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Christchurch City Council
53 Hereford Street
Christchurch 8011

15 June 2016

Attention: Bridget O'Brien

Dear Bridget

Akaroa Wastewater Irrigation to Land Investigations

Please find attached 2 copies each of the following reports on investigations into proposed application of treated wastewater to land at Takamatua:

- Infiltration Testing Results for Akaroa Wastewater Disposal Via Irrigation", PDP, 14th June 2016
- Akaroa Wastewater Upgrade Irrigation – Preliminary Geotechnical Assessment. CH2M Beca Ltd 13th June 2016

Our executive summary of the findings of the two investigations is set out below.

Akaroa Wastewater Disposal Soils Investigation Report (Pattle Delamore Partners Ltd)

Pattle Delamore Partners Ltd (PDP) have been engaged by Beca to carry out site investigations to better determine the suitability of the soils of proposed sites at Akaroa for the irrigation of effluent from a proposed wastewater treatment plant. PDP had previously carried out a desktop analysis to identify suitable land for this purpose.

Site investigations were carried out on 30 & 31 May 2016. These were carried out in conjunction with geotechnical investigations of the loess material at each site. The PDP investigations involved:-

- Assessing the soil type at each location (including the depth of the topsoil, presence and depth of any low permeability layer)
- Measuring the depth of root penetration to assist in estimating the Profile Available Water (PAW).
- Measuring the infiltration rate at the ground surface and, if required, of low permeability layers.

Six test pits were excavated and eight infiltration tests were carried out. The testing at the sites indicated topsoil infiltration rates between 8 - 30 mm/hr. Infiltration rates of the sub-surface soil ranged from 0 to 24 mm/hr. It is considered that the bulk hydraulic conductivity of the loess in the area is of a similar magnitude.

A layer with low permeability (poor drainage) was encountered at a depth of around 150 mm to 270 mm below the ground surface. There was no significant penetration of grass roots below this layer.

The observations indicate that the soils are suitable for irrigation but the water available to plants (the profile available water (PAW)) at 48 mm is lower than the 72 mm estimated previously. This will impact on the detailed design of the irrigation system.

At two locations (blocks A & D) the subsoils had very low permeability. At these locations it is recommended at present that they are only irrigated in summer. However the low permeability layer is shallow and it may be able to be broken up by deep ripping of the soil.

For detailed design (and subject to a preferred irrigation method) the following is recommended:-

- PAW = 48 mm;

- Application Rates for irrigation to trees should not exceed 37.5 mm/week in summer, and 17.5 mm/week in winter;
- Application Rates for irrigation to pasture should not exceed 7 mm/day in summer, and 1 mm/day in winter; and
- Application to Block A and Block D should be limited to irrigation in summer, spring and autumn only.

More detailed investigations of the soils will be required prior to detailed design (and subject to a preferred irrigation method) to confirm the following:

- Application Rates (mm/hr) by measuring the hydrophobicity[1] of the soil;
- Application depths (mm) and return periods; and
- Extent of low permeability layers over selected irrigation areas and potential to modify the permeability (e.g. by ripping).

These tests are in addition to general agricultural soil tests to determine the current nutrient state of the soils and appropriate measures to maximise growth of trees or pasture to maximise nutrient and water uptake from the applied treated wastewater.

Akaroa Wastewater Irrigation Preliminary Geotechnical Assessment (CH2M Beca Ltd)

A ground investigation of land at Takamatua that has been identified as potentially suitable for irrigation of treated wastewater was conducted. The physical investigation comprised six test pits and ten laboratory moisture content tests and was conducted in May 2016. From the results of physical testing infiltration rates for specific sites were established and a preliminary assessment of groundwater mounding and slope stability risks was conducted. Key findings of the work are as follows:

- All the exploratory holes encountered partially saturated Quaternary loess to the full 4m depth of excavation. Groundwater was not encountered in any of the test pits.
- The proposed irrigation rate is expected to result in an increased moisture content and groundwater mounding in the loess for both irrigation under trees and irrigation to pasture? Groundwater mounding will accumulate with time if the application of wastewater is ongoing and is not mitigated by vertical seepage effects.
- A preliminary assessment indicates that the global stability of the steeper areas downslope of the proposed irrigation Block B (the land area directly uphill from Kingfisher Point Subdivision - refer to the map in Appendix A to the Beca Report) may become approximately 10% to 20% less stable in the long term with an increase in groundwater level as a result of wastewater application to the land. This means that if the slopes are currently marginally stable (factor of safety of 1.1 to 1.3), the margin of stability in the longer term is likely to be reduced to the point of slope movement as a result of wastewater application.
- Previous slope stability reports by other consultants have indicated that the higher elevation conceptual irrigation blocks are adjacent to pre-existing land instability features such as tunnel gullies, surface erosion and historic deep seated failures on the loess/rock contact. The impact of irrigation on the existing slope movement features has not been quantified, but is likely to result in an increased frequency of movement compared to that which has occurred in the recent past.

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[1] NZ soils tend to repel water when dry. Soils of this nature are described as being hydrophobic. The rate at which water infiltrates can be measured as the hydrophobicity of the soil.

- With regard to the overall change in stability associated with application of wastewater to land, the change in the slope's Factor of Safety (FoS) is reported rather than an absolute FoS, as the analysis is based on a single cross section and a number of simplifying assumptions. It is not advisable to report an absolute FoS from this analysis as it would not be representative of all of the conditions and slopes in the study area.
- The current stability of the slopes can be inferred from the previous studies by Tonkin and Taylor (T&T) and Geotech Consulting[1]. T&T reported that one third of the mapped area contains active gullies which are subject to ongoing episodic movements and debris run out, in particular triggered by rainstorm events. For both the south facing and north facing slopes of Takamatua Peninsula both studies report that a series of wet winters leading to steady building of groundwater levels is a pre-requisite for widespread movement on a range of scales.
- It is useful to compare the relative stability issues at the Wainui wastewater land irrigation scheme and the proposed Akaroa scheme. At Wainui tunnel gullies were assessed as rare, there was localised relatively shallow instability along gully margins, and the whole area is underlain by an ancient, deep-seated landslide. The application of treated wastewater in re-activating movement on the deep-seated landslide was considered unlikely by Geotech Consulting. On the land on Takamatua Peninsula proposed for Akaroa wastewater disposal tunnel gullies have been identified, slope inclinations are locally steeper, and active gullies including surface erosion and small to medium scale landslides have been identified. These factors suggest an elevated instability risk profile at Takamatua compared to Wainui.
- The difference in stability risk between irrigation to trees and irrigation to pasture options is shown in the time versus groundwater height graph in Figure 5-1 of the Beca Report. This indicates an approximate 25% reduction in the average groundwater mounding for irrigation beneath trees compared to irrigation to pasture. Hence, on average, there is a lesser risk of instability with irrigation to trees based on the change in groundwater mounding. Trees also improve the stability of the ground due to their ability to abstract greater volumes of water than pasture and the mechanical 'reinforcing' effect of their roots.
- Comparing upper slope risks to lower slope risks, the stability analysis identifies that the greatest instability risk occurs on the steep slopes below the upper slopes. Irrigating the land at the bottom of the hill on grades of less than 15 degrees, where there is no steep land below, will significantly reduce the risk of instability occurring compared to irrigating the upper slopes.
- In conclusion, the preliminary geotechnical assessment has found that the effects of wastewater irrigation to land are influenced by the location of the land (upper vs lower slopes), and also by ground cover (trees vs pasture). Irrigating land at the bottom of the hill on grades of less than 15 degrees, where there are no slopes steeper than 15 degrees below and where the irrigation areas are planted with trees will have a lower risk than irrigating higher and/or pasture slopes. Adopting this approach is expected to reduce the amount (and rate) of tunnel erosion, surface erosion and small to medium scale landslide instability compared to other irrigation options.
- Higher elevation areas could be considered further but the risks would be greater. As recommended by Geotech Consulting, further geotechnical investigation and assessment would be required to classify those areas which are suitable. Also as recommended by Geotech Consulting, careful monitoring of wastewater land irrigation on the upper and high risk slopes including groundwater level increases and slope instability, especially on upper slopes, would allow the effects of irrigation to be assessed and risks appropriately managed.
- Should shallow ground movement occur, the resulting damage is expected to be able to be dealt with by carrying out slope re-profiling and stabilising earthworks, installing drainage and possibly constructing retaining walls. Whether these measures are needed will be a function of the nature and location of the

instability in relation to the slope and any infrastructure or other structures. Installing drainage to improve stability may be considered a "double edged sword" in the sense that, while it assists in reducing instability risk, it diverts the water out of the land and directly towards the harbour via a drainage feature of some sort.

- The risks around ground movement, which are higher on the upper steeper slopes, pose an ongoing concern. If instability is observed after irrigation? the Council will need to take remedial action which may include improving drainage (which is counter to the scheme intentions), procurement of other land for wastewater application, or use of other means of disposal for a proportion of the wastewater.

We look forward to discussing the enclosed reports with you at the earliest opportunity.

Yours sincerely

Rae Stewart
Project Manager

PP

on behalf of
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Encl:

2 copies - Infiltration Testing Results for Akaroa Wastewater Disposal Via Irrigation", PDP, 14th June 2016

2 copies - Akaroa Wastewater Upgrade Irrigation – Preliminary Geotechnical Assessment .CH2M Beca Ltd 13th June 2016

Report

Akaroa Wastewater Upgrade Irrigation - Preliminary Geotechnical Assessment

Prepared for Christchurch City Council

Prepared by CH2M Beca Ltd

13 June 2016

Revision History

Revision Nº	Prepared By	Description	Date
1	**Katherine Grindley**	For Information	13/06/2016

Document Acceptance

Action	Name	Signed	Date
Prepared by	**Katherine Grindley**		16/06/2016
Reviewed by	**Ann Williams**	pp	
Approved by	**Greg Offer**		16/6/16
on behalf of	CH2M Beca Ltd		

Executive Summary

CH2M Beca Ltd (Beca) has been commissioned by Christchurch City Council (CCC) to undertake a preliminary geotechnical assessment to inform the option of applying treated wastewater to potential land areas on, and between, Takamatua headland and Takamatua valley. This report summarises the findings of the field investigation, development of a conceptual ground model and a preliminary geotechnical assessment of the effects of the proposed infiltration to land, on the stability of the slopes.

CCC is considering the option of land disposal as a method of discharging treated wastewater from the Akaroa wastewater treatment plant. A preliminary assessment of the total required discharge area is approximately 27 hectares, conceptually divided into ten land blocks. The geotechnical assessment presented in this report has been prepared to inform the option of disposing wastewater to land, recognising that the areas identified for disposal are preliminary and subject to confirmation, including by land owners and on the basis of further geotechnical assessment.

A ground investigation comprising six test pits and ten laboratory moisture content tests was completed in May 2016. All the exploratory holes encountered 4 m of Quaternary loess, which was the maximum depth of exploration. Groundwater was not encountered in any of the test pits. A previous investigation at the proposed wastewater treatment site on Old Coach Road indicated that groundwater may be expected within the underlying volcanic bedrock.

Testing indicated that the loess is presently partially saturated. Desk study data suggests that a number of factors, including soil suction in the partially saturated zone, affect the undrained shear strength of the loess, which may drop by two thirds when its moisture content increases by 5%.

The proposed irrigation rate is expected to result in an increased moisture content and groundwater mounding in the loess. The latter will accumulate with time if the application of wastewater is ongoing and is not mitigated by vertical seepage effects.

A preliminary assessment indicates that the global stability of the steeper areas downslope of the proposed irrigation Block B may become approximately 10% to 20% less stable in the long term with an increase in groundwater level as a result of wastewater application to the land. This means that if the slopes are currently marginally stable (factor of safety of 1.1 to 1.3), the margin of stability in the longer term is likely to be reduced to the point of slope movement as a result of wastewater application..

Previous slope stability reports by other consultants have indicated that the higher elevation conceptual irrigation blocks are adjacent to pre-existing land instability features such as tunnel gullies, surface erosion and historic deep seated failures on the loess/rock contact. The impact of irrigation on the existing slope movement features has not been quantified, but is likely to result in an increased frequency of movement compared to that which has occurred in the recent past.

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Appendices

Appendix A

Proposed Irrigation Areas, Test Pit Locations and Cross Section Location

Appendix B

Test Pit Logs and Photographs

Appendix C

Laboratory Test Results

1 Introduction

1.1 Scope

Christchurch City Council (CCC) has engaged CH2M Beca Ltd (Beca) to undertake a preliminary geotechnical investigation to better inform the option of applying treated wastewater to possible sites on and between Takamatua headland and Takamatua valley. This report presents the results of a field investigation, development of a conceptual ground model and a preliminary geotechnical assessment of the potential effects of the proposed infiltration to land on the stability of the slopes. The preliminary findings are subject to further investigation and assessment, which will be required as the project develops.

The scope of the preliminary geotechnical assessment was detailed in the *Akaroa Wastewater – Preliminary Geotechnical Investigation Proposal* dated 24 May 2016 (Ref: included: NZ1-12548291).

The scope comprised the following items:

- Prepare a geotechnical investigation technical brief to be supplied to a Contractor
- Observe the excavation of 8 test pits up to 5 m deep, record groundwater level (if encountered), take disturbed samples for subsequent laboratory testing and undertake in-situ Scala Penetrometer and hand vane testing as appropriate
- Prepare engineering logs of the soils encountered
- Coordinate the laboratory testing (10 moisture content tests) of loess soils sampled from test pits
- Carry out a literature review of the properties of Bank's Peninsula loess soils and the anticipated groundwater level. Obtain indicative parameters for permeability (hydraulic conductivity), porosity and strength of the loess soils
- Develop a ground model for typical high, intermediate and low sites* and prepare sections through these sites.
- Analyse the stability of these sites for inferred seasonal low and high groundwater levels (as currently estimated)
- Assess the effect of the proposed irrigation infiltration rates into the loess on the groundwater regime and re-analyse the stability of these three sites for inferred low and high groundwater level
- Report on the findings of the assessment in relation to the comparative stability of the sites with and without irrigation. The assessment will allow bounds of potential behavior to be reported without giving absolute details of the stability of specific locations.

* Owing to land access restrictions it was not possible to investigate a 'low' site.

The following report details the findings of the geotechnical investigation and slope stability analysis.

Infiltration testing, to investigate the potential of the soils to receive the proposed irrigation water, was carried out by Pattle Delamore Partners Limited (PDP). The results of this testing and associated assessment are presented in a companion report and the findings are used in this assessment.

1.2 Proposed Development

CCC is considering the option of land disposal as a method of discharging treated wastewater from the Akaroa wastewater treatment plant. A conceptual plan of the proposed discharge areas is presented in Appendix A. The total proposed discharge area is approximately 27 hectares divided into ten wastewater land disposal blocks. Generally these blocks are located on the northern slopes of the Takamatua headland and have a slope angle not greater than 15°. However in many cases the blocks occur above land that is much steeper than 15° (on ridges and spurs).

It is proposed that treated wastewater be applied by either drip irrigation or spray irrigation with a maximum average loading rate of 7.1 mm per day for irrigation to pasture or 5 mm per day beneath trees, over the 27 hectares (Ref. NZ1-11926513 *Akaroa Wastewater – Concept Design Report for Alternatives to Harbour Outfall,* CH2M Beca, 2016*)*.

The design land application rates being considered for land irrigation under trees vary and are:

- Loading rate of 5 mm/day in summer (December to February)
- Loading rate of 1.5 mm/day in winter (June to August)
- Loading rate of 3 mm/day for remainder of the year
- When rainfall exceeds 50 mm/day or averages more than 50 mm/day over a number of days (the maximum is 5 days for the rainfall data available) then no irrigation occurs
- If the allowable irrigation is less that wastewater flows or cannot occur due to high rainfall, wastewater is stored (in the upstream storage basin) and irrigated when there is sufficient capacity in the land.

The average net infiltration rates, accounting for evapotranspiration are expected to be 1.12 mm/day to pasture and 0.85 mm/day beneath trees (Letter report: *Infiltration Testing Results for Akaroa Wastewater Disposal via Irrigation*, PDP, 14 June 2016 and email Brough/Offer 15.6.2016).

2 Existing Data

The following existing information for the Takamatua area has been reviewed as part of this preliminary assessment:

- Tonkin and Taylor Ltd. 2008: *Slope Hazard Susceptibility Akaroa harbour settlements*. Report prepared for Christchurch City Council, dated March 2008
- Geotech Consulting Ltd. 2010: *Preliminary geotechnical appraisal of potential slope stability issues in relation to the proposed wastewater irrigation of areas of land near Akaroa*. Report prepared for Christchurch City Council, dated 15 January 2010.

Additional references, primarily from unpublished theses from the University of Canterbury, were reviewed to inform the selection of geotechnical parameters for slope stability analysis and provide comparison with permeability values obtained from the *in-situ* testing.

2.1 Slope Instability

The report by Tonkin and Taylor (2008) identified the main forms of land instability in the Takamatua area as:

- Active gullying including tunnel gullying, surface erosion, and
- Deep seated land instability in loess and underlying bedrock.

The report states that typically tunnel gullying is thought to occur when the groundwater or surface water permeates through layers within the loess initiating dispersion and erosion of the soil matrix. Tunnel gullies typically start beneath the surface and as the loess continues to erode the overlying loess collapses into the subsurface tunnel forming gullies. Surface erosion is the term used where shallow instability has occurred due to saturation of loess deposits close to the ground surface.

Large landslides in the loess and underlying bedrock have been identified in the Takamatua region. Typically these slope movements have been reported to fail at or near the interface between the loess and the weathered bedrock and are understood to be up to 300 m wide.

Mapping undertaken by Tonkin and Taylor of the Takamatua region indicates active gullying and small landslides in loess located in, or closely downslope of, all of the conceptual wastewater land disposal blocks. Furthermore, a large loess/bedrock landslide has been mapped by others immediately downslope on the south and north sides of Block E, the south side of Block H and upslope of Block I.

Geotech Consulting Ltd undertook an assessment of the potential slope stability issues in relation to options for wastewater irrigation of areas of land near Akaroa. In their report a large historic landslide was identified on the south slope of the Takamatua headland. This feature is located downslope on the south side of Block E and is thought to have a deep slip plane within the volcanic bedrock.

2.2 Rainfall Data 2016

Daily rainfall data for Akaroa was sourced from the NIWA National Climate Database for 1 January 2016 to 29 May 2016 (Figure 2-1). The data indicates that the period between 1 January 2016 and 16 May 2016 was relatively dry with the approximate cumulative rainfall over the five months amounting to 125 mm. In the 12 days leading up to the investigation (17 May 2016 to 29 May 2016) rainfall increased and the cumulative amount for the 12 day period was approximately 190 mm.

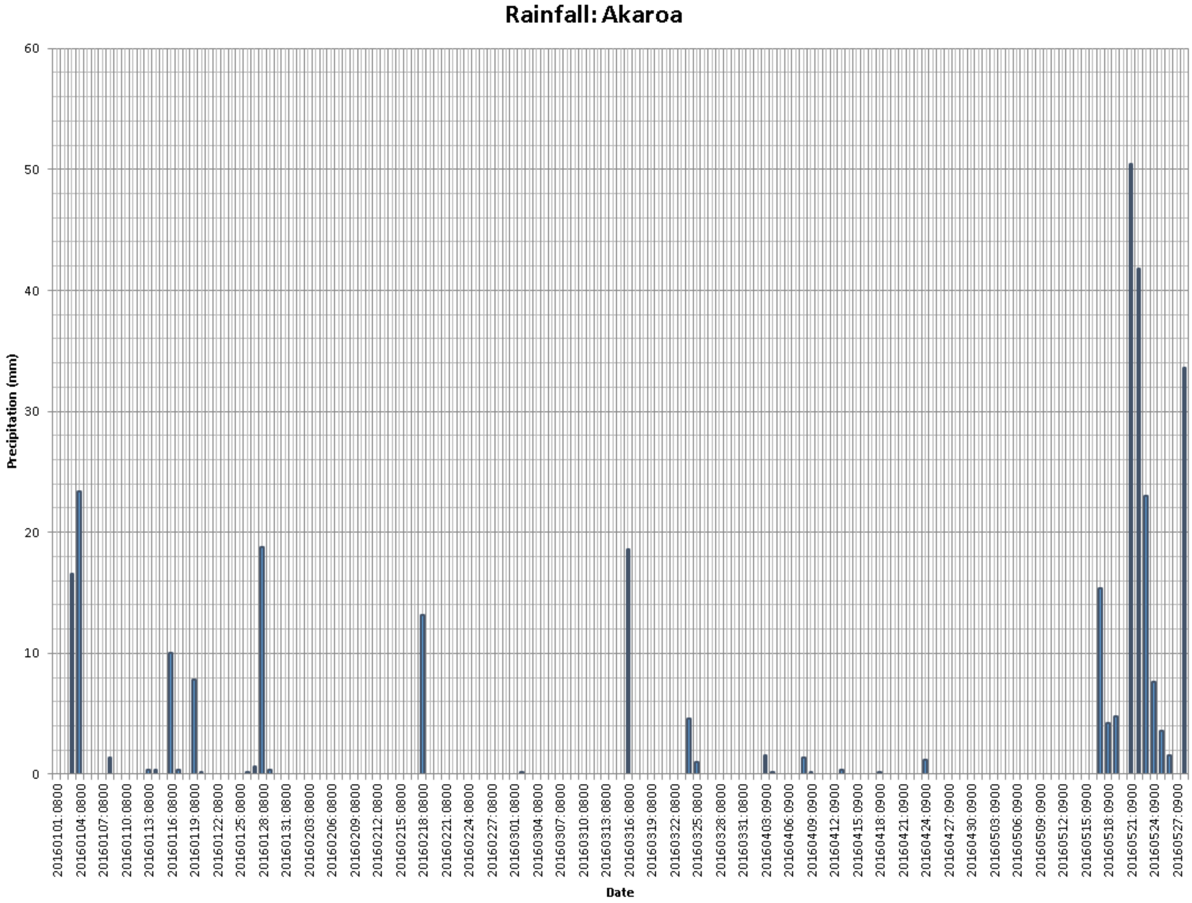


Figure 2-1 Rainfall Data for Akaroa (Station No. 36593) from 1 January 2016 to 29 May 2016. Data sourced from Cliflo: NIWA's National Climate Database on the Web, http://cliflo.niwa.co.nz, Data retrieved 13 June 2016

3 Geotechnical Investigation

3.1 Test Pits

A site investigation was commenced on 30 May 2016 and was completed by 31 May 2016, and comprised the following:

- Six machine excavated test pits with hand held shear vane testing in each location
- Five Scala penetrometer tests commencing at the ground surface and terminating between 1.0 m and 1.9 m depth or refusal
- Four ring infiltration tests conducted at the surface and top of the upper loess layer.

In order to provide material for laboratory testing, the following samples were obtained:

- Small disturbed samples, weighing approximately 0.5 kg were taken at each change in soil type or soil consistency.

The investigation locations have been surveyed using a hand held GPS following excavation in terms of New Zealand Transverse Mercator (NZTM) and are presented in Table 3-1. The test pit locations are presented on a plan in Appendix A.

Table 3-1 - Geotechnical Investigation Locations

Test Pit	Area Location	Hole depth (m)	North (NZTM)	Easting (NZTM)	Approximate Elevation (MSL)
TP1	Block A	4.0	5151841	1595699	99
TP2	Block B	4.0	5151444	1596162	143
TP3	Block E	4.1	5151402	1597211	111
TP4	Block H	4.1	5151302	1598078	169
TP6	Block D	4.0	5151955	1597445	33
TPG	Block G	4.1	5151717	1598582	59

The site investigations were observed by a Beca Engineering Geologist. Unless otherwise stated, all soil and rock logging has been undertaken by a Beca Engineering Geologist in general accordance with New Zealand Geotechnical Society Guidelines (NZGS, 2005). Test Pit logs and photographs are presented in Appendix B. All logs have been verified by a Beca Senior Engineering Geologist.

A list of standards used during the site investigation is shown in Table 3-2, below.

Table 3-2 - Summary of Standards used in this Investigation

Field Procedure	Standard Used
Soil and Rock logging	In general accordance with New Zealand Geotechnical Society Guidelines (NZGS, 2005)
Hand held shear vane testing	In general accordance with New Zealand Geotechnical Society Guidelines (NZGS, 2001)
Scala Penetrometer Testing	NZS4402

3.2 Infiltration Testing

Infiltration testing was undertaken by Pattle Delamore Partners Limited (PDP) in conjunction with the geotechnical testing (PDP, June 2016). The scope of the work comprised:

- Double ring infiltration tests at four locations and two elevations to measure the saturated hydraulic conductivity of the topsoil and of the subsoil (loess)
- Assessment of the topsoil material and measurement of the root depth of the grass.

3.3 Laboratory Testing

Envirolab Geotest Ltd carried out testing on small disturbed bulk samples collected from test pits. The tests undertaken, and the testing specifications, were as follows:

- Natural Moisture Content: NZS4402, 1986; test 2.1

The results of the laboratory testing are given in Appendix D.

4 Conceptual Ground Model

4.1 Ground Profile

The ground conditions encountered in the investigation are broadly consistent with the published geological information and the previous investigation data, comprising Quaternary loess overlying the Akaroa Volcanic Group. The ground conditions at each of the test pit locations were generally similar, apart from minor variation in visually assessed clay and fine sand content with depth at each location.Table 4-1 presents a ground model of the typical materials encountered in the Takamatua area based on information from the six test pits.

Table 4-1 - Ground model of Takamatua area

Unit	Depth (m)	Layer thickness (m)	Description	Shear Vane Undrained shear strength range (average),(kPa)	Geological Unit
-	0	0.15 – 0.25	Topsoil	N/A	N/A
1	0.15-0.25	>4m	SILT, some to trace clay, minor to trace fine sand	Peak: 23 -124 (66) Remoulded: 3 -25 (13)	mQe – Loess/Loess Colluvium

4.2 Ground Properties

Figure 4-1 presents the peak undrained shear strength values from hand held shear vane testing in the loess in the test pits plotted against depth. This demonstrates the wide range in recorded undrained shear strength and suggests a loose trend of increasing strength with depth. The 20kPa to 40kPa undrained shear strengths recorded in some of the shallow tests may reflect a higher moisture content resulting from the recent rainfall.

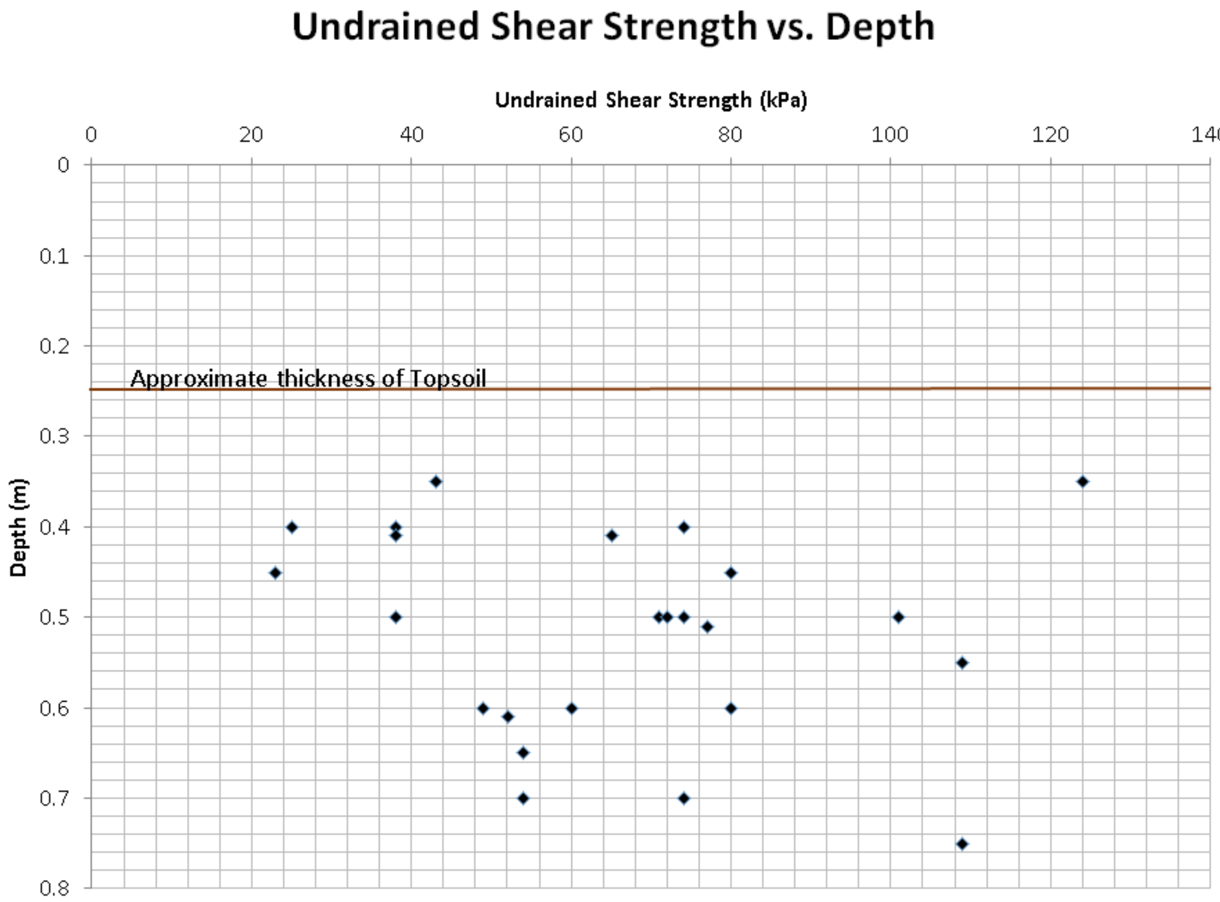


Figure 4-1: Undrained Shear Strength (kPa) vs. Depth (m) data from geotechnical investigation (May, 2016)

Figure 4-2 presents the results from the laboratory water content tests plotted against the depth of samples. The liquid limit and plastic limit average lines and ranges have been sourced from information reviewed in unpublished University of Canterbury theses on loess from Banks Peninsula.

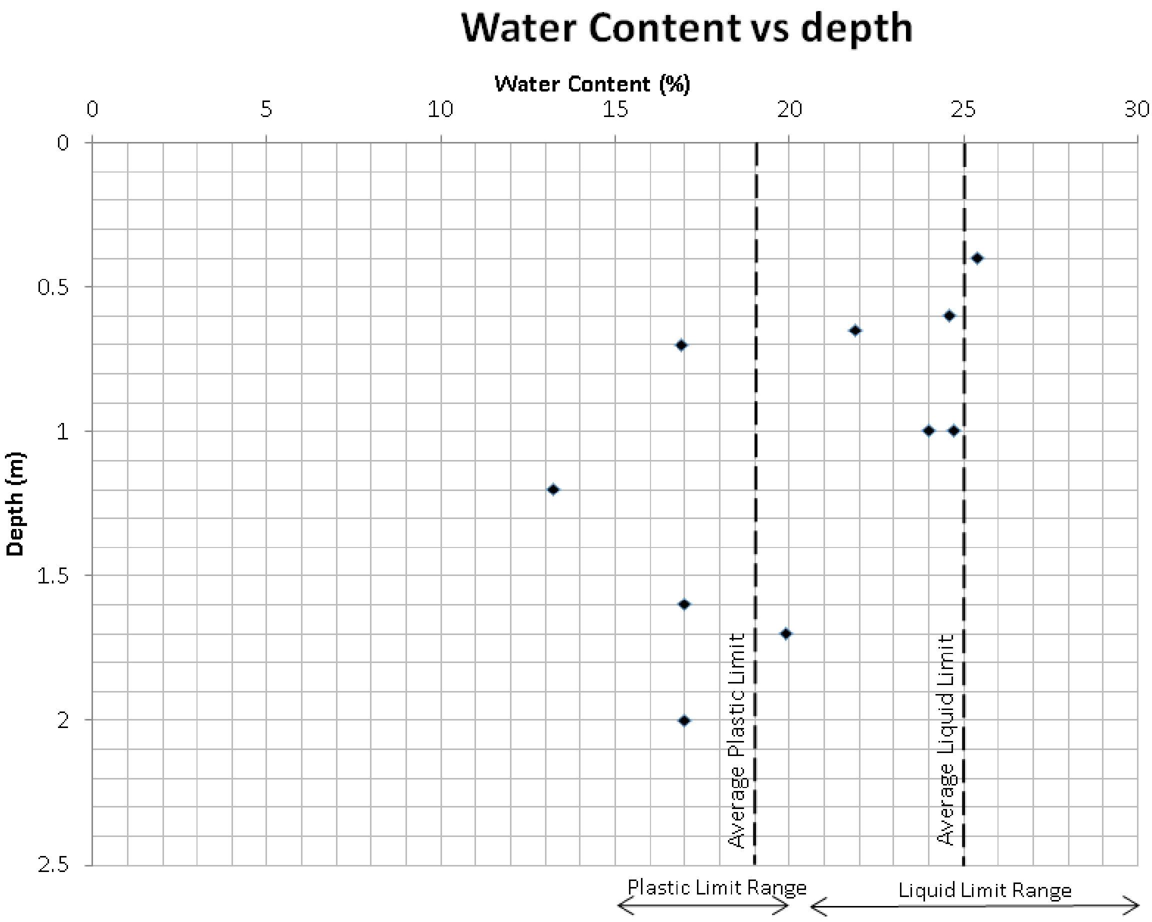


Figure 4-2: Water content test results vs. depth (m). Water content data from Beca Laboratory test results (May, 2016).

The laboratory tests indicated that the water content in the loess ranges from 13 % to 25 %, with an average water content from the tested samples of 20 %. Generally the laboratory test results indicated a decrease in water content with depth.

From the water content tests the degree of saturation has been calculated assuming a dry density from reviewed literature which ranges from 1.29 t/m³ to 1.90 t/³ with an average of 1.67 t/m³. The anticipated ranges in the degree of saturation are presented in Table 4-2. The data indicates that the loess does not reach full saturation within the bounds of the moisture contents obtained from the site testing.

Table 4-2 - Saturation ratio of loess

Assumed Dry Density (t/m^3)	Saturation Ratio calculated for Moisture Contents (M_c) recorded from Laboratory Testing		
	M_c = 13 % (minimum)	M_c = 20 % (average)	M_c = 25 % (maximum)
1.29 – 1.90 (1.67 average)[1]	25 % – 46 % (35 %)	39 % – 71 % (54 %)	49 % – 88 % (68 %)

1 – Data from 77 dry densities sourced from unpublished research theses from University of Canterbury.

Shear strength of loess soils is not well understood, but is thought to be influenced by a combination of factors including soil suction in the partially saturated zone and particle bonding. The maximum degree of saturation assessed here, suggests that soil suction in the partially saturated zone was likely to be present.

The undrained shear strength of loess is sensitive to changes in moisture content. Figure 4-3 has been taken from a University of Canterbury thesis and shows the effect of changing moisture content on the shear strength of loess. The figure suggests that when the moisture content increases by 2.5 % (from 20 % to 22.5 %) the undrained shear strength of loess is approximately halved from 100 kPa to 55 kPa.

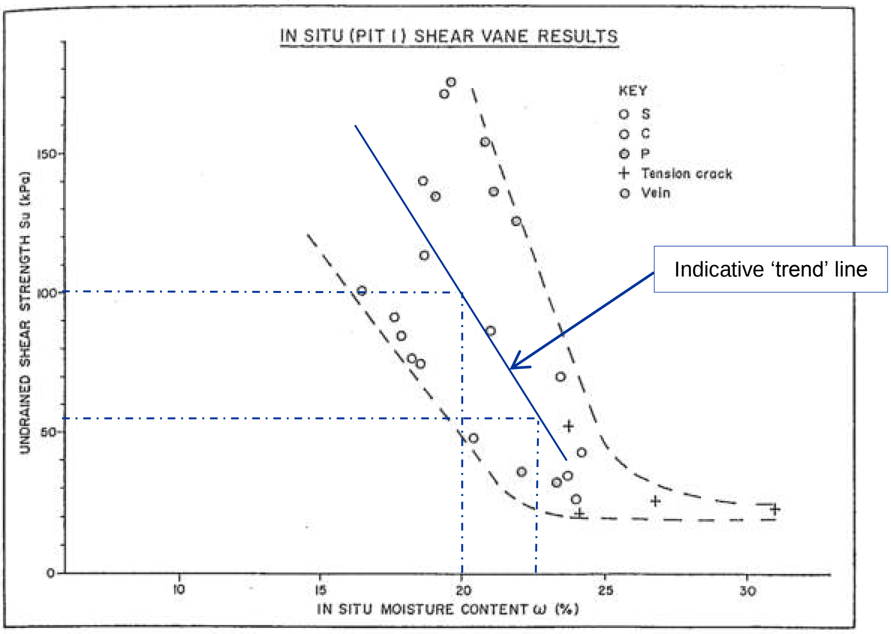


Figure 4-3 Undrained shear strength (Su) measured with hand held shear vane compared with in-situ moisture contents (%). Sourced from Unpublished MSc thesis by Goldwater (1990)

During transient loading, soils behave in an 'undrained' manner, for example when they are subject to seismic loading. Hence, a relatively small increase in moisture content can result in a significant reduction in stability.

4.3 Groundwater

Groundwater was not encountered during the investigation. Perched groundwater seepage was record in the upper 0.5 m of Test Pit 1; this is likely to be due to the rainfall leading up to the geotechnical investigation and the presence of a very stiff, likely less permeable layer at approximately 0.5 m in Test Pit 1.

Review of previous ground investigation data from CH2M Beca (2014) *Akaroa Wastewater Treatment Plant - Geotechnical Assessment Report, dated 2014* indicated that groundwater at the Akaroa Wastewater Treatment plant on Old Coach Rd was typically encountered between 8 m to 11 m below ground level (bgl) within the volcanic rock underlying the loess.

5 Treated Wastewater Infiltration

5.1 Infiltration Rate

The infiltration rates presented in Table 3-3 indicate variability in the loess across the Takamatua area at the time of testing. The subsurface testing undertaken on the top of the loess layer at test pit 1 (Block A) and Test Pit 6 (Block D) indicated an infiltration rate of 0 mm/hr, whereas Block G and Block E presented an infiltration rate of 24 mm/hr and 12 mm/hr respectively.

The proposed loading rate for the wastewater discharge at ground level is up to 7.1 mm/day, with variation in application of the wastewater depending on the season. To provide a preliminary indication of whether the loess in Block E and Block G has capacity to reliably receive the wastewater, the measured infiltration rates have been reduced by a factor of twenty five to allow for variability in ground conditions and the limited number of test results. Table 5-1 presents the factored infiltration test results, which can be compared with the application rates.

Table 5-1: Factored rates from ring infiltration testing

Location	Depth Below Ground Level (m)	Unit	Test Infiltration Rate (mm/hr)	Factored infiltration rate (mm/hr)	Factored infiltration (mm/day)
Block A	0	Topsoil	20	0.80	19.2
	0.38	Top of Loess	0	0.00	0.0
Block E	0	Topsoil	12	0.48	11.5
	0.38	Top of Loess	12	0.48	11.5
Block D	0	Topsoil	8	0.32	7.7
	0.4	Top of Loess	0	0.00	0.0
Block G	0	Topsoil	30	1.20	28.8
	0.3	Top of Loess	24	0.96	23.0

5.2 Groundwater Mounding

A preliminary assessment of potential for groundwater mounding has been undertaken using guidance from the U.S. Environmental Protection Agency (EPA) *Process Design Manual for Land Treatment of Municipal Wastewater (EPA 625/1-81-013).* The purpose of the calculations was to investigate whether groundwater mounding could occur as a result of the application of water to the land and if so, to what extent.

Groundwater mounding can be estimated by applying the heat-flow theory and the Dupuit-Forcheheimer assumptions. These simplifying assumptions are:

- Flow within groundwater occurs along horizontal flow lines whose velocity is independent of depth
- The velocity along these horizontal streamlines is proportional to the slope of the free water surface

The potential for groundwater mounding has been assessed for Block E and Block G, using the assumption that the area under which wastewater will be applied is rectangular and the loess is homogenous with a consistent permeability with depth. It is assumed that no water is lost through evapotranspiration.

Table 5-2 details the parameters used for calculation of groundwater mounding.

Table 5-2 - Parameters for calculation of groundwater mounding

Parameter			Block		Reference
Symbol	**Description**	**Unit**	**E**	**G**	
W	**Width of site**	m	125 m	100 m	Measured approximately from aerial maps.
K	**Hydraulic conductivity of soil**	m/day	0.01	0.02	PDP infiltration testing results factored by 25 to determine the design hydraulic conductivity. A factor of 25 has been applied in accordance with EPA (1984) that estimates that the loading rate measured by ring infiltration testing is 2 - 4 % of the “effective rate”.
D	**Saturated thickness of soil**	m	1	1	Estimated. However a range of values were assessed which indicated that ‘D’ does not have a significant influence on groundwater mounding in this case.
V	**Specific yield**	-	0.18	0.18	Applied 30 % of porosity (called "drainable porosity") because clay will keep some water
t	**Duration of wastewater application**	days	Range	Range	The application of wastewater is proposed to occur all year, depending on the season and rainfall. However, a range of durations were assessed to provide an estimate of the groundwater mounding.
I	**Proposed Loading Rate**	m/day	0.014	0.014	Double the maximum loading rate provided by CH2M Beca (2016) due to half of sites tested showing 0 mm/hr permeability. No account for evapotranspiration.
			0.00112	0.00112	The average net infiltration rates to pasture, accounting for evapotranspiration.
			0.00083	0.00083	The average net infiltration rates beneath trees, accounting for evapotranspiration.

The groundwater mounding calculations indicated the degree of groundwater mounding was affected primarily by the duration which the wastewater was applied. The longer the wastewater was applied the higher the groundwater mounding. Figure 5-1 presents the height of groundwater mounding against duration of loading application for Blocks E and G based on the average net infiltration rates. This indicates that groundwater may mound to 2m over a one year period based on a number of simplifying assumptions.

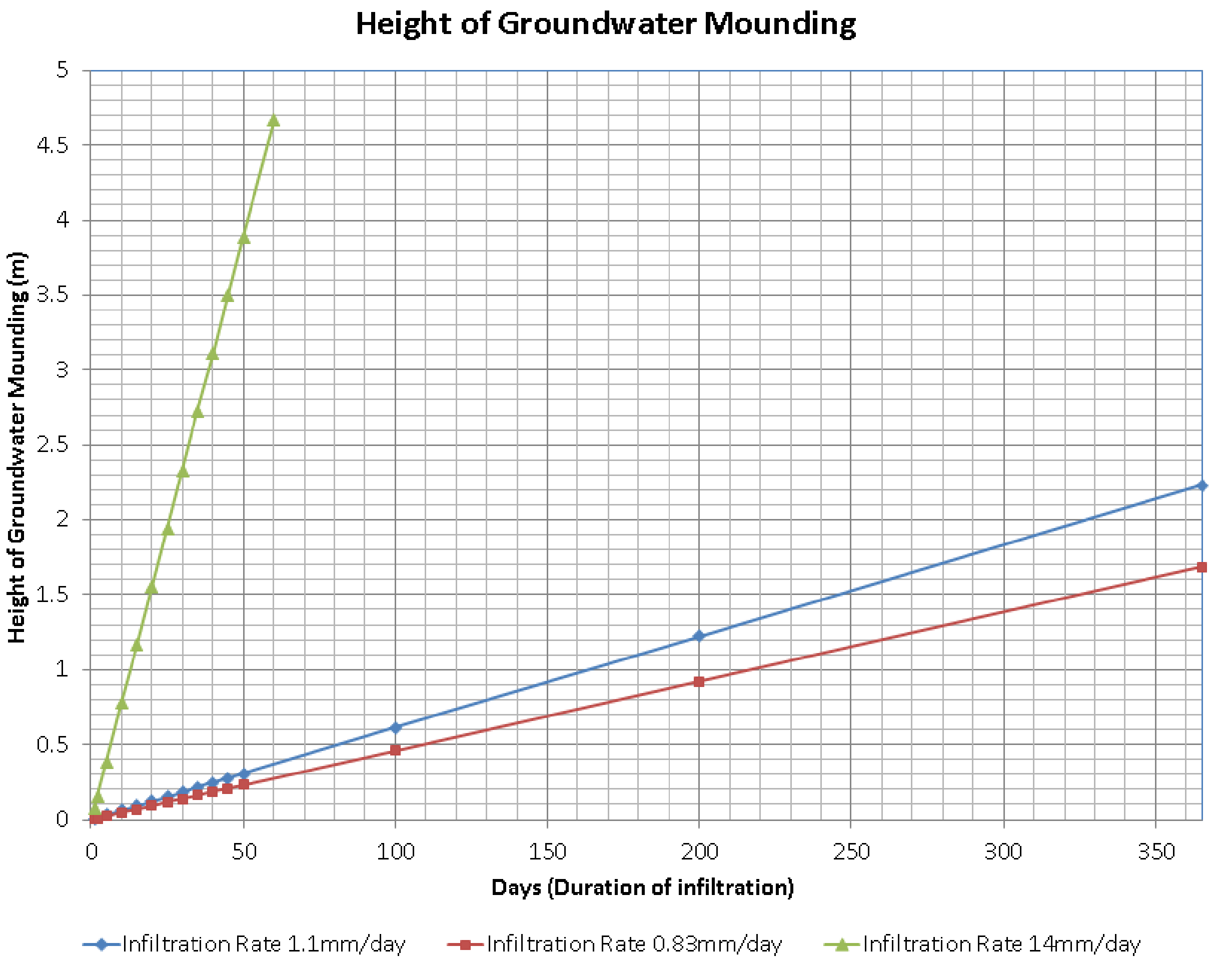


Figure 5-1: Groundwater mounding compared with duration of irrigation (days)

However, this assessment is based on average annual figures and if there were to be a prolonged wet period during the year, the mounding would increase. For example if the net infiltration rate increased to a level equal to the application rate, after 60 days the height of groundwater mounding is calculated to be greater than 4.5 m. If the thickness of loess is between 4 m – 5 m thick the groundwater will be above or within 1 m of the surface layer. The width of the groundwater mounding has not been calculated as part of this assessment.

If significant groundwater mounding occurs, or has the potential to occur, the application rate may need to be reduced or application ceased for a period of time to allow dissipation of groundwater. The length of time that resting would be required has not been calculated as part of this preliminary assessment.

6 Slope Stability

6.1 Background

The reports by Tonkin and Taylor and Geotech Consulting Ltd have identified the presence of shallow and deep seated instability adjacent to the proposed irrigation blocks. According to mapping by Tonkin and Taylor the most prevalent mechanism of failure in the northern slopes of Takamatua appears to be gullying. The preliminary global stability assessment of the slope (presented below) does not consider gullying i.e. the degree to which an increase in groundwater level within the loess may affect the dispersion of fines or shallow erosion. However, it is noted that loess is a highly erodible and moisture sensitive soil which, when subjected to an increased groundwater level in the slope, is likely to experience exacerbated gullying and shallow erosion.

6.2 Preliminary Slope Stability Assessment

The conceptual wastewater irrigation blocks are situated on sloping hillsides with slope angles of up to 15°. Typically below the conceptual irrigation blocks the topography steepens, with Tonkin and Taylor identifying slope failures and some hummocky or uneven ground, indicative of historical shallow and deeper instability, identified during a walkover. Block B is above a residential development and hummocky uneven ground was observed in the area during the geotechnical investigation.

Preliminary simplistic shallow (< 5 m) slope stability analyses were undertaken for a section through Block B for long term (drained) and transient loading (undrained) stability.

A number of simplifying assumptions were adopted as follows. Drained slope stability analyses were undertaken first with an existing groundwater table at the inferred loess/rock contact at 5 m depth, and then with the groundwater level raised in 1 m increments. The groundwater was modelled as a single phreatic surface parallel to the rock/loess contact. The loess was modelled as a single homogenous layer. It is recommended that these assumptions are reviewed and confirmed as the assessment develops.

Figure 6-1 shows the height of groundwater mound compared with relative change in Factor of Safety (FOS).

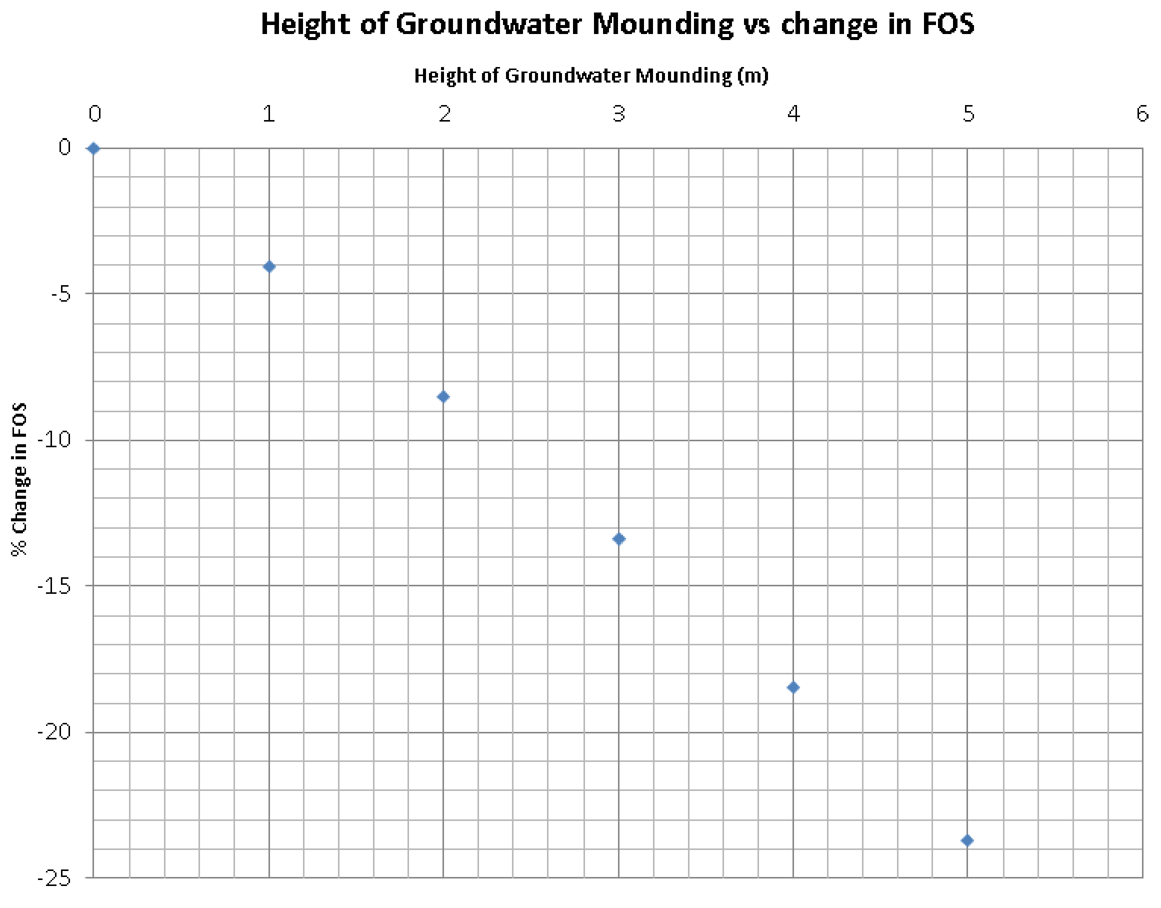


Figure 6-1: Height of groundwater mound compared with relative change in Factor of Safety (FOS)

The analyses showed that if the application of irrigation water results in a 4 m to 5 m high groundwater mound, the FoS is expected to reduce by approximately 20%. If the mound is lesser (say 2 m after 1 year as indicated by analyses using average net infiltration rates reported by PDP (2016)), then a reduction in FoS of about 10% might be anticipated. This means that if a slope currently has marginal stability then the addition of wastewater might result in instability, in particular when combined with a period of rainfall.

Figure 6-2 shows the inferred effect of a change in moisture content with FoS for undrained loading, based on the moisture content versus undrained shear strength relationship given in Figure 4-3.

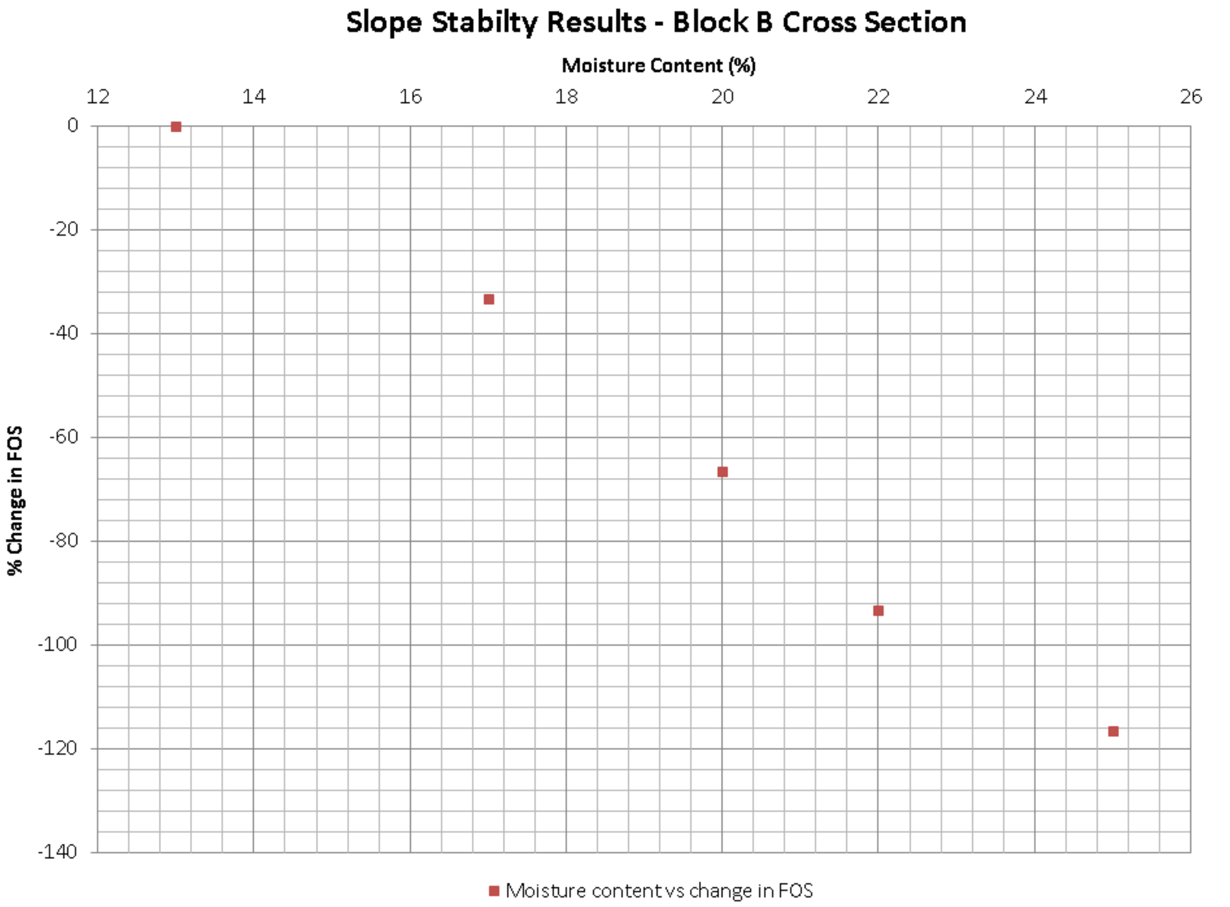


Figure 6-2 Moisture content vs. relative change in Factor of Safety (FOS)

The undrained analyses showed that an increase of moisture content between 2 % and 4 % can reduce the FoS by approximately 30 % and 40 %. This reduction in FoS would apply under seismic loading and is independent of the reduction shown in Figure 6-1.

It was observed in the slope models that because the area downslope of Block B is generally steeper than the area where the wastewater is to be applied, the lower section of the slope was generally where the critical slip surface would occur.

The preliminary slope stability analysis undertaken for this report is based on a number of simplifying assumptions and has considered overall stability only for a conceptual groundwater response to infiltration and limited data on the relationship between moisture content and undrained shear strength. Further work will be required to confirm the feasibility, or otherwise, of this option and to assess the effects of the irrigation on the stability of the land in the vicinity of application at the sites finally selected.

7 Summary

A preliminary geotechnical investigation has been undertaken comprising the excavation and logging of six test pits and laboratory testing of ten natural moisture contents from samples obtained from the test pits. Additionally a desk study of the properties of loess soils on Banks Peninsula has been undertaken. The results from these investigations have informed a preliminary assessment of the slope stability effects of the conceptual land disposal of treated wastewater from the Akaroa wastewater treatment plant onto land.

The loess has been proved to be at least 4 m thick and have a natural moisture content in the range 13 % to 25 % (numerical average of 20 %) which lies within the range of liquid limit and plastic limit data, with the exception of one test. The corresponding degree of saturation is estimated to be between 25 % and 88 %, indicating that the loess is presently partially saturated.

The shear strength of loess soils is not well understood, but is thought to be influenced by a number of factors including soil suction in the partially saturated zone and particle bonding. The undrained shear strength of loess is sensitive to changes in moisture content, with Desk study data indicating a fall from a peak of around 150 kPa when its moisture content is less than 20 % to less than 50 kPa when its moisture content is 25 % or greater.

The proposed loading rate is expected to result in an increased moisture content and groundwater mounding in the loess. The latter will accumulate with time if the application of wastewater is ongoing and is not mitigated by evapotranspiration effects.

An overall simplified stability assessment has been undertaken of the slopes towards the headland of Takamatua peninsula. This indicates that the margin of stability of steeper areas downslope of the proposed irrigation blocks may reduce by 10 to 20 % after 1 year of treated wastewater application. This means that if the stability of the existing slopes is already marginal, then wastewater application is likely to trigger instability. Depending on the effect of the irrigation on the moisture content of the soil, the short term stability, as might be experienced during an earthquake, could decrease by 30 % to 40 % ignoring any reduction in soil suction or mechanical bonding. The impact of irrigation on existing slope movements, such as tunnel gullies, surface erosion and historic deep seated planes at the loess/rock contact, has not been quantified, but it is expected that an increased frequency of movement will result.

References

CH2M Beca Ltd. 2016. Akaroa Wastewater – Concept Design Report for Alternatives to Harbour Outfall. Report prepared for Christchurch City Council. Report No. NZ1-11926513, dated 12 May 2016.

CH2M Beca Ltd. 2016. Akaroa Wastewater Treatment Plant – Geotechnical Assessment Report. Report prepared for Christchurch City Council. Report No. NZ1-8674546, dated 31 March 2014.

Geotech Consulting Ltd. 2010. Preliminary geotechnical appraisal of potential slope stability issues in relation to the proposed wastewater irrigation of areas of land near Akaroa. Report prepared form Christchurch City Council, dated 15 January 2010

Goldwater, S. 1990. Slope Failure in Loess. A detailed investigation, Allendale, Banks Peninsula. Unpublished MSc thesis. University of Canterbury.

Pattle Delamore Partners. 2016. Infiltration Testing Results for Akaroa Wastewater Disposal via Irrigation. Letter report produced for CH2M Beca Ltd, draft report dated 14 June 2016.

Pattle Delamore Partners. 2016. Options Update Letter Report. Letter report produced for CH2M Beca Ltd, dated 24 March 2016.

Tonkin and Taylor Ltd. 2008. Slope Hazard Susceptibility Akaroa harbour settlements. Report prepared for Christchurch City Council, dated March 2008

Applicability

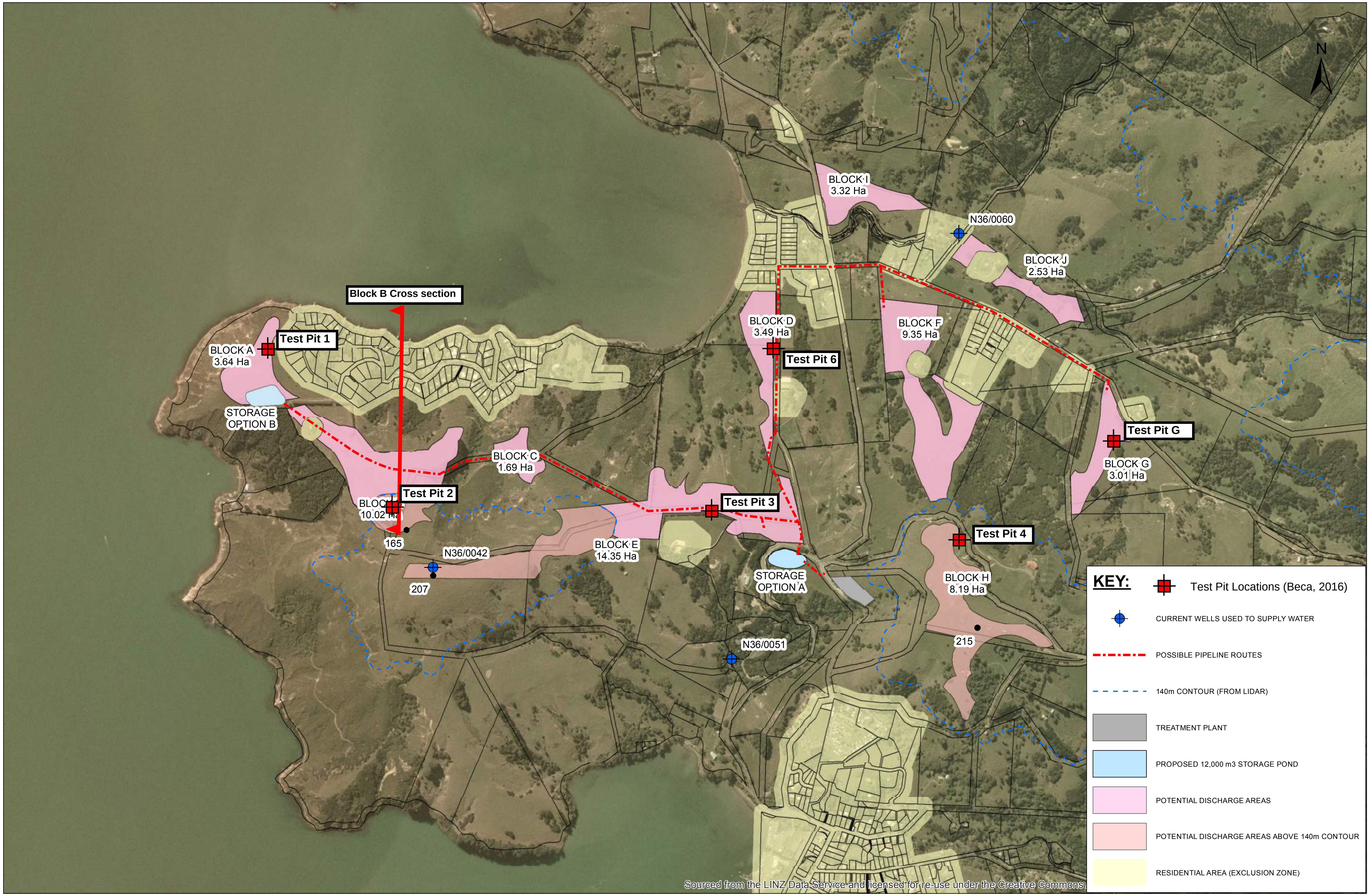
This report has been prepared by Beca on the specific instructions of our Client. It is solely for our Client's use for the purpose for which it is intended in accordance with the agreed scope of work. Any use or reliance by any person contrary to the above, to which Beca has not given its prior written consent, is at that person's own risk.

This is a factual report of field investigations and laboratory testing. The field investigations have been undertaken at discrete locations and no inferences about the nature and continuity of ground conditions away from the investigation locations are made. Furthermore logs are provided presenting description of the soils and geology based on our observation of the samples recovered in the fieldwork and may not be truly representative of the actual underlying conditions.

Should you be in any doubt as to the applicability of this report and/or its recommendations for the proposed development as described herein, and/or encounter materials on site that differ from those described herein, it is essential that you discuss these issues with the authors before proceeding with any work based on this document.

Appendix A

Proposed Irrigation Areas, Test Pit Locations and Cross Section Location



SOURCE:
1. CADASTRAL DATA AND AERIAL IMAGERY SOURCED FROM LAND INFORMATION NEW ZEALAND (LINZ) MAY NOT BE SPATIALLY ACCURATE.

AKAROA WASTEWATER LAND DISPOSAL
OPTION 1 AND 2: YEAR ROUND IRRIGATION

SCALE: 1:12,000 (A3)

0 125 250 375 500
METRES

C02239201Z002_OPTIONS_ASSESSMENT_1_V2.mxd
ISSUE DATE: 05/04/16 VERSION: 2

Appendix B

Test Pit Logs and Photographs

CH2M Beca

TEST PIT No: TP1

TEST PIT LOG

SHEET 1 of 1

PROJECT: Akaroa Wastewater Upgrade
JOB NUMBER: 6517986
SITE LOCATION: Takamatua
CLIENT: Christchurch City Council

CIRCUIT: NZTM
COORDINATES: N 5,151,841 m
E 1,595,699 m
TEST PIT LOCATION: Block A
R L: 99 m
DATUM: MSL

DEPTH (m)	WATER LEVEL	GRAPHIC LOG	USCS	MOISTURE	SOIL / ROCK DESCRIPTION	GEOLOGICAL UNIT	Scala (Blows/100mm)	SV	τ (kPa)	SAMPLES	R L (m)
0.0–0.2			ML	M	Soft, SILT, minor rootlets, trace fine to medium sand; dark brown; moist; non plastic. [TOPSOIL].		2, 1				
0.2–0.65			ML	M	Firm, SILT, minor clay, trace fine sand, trace rootlets; light brown mottled orange; moist; low plasticity. At 0.5m: wet on north and south walls. Seepage of approx. 0.1l/min.	LOESS (mQe)	1, 1, 3, 6	30/4 30/6	38/5 38/8	B	98.5 (0.5)
0.65–1.2			ML	M	Very stiff, SILT, some clay, minor fine to coarse sand; yellowish brown; moist; high plasticity. Grey vertical and horizontal veining trending north-south and east-west. Veining infilled with soft, SILT, minor clay; moist; low plasticity. Vein apperture approximately 1-3cm.	LOESS (mQe)	11, 20	18/4 30/6 UTP	23/5 38/8	B	98.0 (1.0)
1.2–4.0			ML	M	SILT, minor fine to coarse sand, minor clay; yellowish brown; moist; low plasticity. From 2m: Trace fine to medium sand.	LOESS (mQe)				B	97.5 (1.5), 97.0 (2.0), 96.5 (2.5), 96.0 (3.0), 95.5 (3.5)
4.0					END OF LOG @ 4 m						95.0 (4.0), 94.5 (4.5)

DATE EXCAVATED: 30/5/16
LOGGED BY: KRY
SHEAR VANE No: DR3969
CONTRACTOR: Alan Hemsworth
EQUIPMENT: 2t excavator
METHOD: Machine excavation/auger

COMMENTS:
Target Depth reached. No ground water encountered. Upper 2m excavated with bucket, machine auger from 2m to 4m.

FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS SEE KEY SHEET

Revision 0

A4 Scale 1:25

TP1

TP1

TEST PIT LOG

TEST PIT No: TP2

SHEET 1 of 1

PROJECT:	Akaroa Wastewater Upgrade	JOB NUMBER:	6517986
SITE LOCATION:	Takamatua	CLIENT:	Christchurch City Council

CIRCUIT: NZTM
COORDINATES: N 5,151,444 m
E 1,596,162 m

TEST PIT LOCATION: Block B
R L: 143 m
DATUM: MSL

DEPTH (m)	WATER LEVEL	GRAPHIC LOG	USCS	MOISTURE	SOIL / ROCK DESCRIPTION	GEOLOGICAL UNIT	Scala (Blows/100mm)	SV	τ (kPa)	SAMPLES	R L (m)
			ML	M	Soft, SILT, minor rootlets, trace fine to medium sand; dark brown; moist; non plastic. [TOPSOIL].		2				
			ML	M	Very stiff, SILT, trace clay, trace fine sand; yellowish brown mottled orange; moist; low plasticity.	LOESS (mQe)	2				
							1				
							0	90/12	124/16		
0.5							1	74/18	101/23		142.5
					From 0.6m to 1.4m: vertical and horizontal veining infilled with soft, SILT, trace clay; grey; moist; low plasticity. Orange staning surrounding grey veins. Vein apperture approximately 1-3cm.		2				
							2	60/14	80/18	B	
							3	80/12	109/16		
							7				
1.0							8				142.0
							10				
							15				
			ML	M	SILT, trace clay, trace fine sand; yellowish brown; moist; low plasticity.						
1.5											141.5
										B	
2.0											141.0
					From 2.4m: minor fine to medium gravel. Gravel: angular, volcanics, black. Trace fine gravel sized clasts of clay; red, grey; clasts smear upon compression with fingers.						
2.5											140.5
3.0											140.0
3.5											139.5
					From 3.6m: some fine sand						
4.0					END OF LOG @ 4 m						139.0
4.5											138.5

DATE EXCAVATED:	30/5/16	CONTRACTOR:	Alan Hemsworth
LOGGED BY:	KRY	EQUIPMENT:	2t excavator
SHEAR VANE No:	DR3969	METHOD:	Machine excavation/auger

COMMENTS:
Target Depth reached. No ground water encountered. Upper 2m excavated with bucket, machine auger from 2m to 4m.

FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS SEE KEY SHEET

Revision 0

A4 Scale 1:25

TP2

TP2

CH2M Beca

TEST PIT No: TP3

TEST PIT LOG

SHEET 1 of 1

PROJECT: Akaroa Wastewater Upgrade
JOB NUMBER: 6517986
SITE LOCATION: Takamatua
CLIENT: Christchurch City Council

CIRCUIT: NZTM
COORDINATES: N 5,151,402 m
E 1,597,211 m
TEST PIT LOCATION: Block E
R L: 111 m
DATUM: MSL

DEPTH (m)	WATER LEVEL	USCS	MOISTURE	SOIL / ROCK DESCRIPTION	GEOLOGICAL UNIT	Scala (Blows/100mm)	SV	τ (kPa)	SAMPLES	R L (m)
0.0–0.25		ML	M	Soft, SILT, minor rootlets, minor fine to medium sand; dark brown; moist; non plastic. [TOPSOIL].		2, 1				
0.25–1.2		ML	M	Firm, SILT, minor clay, trace fine sand; yellow brown mottled orange and grey; moist; low plasticity.	LOESS (mQe)	1, 1, 1, 1, 2, 3, 6, 5, 20	34/8, 20/2, 38/8, 40/4	43/11, 25/3, 49/11, 52/5	B (approx. 0.65 m)	
1.2–4.1		ML	M	SILT, minor fine sand, trace clay; yellow brown mottled orange; moist; low plasticity when wetted. From 3.5m: yellow brown mottled grey. At approx. 4m: seam of fine to medium SAND, trace silt; grey; moist; non plastic.	LOESS (mQe)				B (approx. 2.0 m)	
4.1				END OF LOG @ 4.1 m						

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5
R L scale: 110.5, 110.0, 109.5, 109.0, 108.5, 108.0, 107.5, 107.0, 106.5

DATE EXCAVATED: 31/5/16
LOGGED BY: KRY
SHEAR VANE No: DR3969
CONTRACTOR: Alan Hemsworth
EQUIPMENT: 2t excavator
METHOD: Machine excavation/auger

COMMENTS:
Target Depth reached. No ground water encountered. Upper 2m excavated with bucket, machine auger from 2m to 4m.

FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS SEE KEY SHEET
Revision 0

A4 Scale 1:25

TP3

TP3

TEST PIT No: **TP4**

TEST PIT LOG

PROJECT:	Akaroa Wastewater Upgrade	JOB NUMBER:	6517986
SITE LOCATION:	Takamatua	CLIENT:	Christchurch City Council

CIRCUIT: NZTM
COORDINATES: N 5,151,302 m
E 1,598,078 m

TEST PIT LOCATION: Block H
R L: 169 m
DATUM: MSL

DEPTH (m)	USCS	MOISTURE	SOIL / ROCK DESCRIPTION	GEOLOGICAL UNIT
0.0–0.25	ML	M	Very soft, SILT, minor rootlets, minor fine to medium sand; dark brown; moist; non plastic. [TOPSOIL].	
0.25–2.0	ML	M	Stiff, SILT, minor fine sand, minor clay; yellowish brown mottled orange; moist; low plasticity.	LOESS (mQe)
0.8			From 0.8m: orange mottling absent.	
2.0–4.1	ML	M	SILT, some fine sand, minor clay; yellowish brown mottled orange; moist; low plasticity.	LOESS (mQe)
3.6			From 3.6m: Trace fine gravel. Gravel: black, angular, volcanics.	
4.1			END OF LOG @ 4.1 m	

Scala (Blows/100mm): 2, 1, 1, 2, 2, 2, 2, 2, 2, 4, 12, 12, 10, 20

SV	τ (kPa)
54/12	71/16
58/18	77/23
42/10	54/14
56/16	74/21

SAMPLES: B (approx. 1.2–1.3 m)

DEPTH (m)	R L (m)
0.5	168.5
1.0	168.0
1.5	167.5
2.0	167.0
2.5	166.5
3.0	166.0
3.5	165.5
4.0	165.0
4.5	164.5

DATE EXCAVATED:	30/5/16	CONTRACTOR:	Alan Hemsworth
LOGGED BY:	KRY	EQUIPMENT:	2t excavator
SHEAR VANE No:	DR3969	METHOD:	Machine excavation/auger

COMMENTS:
Target Depth reached. No ground water encountered. Upper 2m excavated with bucket, machine auger from 2m to 4m.

FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS SEE KEY SHEET

Revision 0

A4 Scale 1:25

TP4

TP4

CH2M Beca

TEST PIT No: TP6

TEST PIT LOG

PROJECT: Akaroa Wastewater Upgrade
JOB NUMBER: 6517986
SITE LOCATION: Takamatua
CLIENT: Christchurch City Council

CIRCUIT: NZTM
COORDINATES: N 5,151,955 m
E 1,597,445 m
TEST PIT LOCATION: Block D
R L: 33 m
DATUM: MSL

DEPTH (m)	WATER LEVEL	GRAPHIC LOG	USCS	MOISTURE	SOIL / ROCK DESCRIPTION	GEOLOGICAL UNIT	Scala	SV	τ (kPa)	SAMPLES	R L (m)
0.0–0.25			ML	M	Soft, SILT, minor rootlets, minor fine to medium sand; dark brown; moist; non plastic. [TOPSOIL].						
0.25–1.7			ML	M	Stiff, SILT, minor fine sand, trace clay; yellow brown mottled orange; moist; low plasticity.	LOESS (mQe)					
0.5								60/10	80/14		32.5
								55/10	72/14		
					From 0.7m: orange mottling absent. From 0.7m to 0.9m: Soft on south side of test pit, more moist.			80/20	109/25		
								42/8	54/11		
1.0					From 1m to 2m: vertical veining infilled with soft SILT, trace clay; grey; moist; low plasticity. Orange staining around veins. Vein apperture approximately 1-3cm.					B	32.0
1.5											31.5
1.7–4.0			ML	M	SILT, minor fine sand, minor clay; yellowish brown; moist; low plasticity.						
2.0											31.0
2.5											30.5
3.0											30.0
3.5											29.5
4.0					END OF LOG @ 4 m						29.0
4.5											28.5

DATE EXCAVATED: 30/5/16
CONTRACTOR: Alan Hemsworth
LOGGED BY: KRY
EQUIPMENT: 2t excavator
SHEAR VANE No: DR3969
METHOD: Machine excavation/auger

COMMENTS:
Target Depth reached. No ground water encountered. Upper 2m excavated with bucket, machine auger from 2m to 4m.

TP6

TP6

CH2M Beca

TEST PIT No: TPG

TEST PIT LOG

PROJECT: Akaroa Wastewater Upgrade
JOB NUMBER: 6517986
SITE LOCATION: Takamatua
CLIENT: Christchurch City Council

CIRCUIT: NZTM
COORDINATES: N 5,151,717 m
E 1,598,582 m
TEST PIT LOCATION: Block G
R L: 59 m
DATUM: MSL

DEPTH (m)	WATER LEVEL	GRAPHIC LOG	USCS	MOISTURE	SOIL / ROCK DESCRIPTION	GEOLOGICAL UNIT	Scala (Blows/100mm)	SV	τ (kPa)	SAMPLES	R L (m)
			ML	M	Very soft, SILT, minor rootlets, minor fine to medium sand; dark brown; moist; non plastic. [TOPSOIL].		2, 2				
			ML	M	Stiff, SILT, minor clay, trace fine sand; yellowish brown mottled orange; moist; low plasticity.	LOESS (mQe)	1, 3, 3, 6, 8, 12, 13	56/10, 50/10, 56/10, 46/8	74/14, 65/14, 74/14, 60/11		
0.5											58.5
1.0					From 1m to 1.6m: vertical veining infilled with soft SILT, trace clay; grey; moist; low plasticity. Orange staining around veins. Vein apperture approximately 1-3cm.		2, 7, 14, 9, 14			B	58.0
1.5							11, 7, 8, 10				57.5
			ML	M	SILT, minor fine sand, trace clay, trace fine gravel sized inclusions of grey and black clay; yellowish brown; moist; low plasticity.						
2.0											57.0
2.5											56.5
3.0											56.0
3.5											55.5
4.0											55.0
					END OF LOG @ 4.1 m						
4.5											54.5

DATE EXCAVATED: 31/5/16
LOGGED BY: KRY
SHEAR VANE No: DR3969
CONTRACTOR: Alan Hemsworth
EQUIPMENT: 2t excavator
METHOD: Machine excavation/auger

COMMENTS:
Target Depth reached. No ground water encountered. Upper 2m excavated with bucket, machine auger from 2m to 4m.

TPG

TPG

Appendix C

Laboratory Test Results

Geotest

Document Register & Transmittal Notice

Project: AK9009 Wastewater Treatment Plant consents 6517986/606/005

Disciplines: 320 - Geotechnical

Sheet: 1 **of** 1

We enclose the documents indicated below.

Please destroy or mark superseded all previous issues.

				Date of Issue
Drawings	Specs		Day	03
Sketches	Manuals		Month	06
Reports	Other		Year	16

Doc Nº	Document Title	Revision
1788L:02	Lab. Testing Report	

Distribution: Attention	Size/Media*	Copies
Katherine Yates	A4	

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A - Approval	P - Preliminary	T - Tender	R
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C - Construction	R - Requested		
I - Information	S - Shop Drawing		

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T: +64 9 300 9000, E: geotest@beca.com // www.beca.com

Geotest

21 Pitt Street
P O Box 6345
Auckland 1141
Ph. 300-9380

SUMMARY OF TEST RESULTS

Report: 1788L:02

Job Name: Akaroa Wastewater Treatment Plant Consents **Job No:** 6517986/606/005

Client: Christchurch City Council **Date:** 3 June 2016

Test Pit No.	Sample No.	Depth (m)	Sample Type	Sample Description	Natural		Atterberg Limits		Grading	Pσ t/m³	Clay Index	Consol	CBR	Compaction	Perm k m/s	Triaxial CUPP
					WC%	Bulk Density t/m³	LL/ CPL	PL								
TP01	P429	0.4	SD	Clayey SILT, some sand, minor gravel, trace organics; orange/brown, mottled orange, speckled grey; wet, highly plastic.	25.4											
TP01	P430	0.7	SD	Clayey SILT, minor sand, trace organics; yellowish brown; moist, highly plastic.	16.9											
TP01	P431	1.7	SD	Clayey SILT, minor sand; yellowish brown; moist, highly plastic.	19.9											
TP02	P432	0.65	SD	Clayey SILT, minor sand; greyish brown, mottled orange; moist, highly plastic.	21.9											
TP02	P433	1.6	SD	Clayey SILT, minor sand; yellowish brown, speckled light brown; moist, highly plastic.	17.0											
TP03	P434	0.6	SD	Clayey SILT, minor sand; orange brown, mottled light grey; moist, highly plastic.	24.6											
TP03	P435	2.0	SD	Clayey SILT, minor sand; yellowish brown; moist, highly plastic.	17.0											
TP04	P436	1.2	SD	Clayey SILT, minor sand; yellowish brown; moist, highly plastic.	13.2											
TP06	P437	1.0	SD	Clayey SILT, minor sand; orange brown, mottled light grey; wet, highly plastic.	24.7											
TPG	P438	1.0	SD	Clayey SILT, minor sand, trace organics; yellowish brown, mottled orange; moist, highly plastic.	24.0											

IANZ new zealand accredited laboratory

REPORT RELATES ONLY TO SAMPLES TESTED, SAMPLING WAS UNDERTAKEN BY OTHERS.

X = DATA ATTACHED, SD = SMALL DISTURBED SAMPLES

TEST STANDARDS:

NZS 4402: 1986; Test 2.1

AUTHORISED SIGNATORY

S.Shah – Authorised Signatory