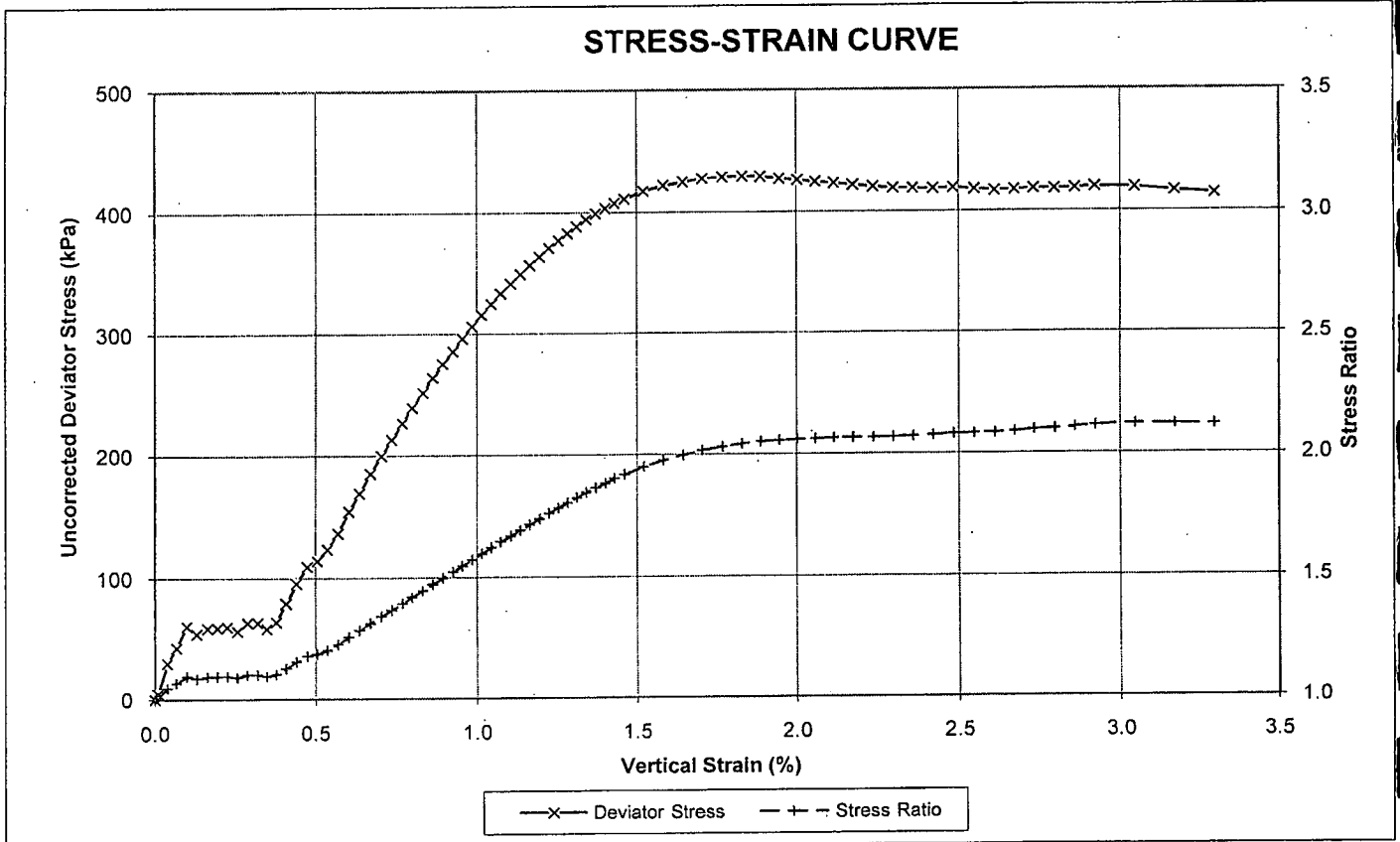
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Form Date:	July 2003
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Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH6 Sample No.: SS2 Depth: 7.95 -- 8.05 (m)

STAGE 3 GRAPHS CONSOLIDATION



STRESS-STRAIN CURVE



Entered by: *un* Date: *8/06/10* Checked by: *SDG* Date: *15/6/10*

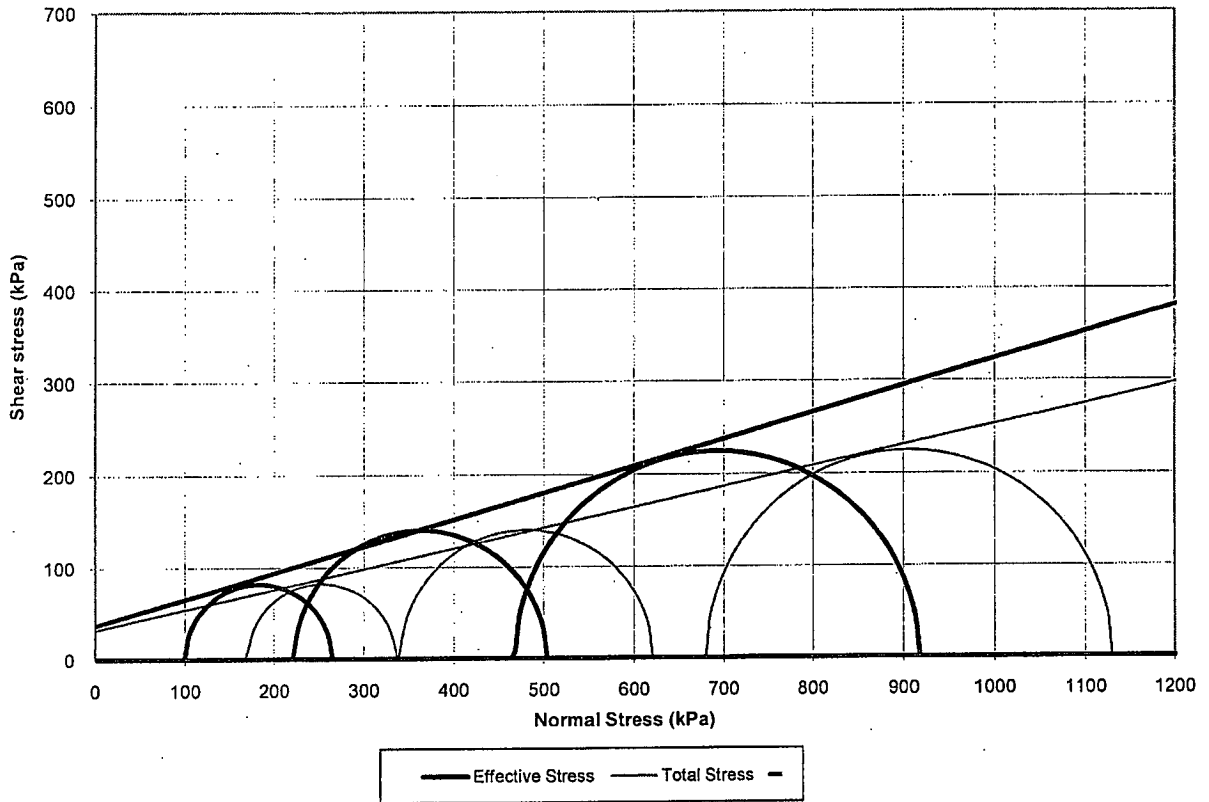


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Form Date:	July 2003
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Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Titrangi Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH6 Sample No.: SS3 Depth: 8.40 – 8.55 (m)
 Test method used: BS1377:Part 8:1990:Clause 5 Saturation BS1377:Part 8:1990:Clause 6 Consolidation
 BS1377:Part 8:1990:Clause 7 Consolidated-undrained triaxial compression test with pore pressure measurement

CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST (3 STAGES) MOHR CIRCLES OF TOTAL AND EFFECTIVE STRESSES



Initial Sample Height:	121.44	mm	Initial Water Content:	49.5	%
Initial Sample Diameter:	54.57	mm	Initial Bulk Density:	1.72	t/m ³
Initial B Value:	44	%	Initial Dry Density:	1.15	t/m ³
B Value before Consolidation:	100	%	Final Water Content:	45.2	%

	Consolidation Stage			Failure Values				
	Cell Pressure (kPa)	Back Pressure (kPa)	Eff. Consol. Stress	Deviator Stress (kPa)	Pore Pressure Change During Shearing Δu (kPa)	Effective Principal Stress (kPa)		Vertical Strain (%)
						Major σ_1'	Minor σ_3'	
STAGE 1	470	300	170	164.89	70.4	264.49	99.60	2.13
STAGE 2	640	300	340	280.44	117.4	503.04	222.60	1.25
STAGE 3	980	300	680	449.25	212.2	917.05	467.80	1.96

	Total		Effective
Angle of Frictional Resistance:	$\phi = 12^\circ$		$\phi' = 16^\circ$
Cohesion:	$c = 32$ kPa		$c' = 37$ kPa
Linear Regression Coefficient:	$r = 0.996$		$r = 0.996$

Sample History: Undisturbed core trimmed at natural water content.

Soil description: SILT, sandy, firm to stiff, brown with light orange, low plasticity, dilatant. There was an existing shearing plane in the lower part of the sample.

Failure Mode: Planar Test Speed: 0.028 (mm/min)

Test Remarks: The sample was saturated by increments of cell pressure and back pressure. Failure for each stage was determined by the maximum deviator stress. Strength parameters have been derived by using a linear regression fitting method.

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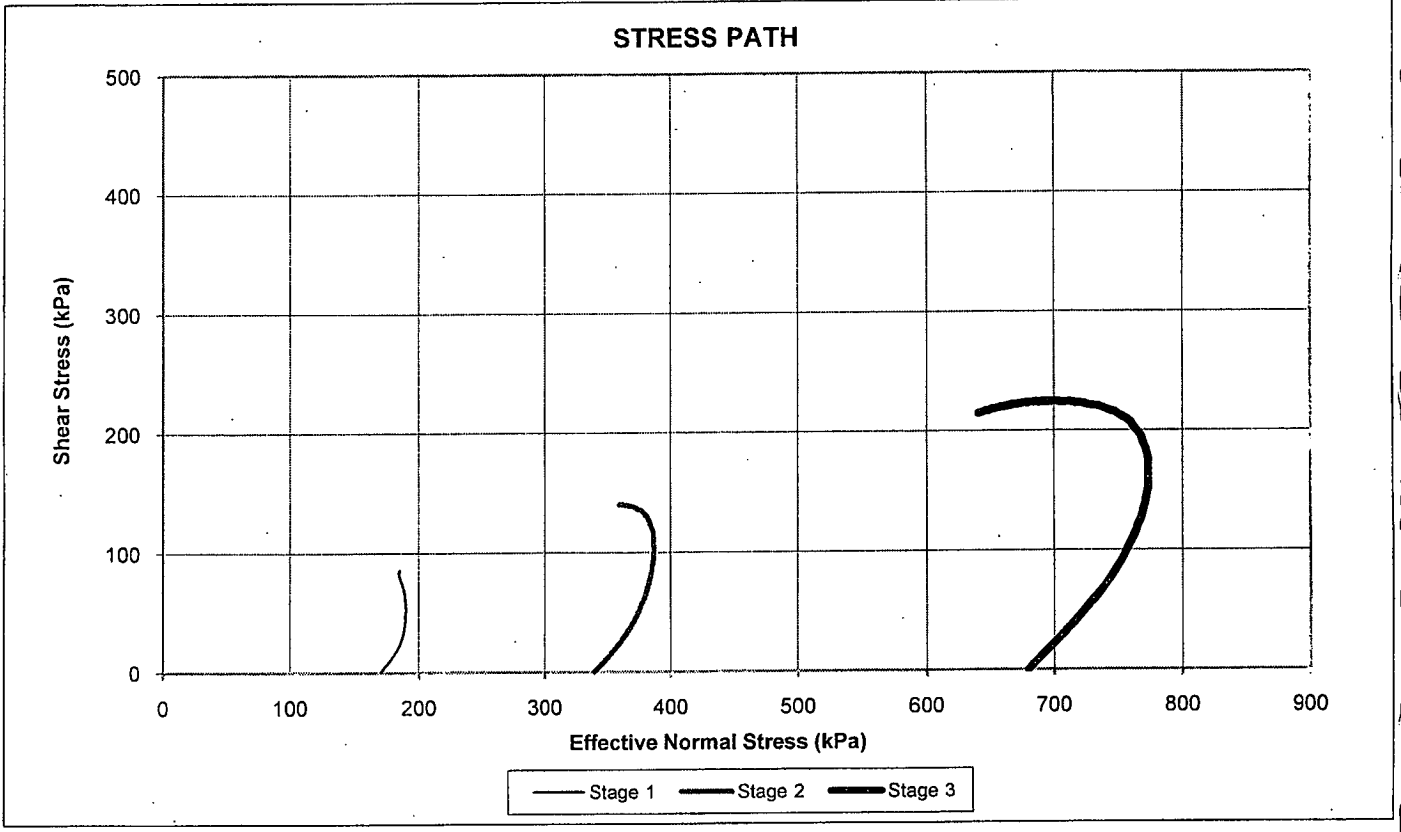
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Form No.:	TG2
Form Date:	July 2003
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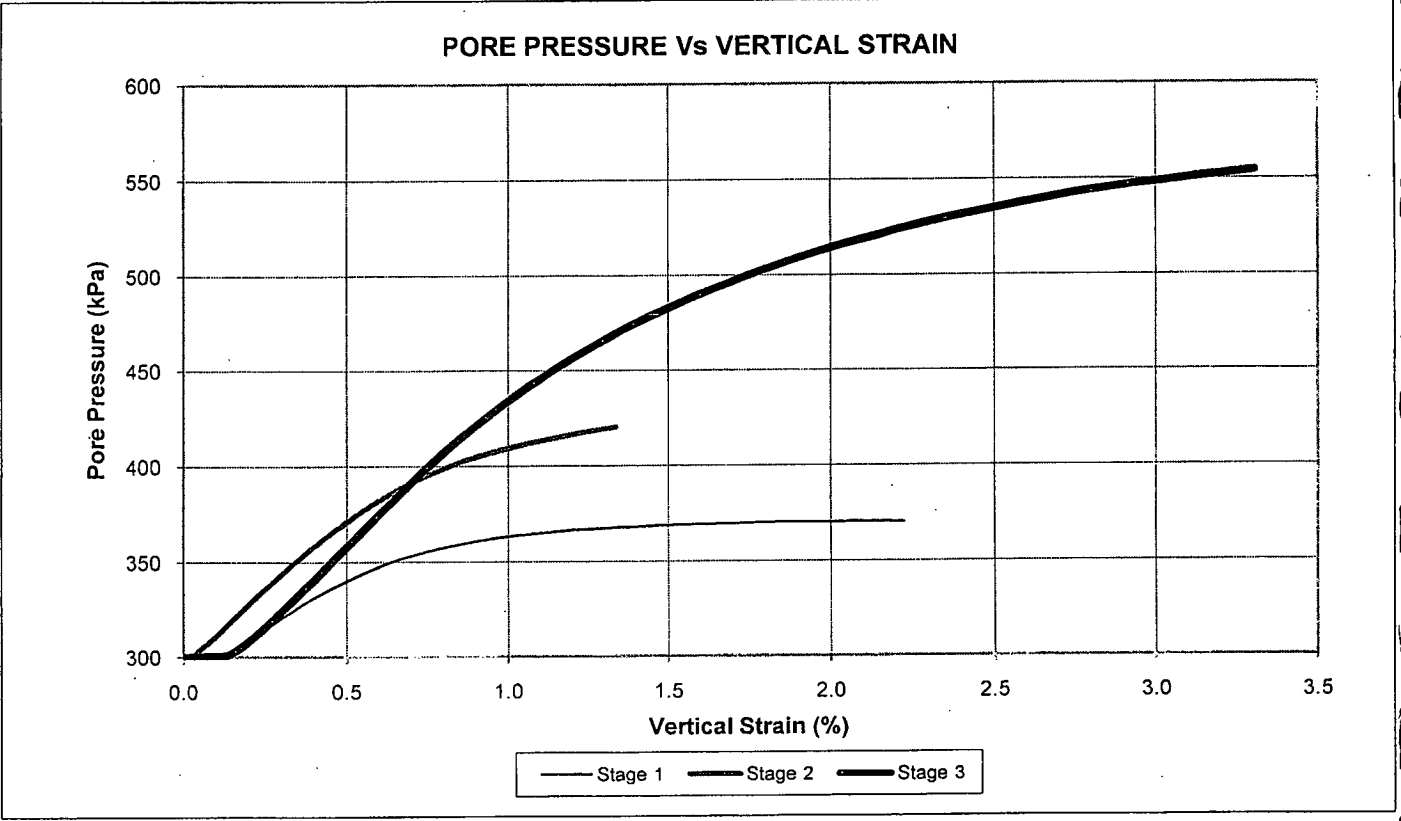
Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH6 Sample No.: SS3 Depth: 8.40 -- 8.55 (m)

GRAPHS

STRESS PATH



PORE PRESSURE Vs VERTICAL STRAIN



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Form Date: July 2003

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Plate No.:

Page of

Site: Huia Watercare Plant, Your Ref No.: 27064.001

Job No.: 615300.001

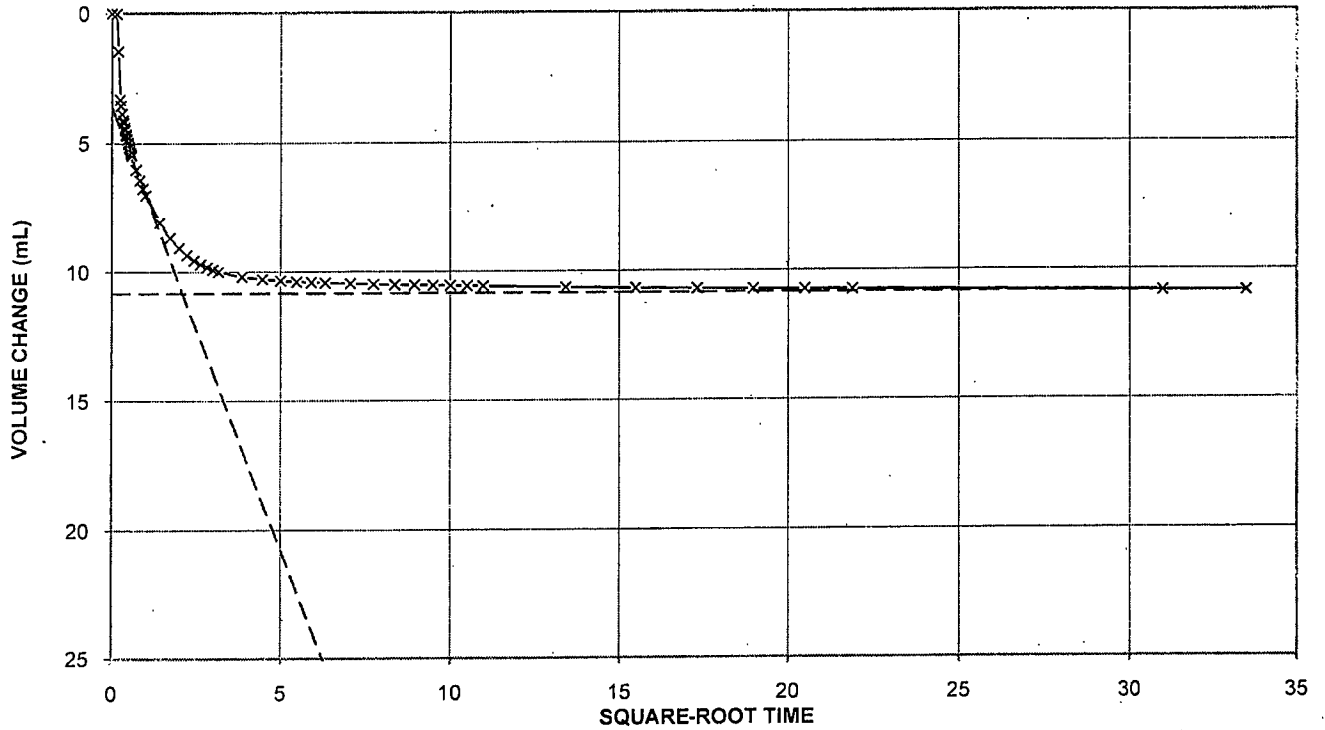
Test pit/Bh No.: BH6

Sample No.: SS3

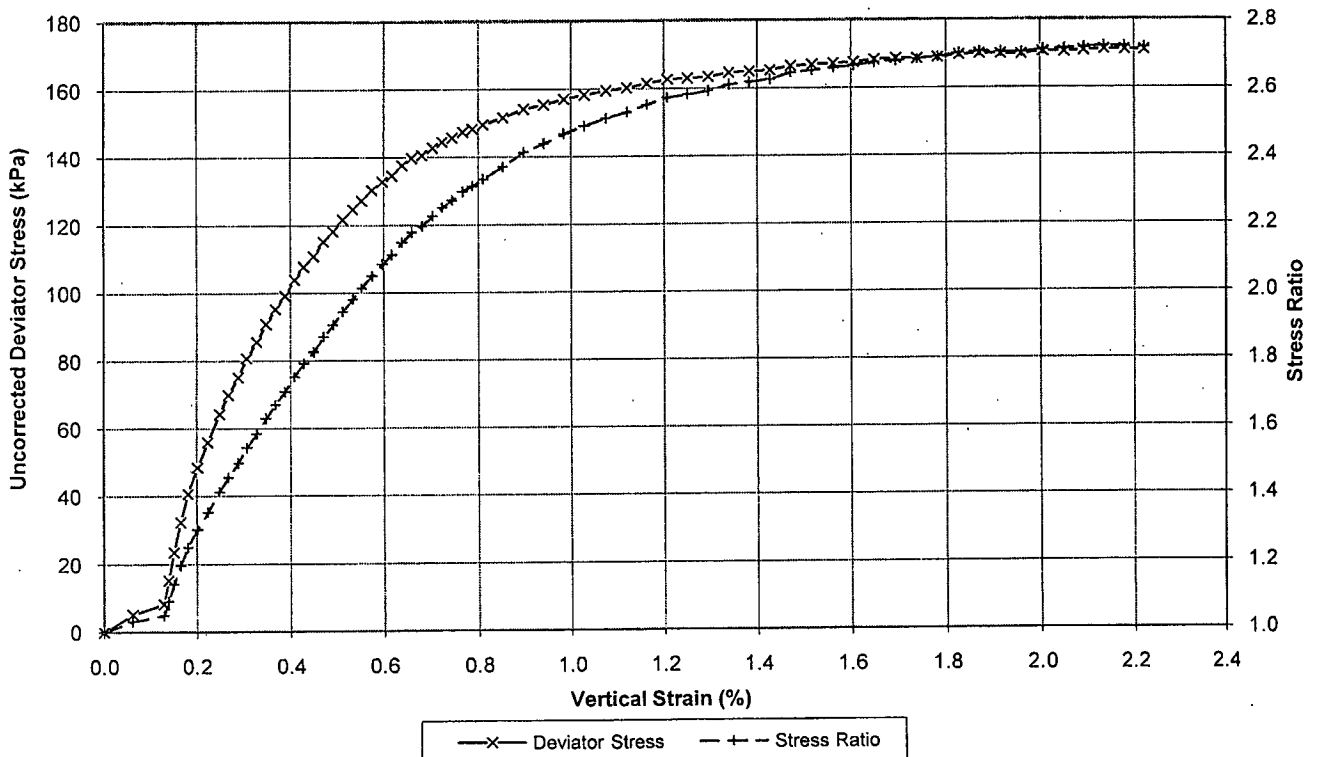
Depth: 8.40 -- 8.55 (m)

STAGE 1 GRAPHS

CONSOLIDATION



STRESS-STRAIN CURVE



Entered by:

lm

Date:

8/06/10

Checked by:

SDG

Date:

15/6/10



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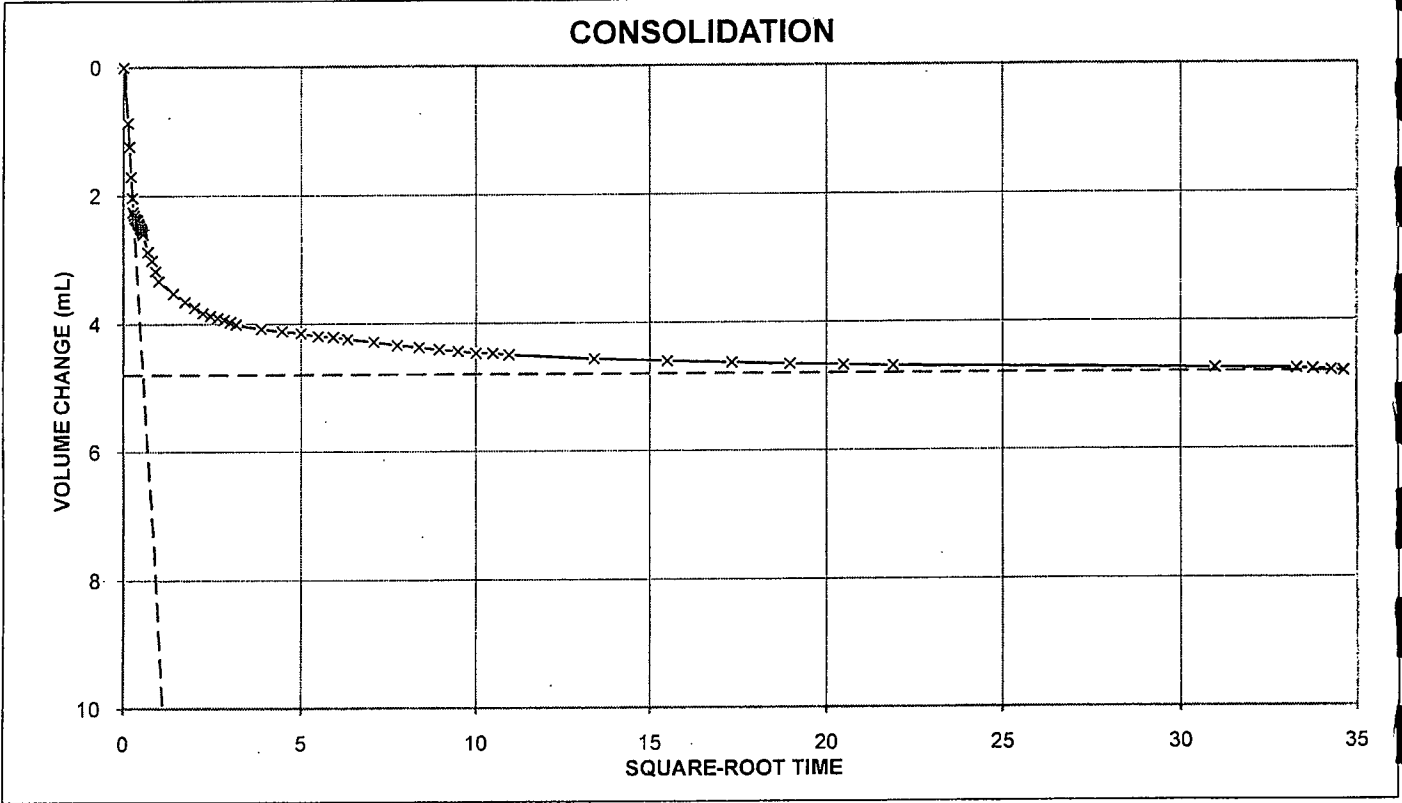
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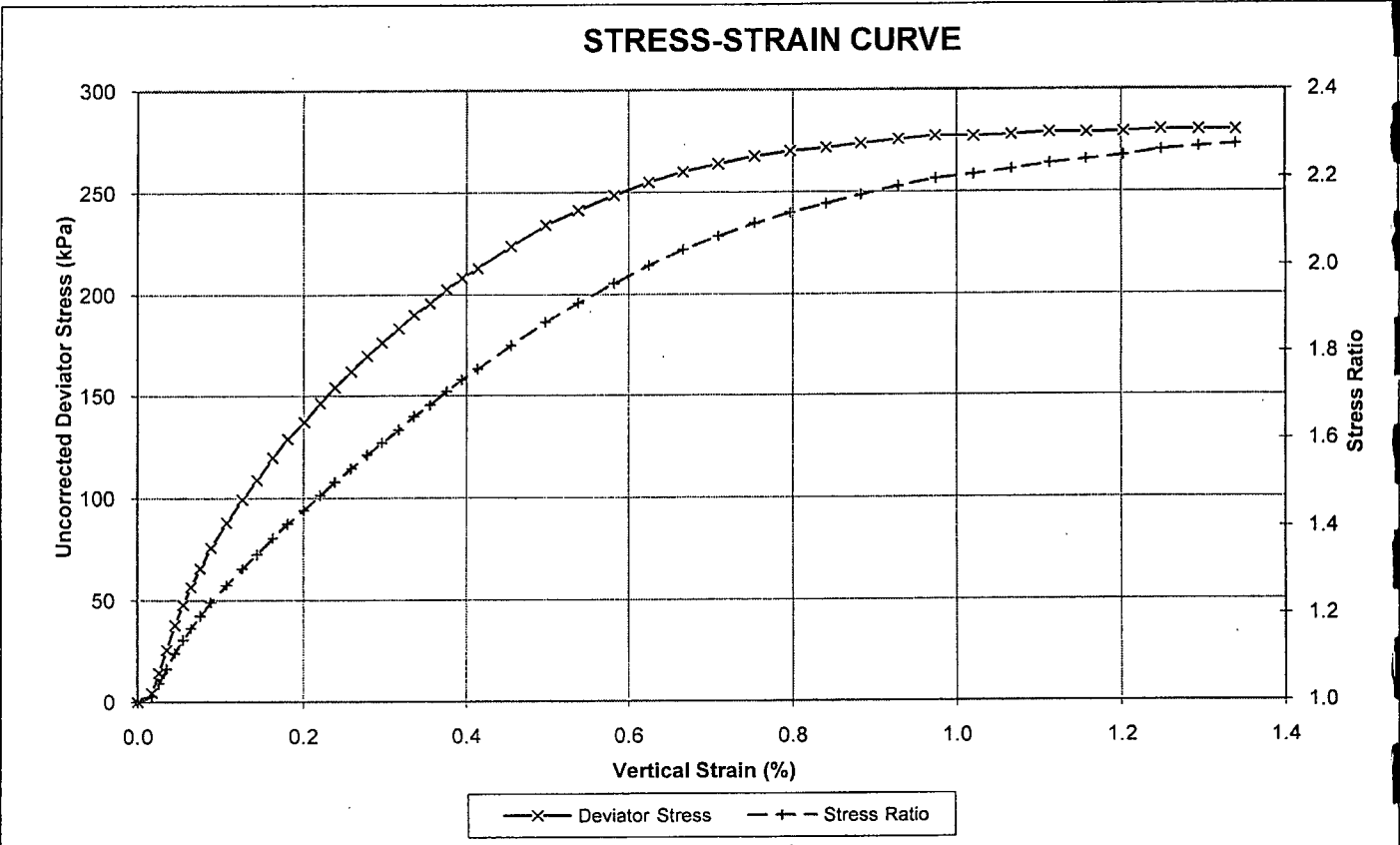
Form No.:	TG1-2
Form Date:	July 2003
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Plate No.: _____ Page _____ of _____
 Site: Huia Watercare Plant, Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH6 Sample No.: SS3 Depth: 8.40 -- 8.55 (m)

STAGE 2 GRAPHS CONSOLIDATION



STRESS-STRAIN CURVE



Entered by: *Wm* Date: *9/06/10* Checked by: *SDG* Date: *15/6/10*

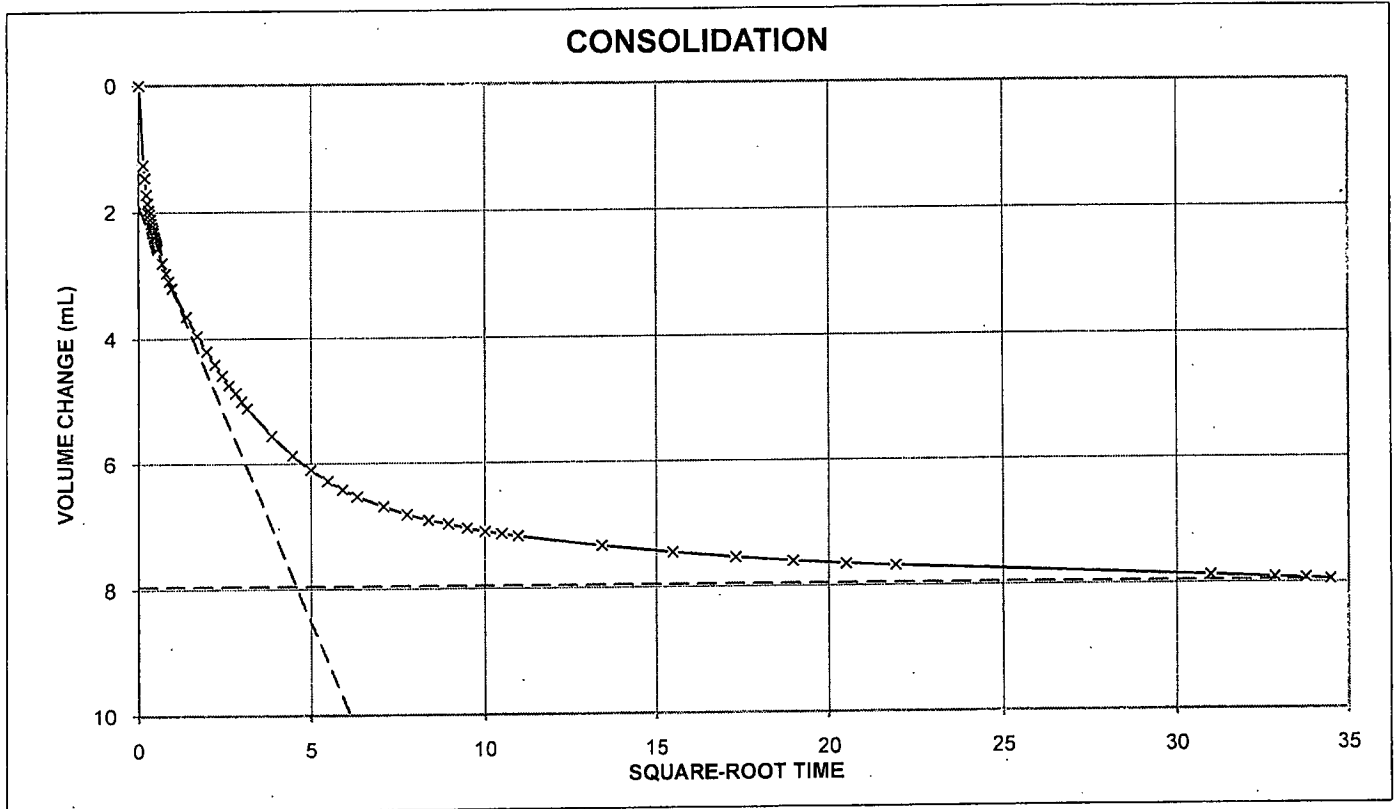


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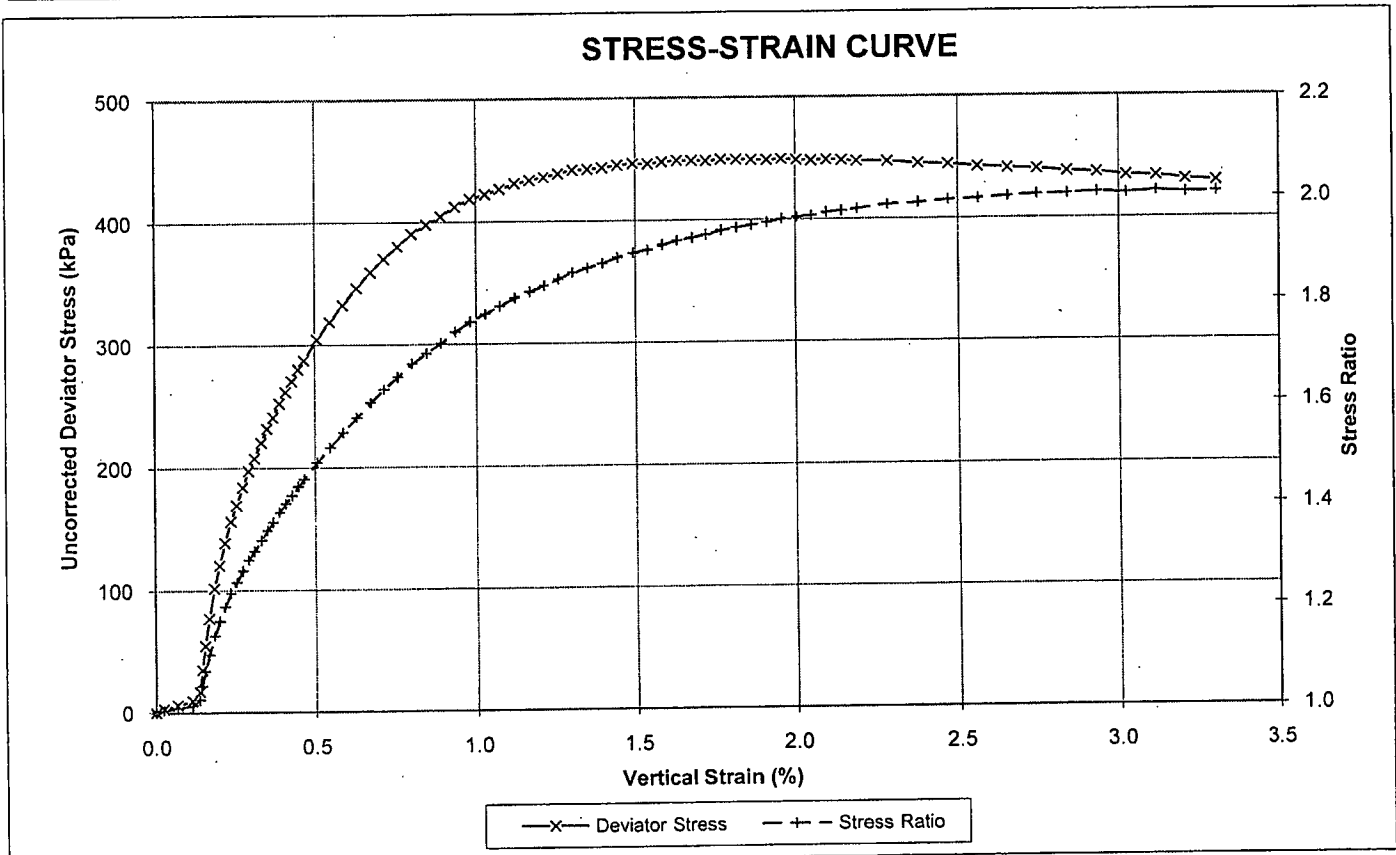
Form No.:	TG1-3
Form Date:	July 2003
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Plate No.: _____ Page of _____
 Site: Huia Watercare Plant, Your Ref No.: 27064.001 Job No.: 615300.001
 Test pit/Bh No.: BH6 Sample No.: SS3 Depth: 8.40 -- 8.55 (m)

STAGE 3 GRAPHS CONSOLIDATION



STRESS-STRAIN CURVE



Entered by: *lm* Date: *8/06/10* Checked by: *SDG* Date: *15/6/10*

Appendix E:

SlopeW Stability Analyses

Analysis Notes:

1. Method: Morgenstern-Price
2. Direction of movement: Left to Right
3. Optimization: Yes
4. Soil Strength Models: Mohr-Coulomb
5. PWP Conditions Source: Piezometric Line
6. Slip Surface Option: Auto-Search
7. C-Phi Correlation Coeff: 0 (All Soils)
8. Tension Crack Angle: 0
9. Horz Seismic Load:
10. FOS Calculation Option: Constant

Material Properties:

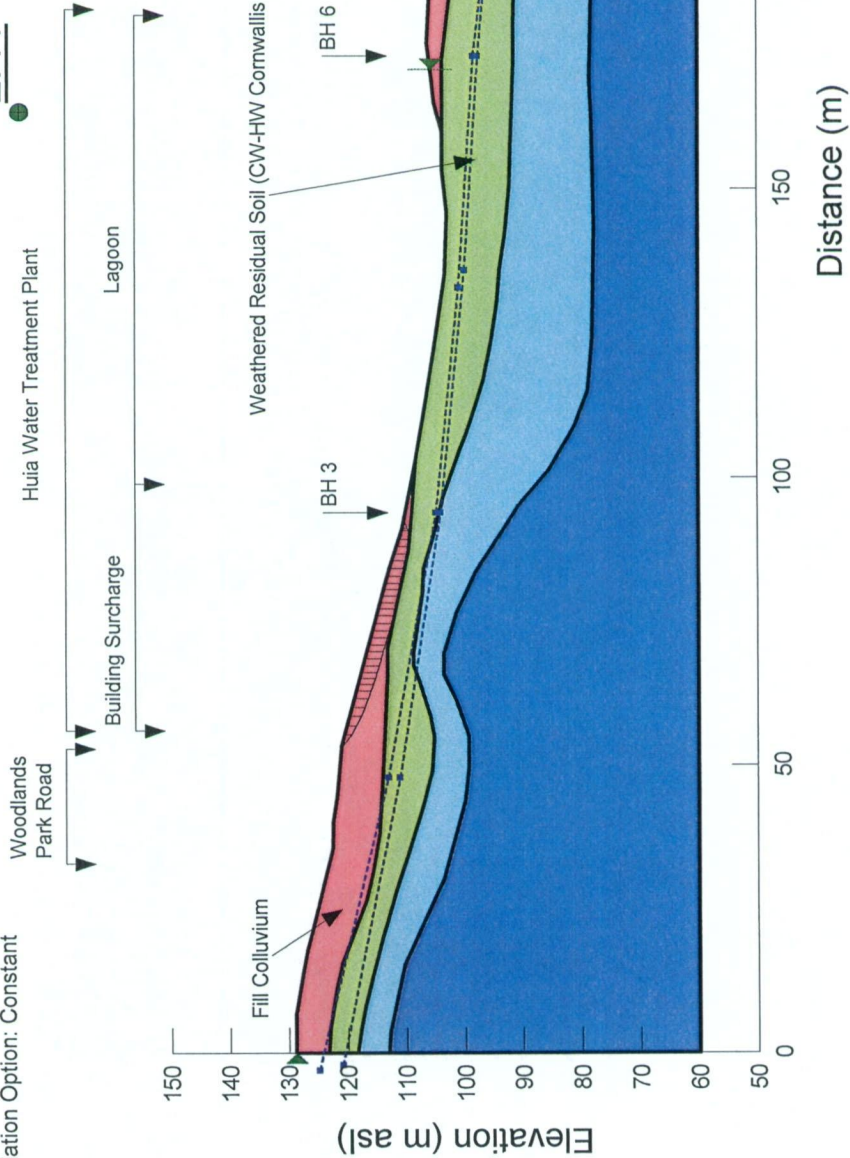
Name: Fill/Colluvium
 Unit Weight: 16 kN/m³
 Cohesion: 2 kPa
 Phi: 30°
 Piezometric Line: 2

Name: Weathered Residual Soil (CW-HW Cornwallis Formation)
 Unit Weight: 17.5 kN/m³
 Cohesion: 8 kPa
 Phi: 28°
 Piezometric Line: 2

Name: Softened MW Cornwallis Formation
 Unit Weight: 18 kN/m³
 Cohesion: 5 kPa
 Phi: 35°
 Piezometric Line: 1

Name: Sandstone Rock (MW-SW Cornwallis Formation)

2.41



Analysis Notes:

1. Method: Morgenstern-Price
2. Direction of movement: Left to Right
3. Optimization: Yes
4. Soil Strength Models: Mohr-Coulomb
5. PWP Conditions Source: Piezometric Line
6. Slip Surface Option: Auto-Search
7. C-Phi Correlation Coeff: 0 (All Soils)
8. Tension Crack Angle: 0
9. Horz Seismic Load:
10. FOS Calculation Option: Constant

Material Properties:

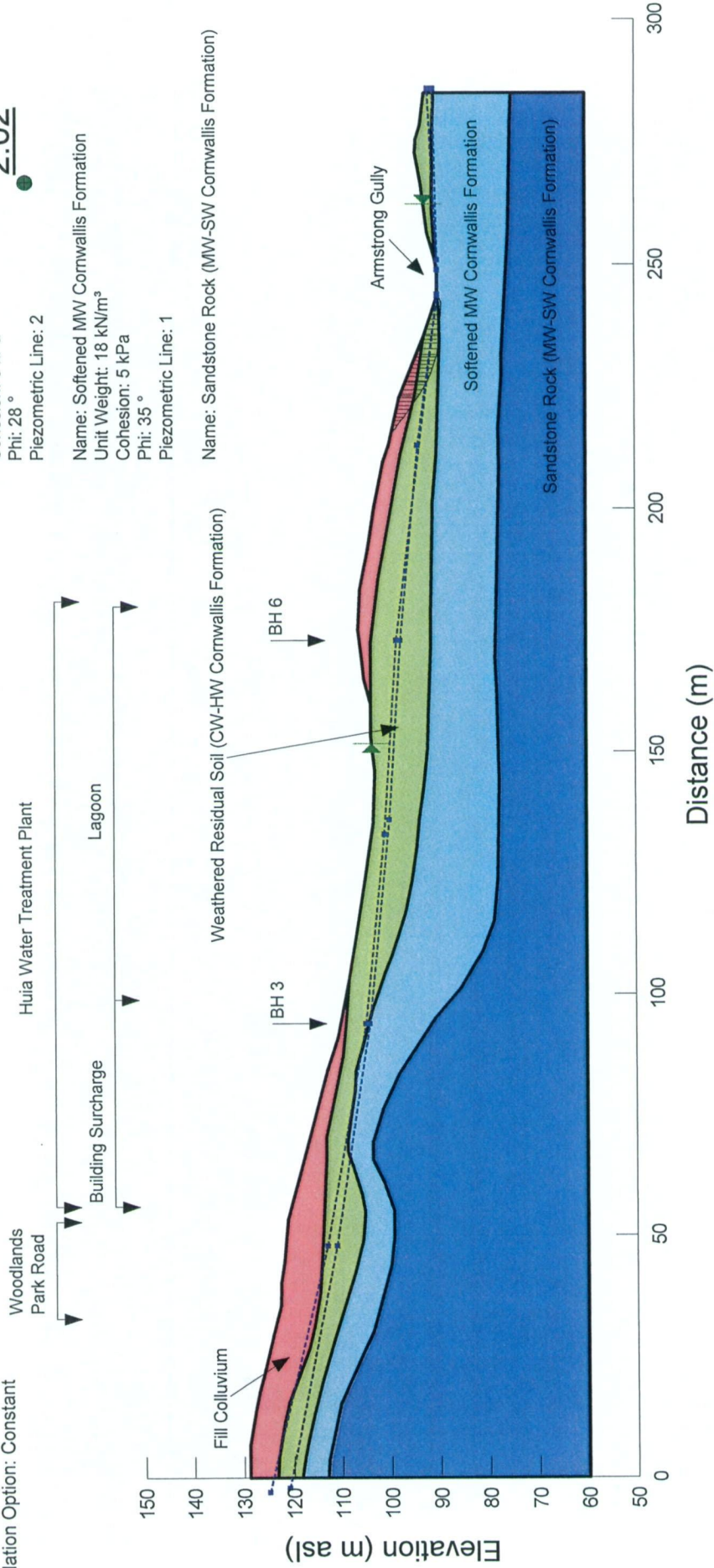
Name: Fill/Colluvium
 Unit Weight: 16 kN/m³
 Cohesion: 2 kPa
 Phi: 30°
 Piezometric Line: 2

Name: Weathered Residual Soil (CW-HW Cornwallis Formation)
 Unit Weight: 17.5 kN/m³
 Cohesion: 8 kPa
 Phi: 28°
 Piezometric Line: 2

2.02

Name: Softened MW Cornwallis Formation
 Unit Weight: 18 kN/m³
 Cohesion: 5 kPa
 Phi: 35°
 Piezometric Line: 1

Name: Sandstone Rock (MW-SW Cornwallis Formation)



Analysis Notes:

1. Method: Morgenstern-Price
2. Direction of movement: Left to Right
3. Optimization: Yes
4. Soil Strength Models: Mohr-Coulomb
5. PWP Conditions Source: Piezometric Line
6. Slip Surface Option: Auto-Search
7. C-Phi Correlation Coeff: 0 (All Soils)
8. Tension Crack Angle: 0
9. Horz Seismic Load: 0.31
10. FOS Calculation Option: Constant

Material Properties:

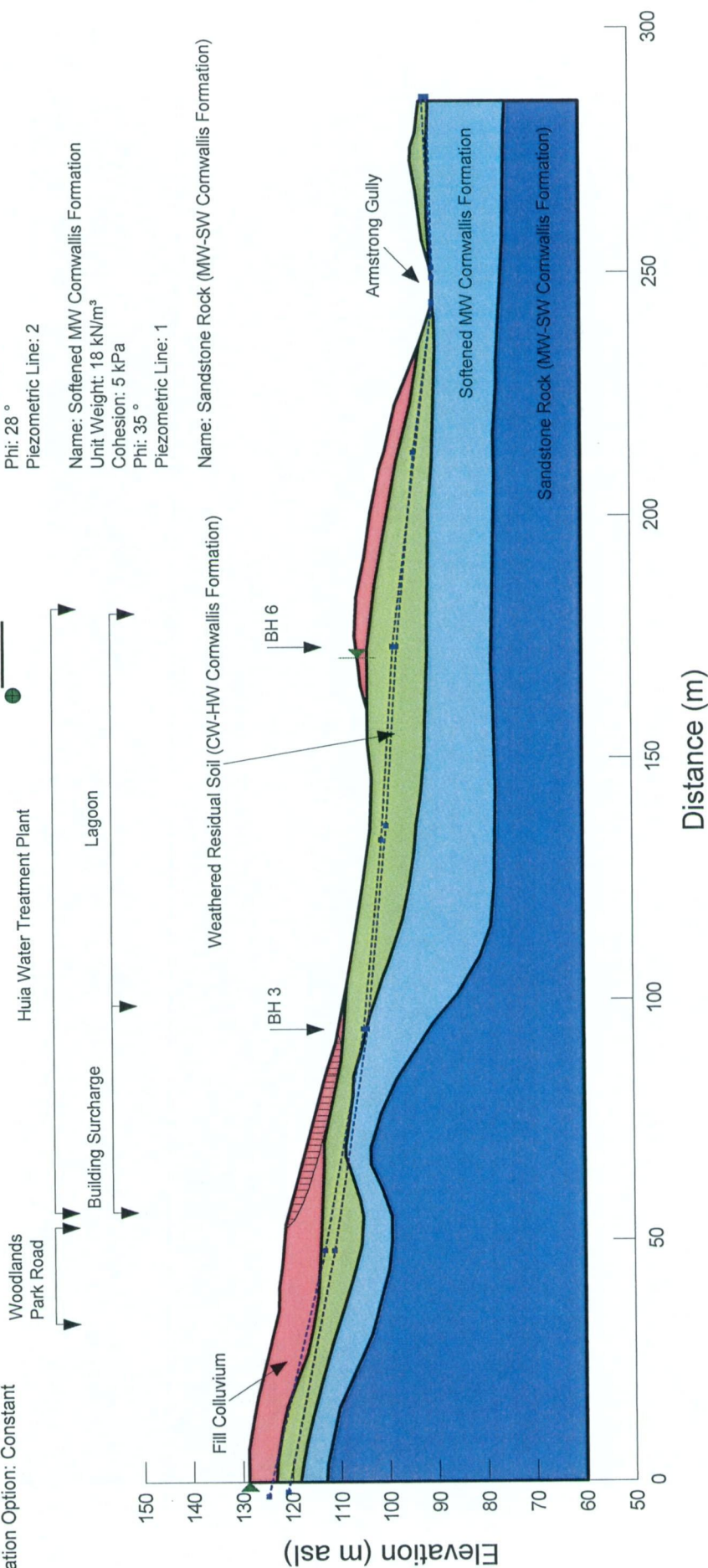
Name: Fill/Colluvium
 Unit Weight: 16 kN/m³
 Cohesion: 2 kPa
 Phi: 30°
 Piezometric Line: 2

Name: Weathered Residual Soil (CW-HW Cornwallis Formation)
 Unit Weight: 17.5 kN/m³
 Cohesion: 8 kPa
 Phi: 28°
 Piezometric Line: 2

Name: Softened MW Cornwallis Formation
 Unit Weight: 18 kN/m³
 Cohesion: 5 kPa
 Phi: 35°
 Piezometric Line: 1

Name: Sandstone Rock (MW-SW Cornwallis Formation)

1.05



Analysis Notes:

1. Method: Morgenstern-Price
2. Direction of movement: Left to Right
3. Optimization: Yes
4. Soil Strength Models: Mohr-Coulomb
5. PWP Conditions Source: Piezometric Line
6. Slip Surface Option: Auto-Search
7. C-Phi Correlation Coeff: 0 (All Soils)
8. Tension Crack Angle: 0
9. Horz Seismic Load: 0.31
10. FOS Calculation Option: Constant

Material Properties:

Name: Fill/Colluvium
 Unit Weight: 16 kN/m³
 Cohesion: 2 kPa
 Phi: 30°
 Piezometric Line: 2

Name: Weathered Residual Soil (CW-HW Cornwallis Formation)
 Unit Weight: 17.5 kN/m³
 Cohesion: 8 kPa
 Phi: 28°
 Piezometric Line: 2

0.97

Name: Softened MW Cornwallis Formation
 Unit Weight: 18 kN/m³
 Cohesion: 5 kPa
 Phi: 35°
 Piezometric Line: 1

Name: Sandstone Rock (MW-SW Cornwallis Formation)

