NZ TRANSPORT AGENCY
WAKA KOTAHI

Roads of national significance

Ara Tūhono – Pūhoi to Wellsford

This document records technical and factual information used to support the NZTA's Assessment of Environmental Effects for the Pūhoi to Warkworth Project. It has been supplied to the Environmental Protection Authority by the NZTA in response to a section 149(2) Resource Management Act 1991 request. This document did not form part of the NZTA's application for the Project, which was lodged on 30 August 2013.

FURTHER NORTH

Pūhoi to Warkworth

Water Assessment Factual Report 2
Tests for Chemical Treatment

August 2013

Pūhoi to Warkworth

Document title:	**Water Assessment Factual Report 2** **Tests for Chemical Treatment**
Version:	Final
Date:	20 August 2013
Prepared by:	Stephen Leech and Danny Williams
Approved by:	Graeme Ridley 
	Tony Innes 
File name:	500-063 WAFR 02 Tests for Chemical Treatment_Final_20 August 2013

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Puhoi – Warkworth Motorway Development

Sediment Pond Chemical Bench Testing Report

May 2013

Prepared For: Graeme Ridley, Ridley Dunphy Environmental, Waitakere

Prepared By: Stephen Leech, Consulting Engineer, Auckland

Aims:

- Evaluate performance of coagulant chemicals on soil samples collected from Ara Tuhono – Puhoi to Wellsford Road of National Significance – Puhoi to Warkworth sector.
- Check settling rates for chemical combinations
- Determine performance of coagulants on three samples submitted

Summary:

This testing was done on three soil samples supplied by Ridley-Dunphy Environmental.

The soil samples were mixed with water to give a solids content of 20.0 kgs/m³ (20 gms/litre) for testing purposes.

The testing procedures are based on standard water treatment testing procedures incorporating the dosing of coagulants & polymers

The testing is compliant with the Auckland Regional Council's Technical Publication TP90 'Flocculation Guidelines' and also considers TP 227 Flocculation Guidelines.

- It was found that all three coagulants gave settling rates & clarities that would meet typical resource consent discharge requirements through settling ponds on all three samples.

- Poly Aluminium Chloride (PAC) gave results that are typical of Auckland soil types

- Fontis P-Dadmac gave very good results with very low dosages compared to PAC

- Fontis 7825 gave extremely good clarities at lower dosages than PAC or P-Dadmac

- Fontis 7825 had no impact on final water pH

- Fontis P-Dadmac had no impact on final water pH

- If further settling is required in ponds anionic polymers can be added to both improve discharge water quality and settling rates

Recommendations:

1. PAC be the initial product used on site, because it is used in TP 90.

2. Fontis P-Dadmac or Fontis 7825 be considered for this application as better performing alternatives (to PAC) as shown by this work

3. That anionic polymer addition be considered as an option to improve both settling & final pond discharge turbidity if required, especially if ponds are hydraulically overloaded or sediment loads are high or sediment is hard to settle

Chemical Screening Methodology & Results:

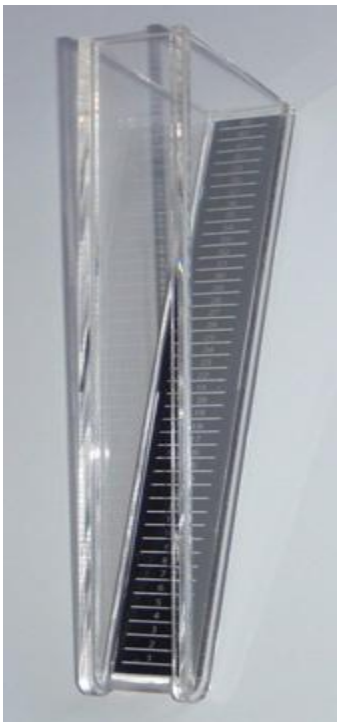
The flocculation testing was carried out on three representative soil samples to determine typical dose rates and the performance of the three coagulants evaluated.

The chemical dose required in order to achieve satisfactory suspended solids removal is dependent on both physical and chemical properties of the sample. A representative run-off water sample was established by mixing 200 gms of soil into 10 litres of water. One litre samples were then taken from this and settling tests conducted with the samples dosed with the varying amounts of coagulant and then mixed to imitate the mixing that would occur in a typical fore-bay associated with sediment retention ponds.

Each sample was then assessed for clarity with the use of a Clarity Wedge*. The clarity of the supernatant was measured at 5, 10, 20 and 60 minute intervals and recorded.

The coagulants used were made down to 1% solutions for ease of use.

The Clarity Wedge



ISO 10086 specifies a method for the comparative evaluation of the performance of flocculants for clarification, thickening and sedimentation on a given slurry. Their performance can be evaluated by settling velocity, sediment volume and the clarity of the supernatant liquid.

The CLARITY WEDGE as shown has a graduated scale on the rear surface which measures the clarity.

After the sample has settled, pour the supernatant into the CLARITY WEDGE and determine the clarity by observing the highest value visible through the liquid.

The higher the Clarity number, the cleaner the supernatant or the lower the suspended solids loading.

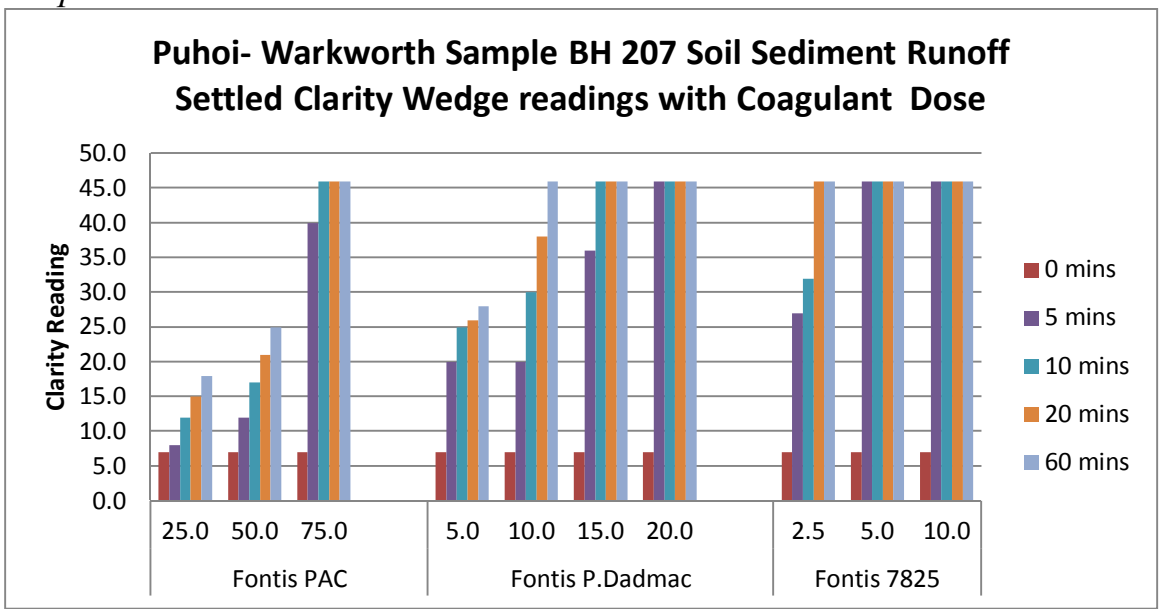
Results:

The results from the testing are shown in the following graphs and tables.

These results compare the Clarity Reading of the supernatant at 5, 10, 20 and 60 mins after coagulation began.

The higher the clarity reading, the cleaner the supernatant is.

Graph One



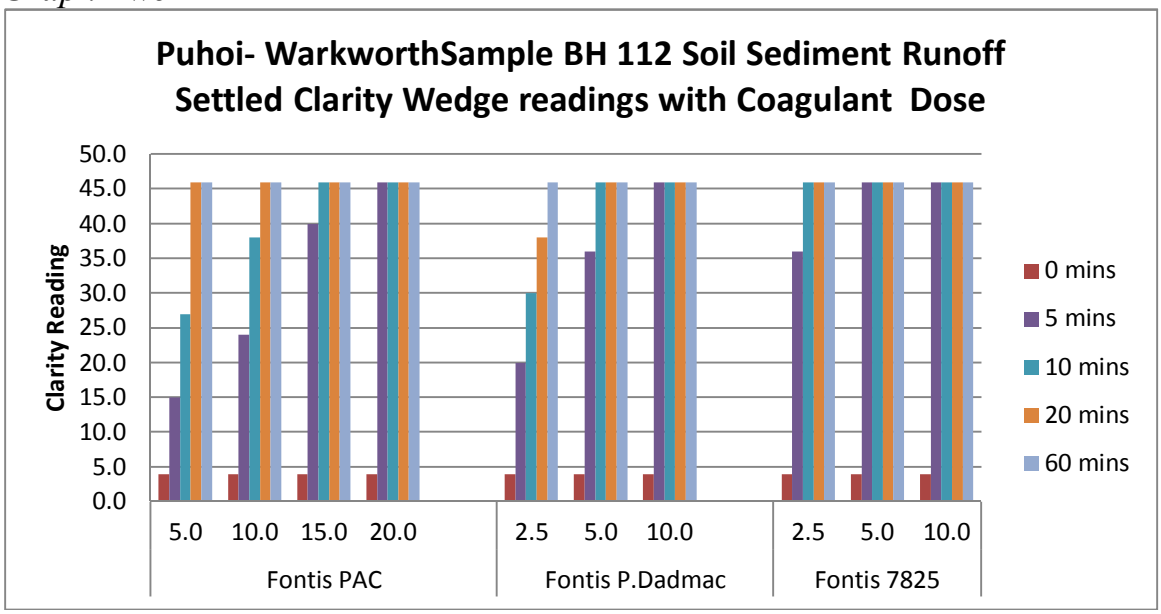
Graph One above shows the Clarity readings for the the soil sample BH 207, which is a top soil material. As can be seen all three products produce water with clarity of 46 with increasing dosages.

The best performing (based on lowest dosages) is the product Fontis 7825 which gave a supernatant clarity of 46 at 2.5 ppm after 20 minutes settling.

The Fontis P-Dadmac product was next best performing based on dosage.

The PAC dose response results were typical for Auckland soils.

Graph Two

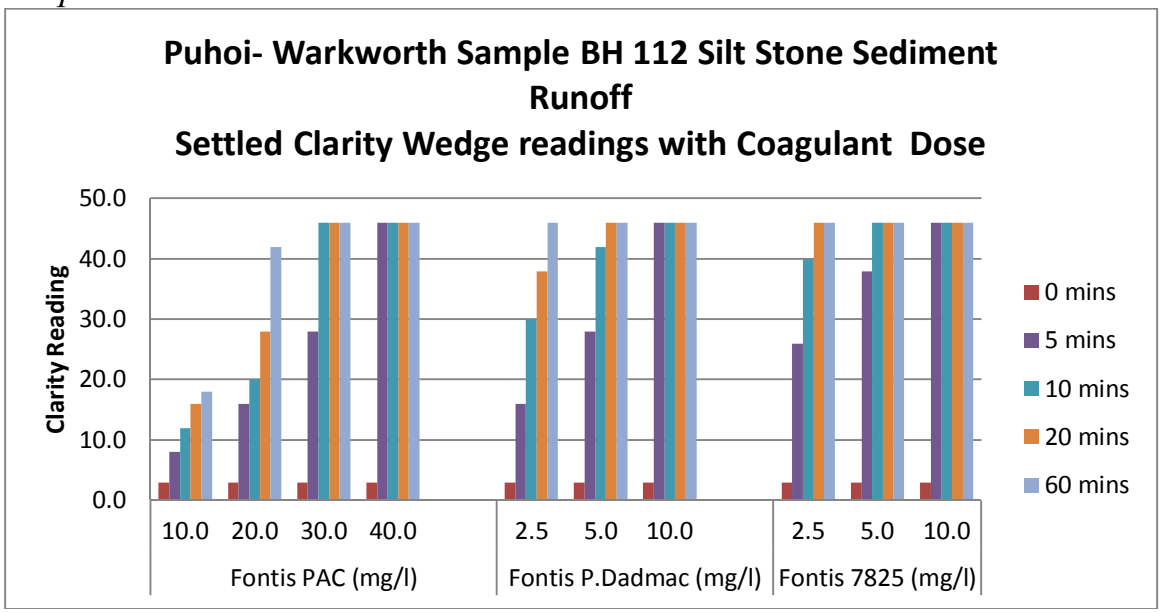


Graph Two, above shows a much lower dose range (5.00 to 20.0 ppm) for the PAC compared to the first sample and this is due to the sample being a sample from 6-7 meters below ground level, which would be typical of material being exposed in the process of opening up cuttings.

The comparison between the performance of the products is again around the dosages rather than performance of the supernatant produced, as all three products produced flocs and they all settled very well, with improvements in clarity with increasing dosage, as shown by the results.

All three products would provide settling rates and water clarity results that would allow water to be discharged from settling ponds.

Graph Three



Graph three, above, shows Clarity results from the sample of Siltstone after it was crushed and added to water. This would simulate material from drilling and blasting.

Again the results show that all three products will produce supernatant water of a quality suitable for sediment pond settling applications on the soil samples tested.

Discussion and Recommendations

PAC, P-dadmac & Fontis 7825 coagulants all gave good clarity results on the soil samples tested. These chemicals were able to treat the water to a much better standard than if the sample was just allowed to stand untreated.

The untreated samples had 60 minute settled clarities as shown in the table below and compared to treated samples.

Soil Sample	Description	60 mins Clarity	Best Treated
BH 207	Clays	7	>46
BH 112	6-7 m	4	>46
BH 112 Silt Stone	Silt Stone	3	>46

Chemical Comparison

Chemical	Dose rate	Clarity	Comment
	ppm **(as received)**		
PolyAlumimun Chloride	5.0-70.0	>46	Ok, slow settling
Fontis 7825	2.5-10.0	>46	Low dose, fast settling
Fontis p-dadmac	2.5 -15.0	>46	Low dose rate, good settling

At these levels of dosing the final water sample supernatant was at the levels shown, >46, which is very clean.

Fontis 7825 gave much quicker settling and better overall water quality than either PAC or P-Dadmac at a much reduced dose. The pH of the water sample tested ranged between 4.5 and 6.0. The pH reduced with increasing PAC dose but was unaffected by the other two chemicals tested.

Technical Support

Typically chemical suppliers will offer some degree of technical assistance to optimise operation and troubleshoot any problems encountered with the supply of their products.

I can also provide routine monitoring services to meet resource consent requirements.

If you have any questions regarding this report and/or the products mentioned, please do not hesitate to contact me to discuss.

Kind regards,

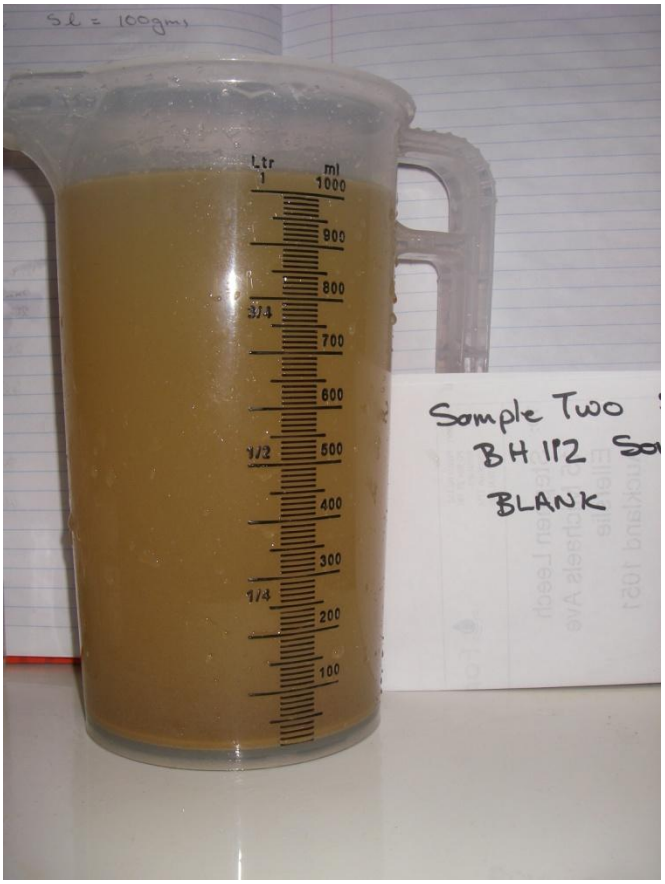
Stephen Leech, B.Eng
Water & Wastewater Specialist

Appendix.....Clarity Data

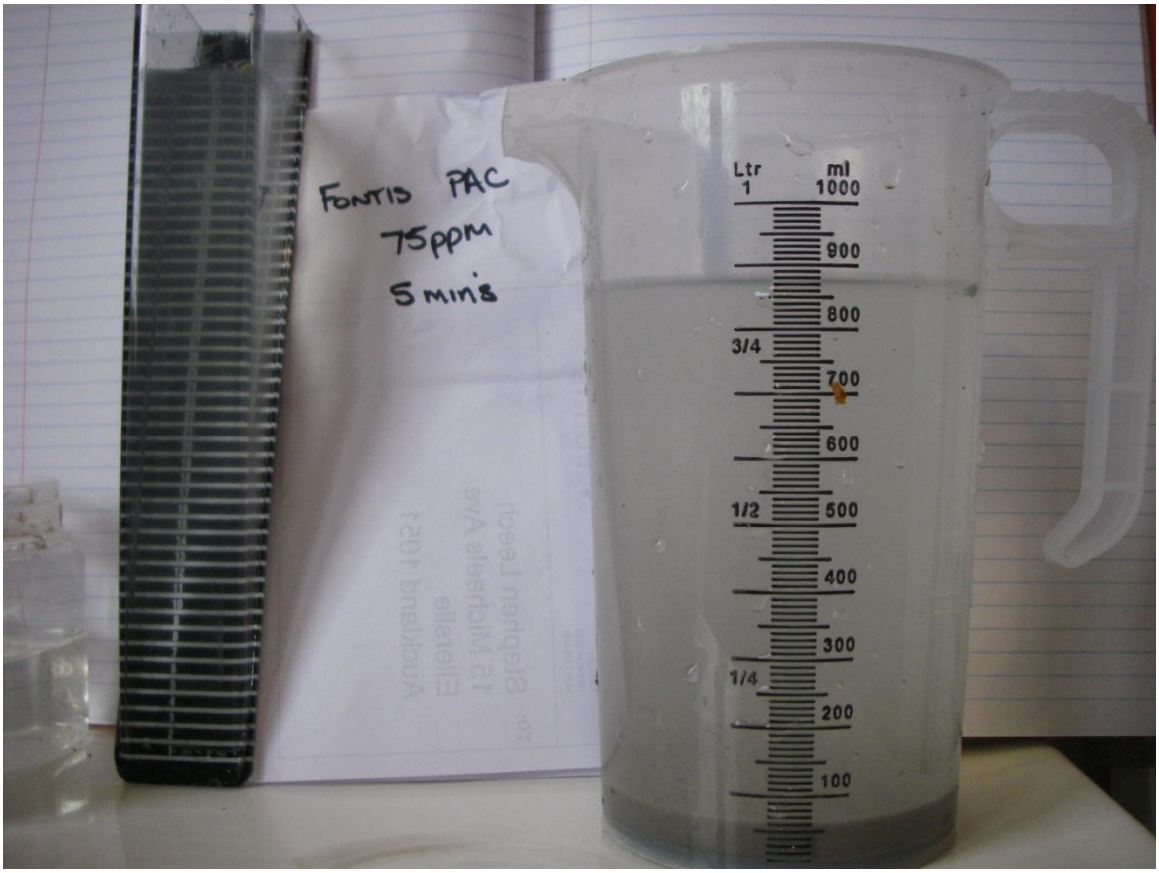
sample BH 207						
Chemical	Dose (ppm)	0 mins	5 mins	10 mins	20 mins	60 mins
	(as received)					
Fontis PAC	25.0	7.0	8	12	15	18
	50.0	7.0	12	17	21	25
	75.0	7.0	40	46	46	46
Fontis P.Dadmac	5.0	7.0	20	25	26	28
	10.0	7.0	20	30	38	46
	15.0	7.0	36	46	46	46
	20.0	7.0	46	46	46	46
Fontis 7825	2.5	7.0	27	32	46	46
	5.0	7.0	46	46	46	46
	10.0	7.0	46	46	46	46

Sample BH 112						
Chemical	Dose (ppm)	0 mins	5 mins	10 mins	20 mins	60 mins
	(as received)					
Fontis PAC	5.0	4.0	15	27	46	46
	10.0	4.0	24	38	46	46
	15.0	4.0	40	46	46	46
	20.0	4.0	46	46	46	46
Fontis P.Dadmac	2.5	4.0	20	30	38	46
	5.0	4.0	36	46	46	46
	10.0	4.0	46	46	46	46
Fontis 7825	2.5	4.0	36	46	46	46
	5.0	4.0	46	46	46	46
	10.0	4.0	46	46	46	46

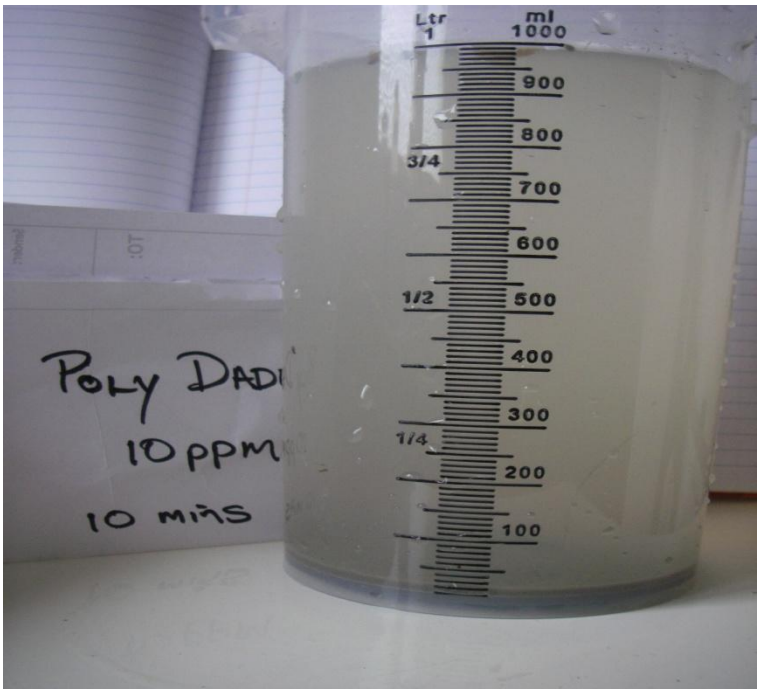
Sample BH112 Silt Stone						
Chemical	Dose (ppm)	0 mins	5 mins	10 mins	20 mins	60 mins
	(as received)					
Fontis PAC (mg/l)	10.0	3.0	8	12	16	18
	20.0	3.0	16	20	28	42
	30.0	3.0	28	46	46	46
	40.0	3.0	46	46	46	46
Fontis P.Dadmac (mg/l)	2.5	3.0	16	30	38	46
	5.0	3.0	28	42	46	46
	10.0	3.0	46	46	46	46
Fontis 7825 (mg/l)	2.5	3.0	26	40	46	46
	5.0	3.0	38	46	46	46
	10.0	3.0	46	46	46	46



Showing what the soil sample looks like when diluted down at 20 gms/litre suspended solids



Sample treated with 75 ppm of PAC & left for 5 minutes to settle, Clarity reading 40. Note Clarity Wedge is full of sample supernatant.



Sample treated with P-dadmac at 10 ppm & clarity reading 46

ORICA CHEMNET

AUCKLAND REGIONAL COUNCIL

SEDIMENT ANALYSIS FOR TRANSIT NZ

SEDIMENTATION TESTS INCLUDING CHEMICALLY ASSISTED SEDIMENTATION

Settling analysis on soil samples provided by Ridley Dunphy Environmental from the roading project "Northern Gateway extension from Puhoi"

(April 2013)

Prepared by: Danny Williams
Orica Chemicals – Water Chemicals

Introduction

Sediment control from earthworks sites has recently been highlighted as a potential source of environmental pollution and a risk to New Zealand native species and habitats in waterways.

Particle size, soil chemistry and rainfall intensity are the main factors influencing the settling rate of suspended particles in a rain event.

Bench testing of soil types likely to be encountered in an earthworks project and highlighting potential problematic soil types has been beneficial in alerting consent issuing authorities to aid in enforcing guidelines or regulations to minimise and for the most part eliminate sediment effects on ecosystems and waterways around or potentially affected by recent projects in New Zealand.

When required the use of chemicals to assist coagulation and/or flocculation, and subsequently reduce settled water turbidity exiting a sediment pond has shown to be very beneficial in reducing or eliminating effects on receiving waters.

The aim of the tests performed on the samples provided was to determine the settling rates of suspended solids mobilised by rainfall events, and if deemed necessary the optimum treatment chemical(s) and approximate dose rate(s) to effectively settle and compact the colloidal or very fine sediment in a retention pond.

Unassisted settling, coagulation and/or flocculation, settled water turbidity and pH was observed and recorded for each jar test and the results used to determine the optimum chemical and approximate dose rate (if any) for each type of soil/sediment provided.

Methodology

Unassisted settling tests

~1L volume of sample was suspended via agitation in ~20L of town supply tap water. The unassisted settling tests were performed first where samples were drawn from the surface of the settling sample, followed by further agitation of the sample prior to each chemically assisted test.

Each test sample was prepared in 20L plastic pails which were subsequently settled indoors and were not subjected to wind action or significant changes in temperature other than ambient.

Turbidity (NTU) measurement was used to determine the level of clay or colloidal contamination in the sample.

Chemically assisted settling tests

Each settling test was performed on 500mL samples of the suspension as used for the unassisted settling tests.
Each sample was dosed with chemical, then agitated in a “Boltac” coagulation simulator for 10 seconds at 150rpm (to imitate chemical addition prior to the sediment pond fore bay and subsequent mixing in the fore bay and overflow to the pond), followed by 2 minutes at 30rpm (to imitate slow agitation and minimal mixing in the sediment pond), followed by 10 minutes of settling before sampling from the surface of the treated sample.
In an actual sediment pond we would believe this type of test regime to be indicative of the worst case scenario and in working ponds there is likely to be considerably more settling time. However if there is the potential for significant wind action across the pond then this type of test regime will be more likely indicative of actual settling achieved in practice.

To allow distinct measureable doses to be added to the bench tests it is generally accepted that the concentrated chemicals be diluted before addition.
The dilution of chemicals used for the bench testing was based on the following detail as normally specified as water/waste water industry standards.
24 mL of LiquiPAC (Poly aluminium chloride 33.7% or 10.1% as Al_2O_3) as supplied was diluted with 1L of tap water to give 1% solution as PAC.
10 mL of Crystalfloc L3RC (PolyDADMAC 40%) as supplied was diluted with 1L of tap water to give 1% solution as L3RC supplied.
16 mL of Profloc A23 (Aluminium Chlorohydrate 50% or 23% as Al_2O_3) as supplied was diluted with 1L of tap water to give 1% solution as ACH.
16 mL of Alum (Aluminium Sulphate 47% or 8% as Al_2O_3) as supplied was diluted with 1L of tap water to give 1% solution as Alum.

Given the above dilutions the samples were tested on the basis that 1mL of the 1% solutions per litre of testing sample/suspension is equivalent to 10 parts per million or 1 mL of the 0.1% solution is equivalent to 1 part per million (ppm or g/m^3).

Summary

Two of the three samples provided had a very mobile clay/organic or very fine colloidal particles which remained in suspension long enough to potentially create settling issues in an earthworks/roading project (Samples BH112 soil and BH207 soil).
The third sample BH112 siltstone/rock had the potential to provide colloidal component such as BH207, however sample was essentially rock and even after crushing and suspension only a fraction of the total possible colloidal component could be liberated into suspension, and the subsequent testing showed the limited impact of the suspended solids on coagulant requirement.

The pH of the sample BH112 soil has the potential to be an issue as the untreated sample pH was 5.01.

Discussion

The use of town supply tap water (as used in this testing) will add a small amount of alkalinity to the test sample, which in general will tend to give slightly higher settled water pH than tests performed with rain water or actual results in practice.

Recommendations Summary

Given the potential issue with the low pH of sample BH112 soil from this project we recommend that ARC investigate the typical receiving waters and determine what risks (if any) are involved with the discharge of settled water with low pH and also the levels of dissolved metals or other contaminants potentially present at relative ambient low pH.

The optimal dose rate of coagulants LiquiPAC (Poly Aluminium Chloride) and Crystalfloc L3RC (PolyDADMAC) for all three samples had a relatively wide range and coagulation started at what could be typically described as very low range dose rates for colloidal clay type soils.

We would not normally recommend the use of an aluminium based coagulant (such as LiquiPAC or Poly Aluminium Chloride) for the type of sediment found in suspended solids for sample BH112 soil, however the dose rate required was very low and potentially minimises the effect on pH of the treated water. LiquiPAC also performed well on the other two samples at relatively low dose rates.
Crystalfloc L3RC (PolyDADMAC) performed well on all of the samples also at relatively low dose rates.

Recommendations Sample BH 112 Soil

This sample had a relatively high mobile colloidal component which remained in suspension long enough to be an issue in a standard sediment pond.
The sample did "self settle" without coagulant addition, however increased capacity of pond design may need to be implemented to allow provision for a system which does not allow for coagulant dosing.
LiquiPAC (Poly Aluminium Chloride) gave the lowest settled water turbidity at the lowest cost with minimal impact on treated water pH, however the Crystalfloc L3RC (polyDADMAC) results were close behind and possibly lower operational cost.

The sample required a relatively low dose rate of coagulant to create a floc which would easily settle in a sediment pond.

LiquiPAC (Poly Aluminium Chloride) had been used very effectively on the Northern Gateway project, and although the soil types through the extension project vary from typical Waitemata clays, the type of soil in the BH 112 sample was also treated effectively using LiquiPAC previously. LiquiPAC can be dosed either by displacement dosing or by shock dosing via broadcast dosing.

Crystalfloc L3RC (liquid polyDADMAC) can be dosed via a displacement dosing system but is not suitable for shock or broadcast dosing.
Crystalfloc B3H (powder polyDADMAC) can be dosed via a "floc sock" where sediment laden water is passed over the sock to dissolve product and the floc sock size/number is customised for the flow rates entering the sediment pond.

Given the relatively short time frame for settling of this soil type without coagulant dosing the use of a displacement dosing system in peak load times may be all that is required for this soil type, as long as a collect/settle and decant regime is managed appropriately.

Recommendations Sample BH 112 silt stone/rock

This sample had a relatively low mobile colloidal component in the tests which did remain in suspension long enough to be an issue in a sediment pond if the works in the area enabled the material to be crushed/worked to liberate a higher loading of suspended solids.
LiquiPAC (Poly Aluminium Chloride) gave the lowest settled water turbidity at the lowest cost for the sample.

The sample required a relatively low dose of coagulant to create a floc which would easily settle in a sediment pond.

LiquiPAC (Poly Aluminium Chloride) had been used very effectively on the Northern Gateway project, and although the soil types through the extension project vary from typical Waitemata clays, the type of soil in the BH 112 silt stone/rock sample was also treated effectively using LiquiPAC previously. LiquiPAC can be dosed either by displacement dosing or by shock dosing via broadcast dosing.

Crystalfloc L3RC (liquid polyDADMAC) can be dosed via a displacement dosing system but is not suitable for shock or broadcast dosing.
Crystalfloc B3H (powder polyDADMAC) can be dosed via a “floc sock” where sediment laden water is passed over the sock to dissolve product and the floc sock size/number is customised for the flow rates entering the sediment pond.

As this deposit is scoped to be worked on site we suggest some follow up work is carried out to confirm the possible/actual suspension of fine material across the area to be worked and what suspended solids may enter run off. The type of works may also contribute to the possible suspension of materials such as the requirement for simple excavation or requirement for blasting in pre determined areas.
There is potential for some parts of this deposit to require treatments as per required for BH 207 sample, whereas provision for LiquiPAC or Crystalfloc L3RC dosing may be required.

Recommendations Sample BH 207

This sample had a relatively high mobile colloidal component in the tests which remained in suspension for extended time frames and would almost certainly be an issue in a sediment pond.
LiquiPAC (Poly Aluminium Chloride) gave the lowest settled water turbidity at the lowest cost for the sample, however the Crystalfloc L3RC (polyDADMAC) results were close behind and possibly similar operational cost.

The sample required a relatively low dose of coagulant to create a floc which would easily settle in a sediment pond.

LiquiPAC (Poly Aluminium Chloride) had been used very effectively on the Northern Gateway project, and although the soil types through the extension project vary from typical Waitemata clays, the type of soil in the BH 207 soil sample was also treated effectively using LiquiPAC previously. LiquiPAC can be dosed either by displacement dosing or by shock dosing via broadcast dosing.

Crystalfloc L3RC (liquid polyDADMAC) can be dosed via a displacement dosing system but is not suitable for shock or broadcast dosing.
Crystalfloc B3H (powder polyDADMAC) can be dosed via a “floc sock” where sediment laden water is passed over the sock to dissolve product and the floc sock size/number is customised for the flow rates entering the sediment pond.

As this deposit is scoped to be worked on site we suggest some follow up work is carried out to confirm the possible/actual suspension of fine material across the area to be worked and what materials may enter run off.

Unassisted Settling Test Data

Time	Sample BH 112 soil	Sample BH 112 silt stone/rock	Sample BH 207
Start	>1000	>1000	>1000
1 hour	58.5	128.0	>1000
2 hours	24.5	75.8	>1000
5 hours		52.8	>1000
24 hours (1 day)		39.2	545.0
48 hours (2 days)			240.0
72 hours (3 days)			158.0
96 hours (4 days)			121.0
192 hours (8 days)			106.0

Discussion of Unassisted Settling Test Data for "Northern Gateway Extension" samples

The table above shows sample BH 207 had the highest risk in terms of settled water turbidity vs time and appeared to contain a very fine colloidal/organic component which gave the settled water a grey colouration even after an extended period of settling.
All of the samples were tested for optimal coagulation chemical(s) on the basis they may all be an issue in a sediment pond.

Chemically Assisted Settling Test Data
Northern Gateway Extension samples

Best of test results shown but other data available if required.
Note this fill colour denotes optimum dose rate/range

Sample BH 112 soil

PAC ppm	pH	Turbidity NTU @ T=10min
0	5.01	176.0
3	4.89	9.32
6	4.81	7.76
10	4.76	13.8
20	4.70	14.5
30	4.62	17.3
40	4.50	19.2

L3RC ppm	pH	Turbidity NTU @ T=10min
0	5.01	176.0
0.5	4.91	10.4
1	4.91	9.77
2	4.90	15.9
3	4.90	18.3
4	4.89	25.4

ACH ppm	pH	Turbidity NTU @ T=10min
0	5.01	176.0
5	4.85	15.5
10	4.80	17.0
15	4.78	18.7
20	4.75	19.2

Sample BH 112 silt stone/rock

PAC ppm	pH	Turbidity NTU @ T=10min
0	8.44	128.0
3	8.29	31.5
6	8.03	17.7
10	7.68	11.0
20	7.30	3.49
30	7.05	2.34
40	6.80	1.16

L3RC ppm	pH	Turbidity NTU @ T=10min
0	8.44	128.0
1	8.44	45.6
2	8.43	45.0
3	8.43	51.9
4	8.42	51.8

Sample BH 207 soil

PAC ppm	pH	Turbidity NTU @ T=10min
0	8.39	>1000
3	8.17	22.6
6	8.09	8.61
10	8.03	7.22
20	7.97	3.70
30	7.91	3.52
40	7.80	2.27

L3RC ppm	pH	Turbidity NTU @ T=10min
0	8.39	>1000
1	8.38	26.8
2	8.38	10.6
3	8.37	9.86
4	8.36	9.49

Indicative Chemical Costs

LiquiPAC (Poly Aluminium Chloride 33.7% liquid)

1000L pods $1550/pod, 200L drums $450 each.

Crystalfloc L3RC (PolyDADMAC liquid) single item

1000L pods $7.50/kg, 200L drums $8.50/kg, 20L jerrycan $9.50/kg

Crystalfloc B3H (PolyDADMAC powder) single item

25kg bags $16/kg

Crystalfloc B3H (PolyDADMAC powder) single item

1 to 3kg floc sock $35/kg

Borehole Sample Information

Log of Investigation

Project: **Puhoi to Warkworth Preliminary Site Investigation**	**Drillhole**
Location: **Redwoods Rd** Project No: **ZB01072**	Hole ID: **BH112**
Client: **NZTA**	Date: **7/02/2011**

R.L. (m)	Depth (m)	Drilling Method	Drilling Flush Return (%)	TCR (%)	RQD	Spacing of Natural Defects (mm)	In-Situ Testing	Sampling	Relative Strength	Weathering Grade	Geology Legend	GroundWater	Description of Strata	Geological Unit
168.0	0.0												Silty CLAY; orange brown. Soft, moist, high plasticity.	
167.5	0.5	HQ3		21									No Sample Recovery.	
167.0	1.0													
166.5	1.5	SPT		100			SPT_s=1,1,2 N=3						Silty CLAY; orange brown. Soft, moist, high plasticity. 1.76m: A moderately thin (60mm) bed of silty fine SAND with trace clay; orange brown. Loose, moist.	
166.0	2.0													
165.5	2.5	HQ3		22										
165.0	3.0	SPT		0			SPT_s=1,0,0 N<1						No Sample Recovery.	
164.5	3.5												3.45m: A moderately thin (300mm) bed of silty fine SAND with trace clay; orange brown mottled light brownish white. Very loose, moist. Clay is low plasticity. Silty CLAY; orange brown. Soft, moist, high plasticity. 3.71m: Becomes firm.	
164.0	4.0	HQ3		47										

Started: 7/02/2011
Finished: 10/02/2011
Driller: DCN Drilling
Plant: Morooka MST800
Logged: ME
Checked: RGK

Depth Related Remarks

From	Remarks

Groundwater Observations

No.	Struck (m)	Date	Observations	Standing (m)
1.	6.2m	9/02/2011		6.2m

Remarks
Borehole positions were surveyed on 16/02/2011 by Harrison Grierson.

Co-ordinates:
NZTM2000
5965011.2mN
1746741.9mE
Elevation: 168.00mRL
Auckland 1946
Inclination: -90°

Log of Investigation

Project: **Puhoi to Warkworth Preliminary Site Investigation**	**Drillhole**
Location: **Redwoods Rd** Project No: **ZB01072**	Hole ID: **BH112**
Client: **NZTA**	Date: **7/02/2011**

R.L. (m)	Depth (m)	Drilling Method	Drilling Flush Return (%)	TCR (%)	RQD	Spacing of Natural Defects (mm)	In-Situ Testing	Sampling	Relative Strength	Weathering Grade	Geology Legend	Groundwater	Description of Strata	Geological Unit
163.5	4.5	SPT		100			SPT_c=5,8,34 N=42						4.39m: Becomes mottled reddish brown. 4.56m: A very thin (10mm) bed of dark orange brown limonite. 4.57m: Becomes stiff. Sandy SILT with minor clay; orange brown. Loose, moist, fine sand; low plasticity clay. 4.75m: A moderately thin (100mm) bed of CLAY; grey, stiff, moist, low plasticity.	
163.0	5.0												Slightly weathered, grey, fine grained SANDSTONE; massive, weak. 5.06m: *BF (10°), T, [I] C.* 5.13 - 5.18m: *JT (90°), Vn, [II] C.* 5.17 - 5.19m: *JT (20°), N, [VII] C.*	
162.5	5.5	HQ3		88	60			C1					5.29 - 5.31m: *FZ. Crushed SANDSTONE and SILTSTONE.* 5.38m: *BF (5°), T, [VII] C.* 5.57 - 5.62m: *JT (85°), T, [IV] C.* 5.76m: *BF (5°), T, [I] C.* 5.8 - 6m: *JT (88°), T, [V] C.*	
162.0	6.0	SPT		0	0		SPT_c=25 N=25/20Hammer bouncing					1	6.1m: A thin (50mm) bed of subhorizontal, thinly laminated to very thinly bedded SILTSTONE. 6.13m: Bedding becomes undulating and irregular. 6.28m: *BF (5°), Vn, [V] C.* 6.3m: Becomes subhorizontal, very closely spaced, thinly laminated SILTSTONE. 6.41m: *BF (5°), Vn, [V] C.* 6.53m: A moderately thin (150mm) bed of SILTSTONE; weak.	
161.5	6.5	HQ3		99	80								6.67m: *BF (0°), Vn, [IV] C.* 6.84m: *JT (10°), Vn, [IV] C.* 6.87 - 6.88m: *JT (5°), Vn, [II] C.* 6.96m: *BF (0°), N, [VII] C.* 6.99 - 7.01m: *JT (20°), N, [I] C.* 7 - 7.1m: *JT (85°), T, [I] C.* 7.04m: *BF (5°), T, [VIII] C.*	
161.0	7.0												7.3 - 7.38m: *JT (90°), T, [VIII] C.*	
160.5	7.5	SPT		0	0		SPT_c=25 N=25/25Hammer bouncing						7.5m: With subhorizontal, extremely closely spaced, thinly laminated bedding. 7.59m: *BF (5°), N, [VIII] C.* 7.6 - 7.69m: *JT (80°), T, [IV] C of greenish grey discolouration around the joint.* 7.7 - 7.74m: *JT (80°), T, [IV] C.* 7.72m: A moderately thin (70mm) bed of laminated, SILTSTONE; massive, weak. 7.74m: *BF (5°), T, [VII] C.*	
160.0	8.0													

Started: 7/02/2011
Finished: 10/02/2011
Driller: DCN Drilling
Plant: Morooka MST800
Logged: ME
Checked: RGK

Depth Related Remarks

From	Remarks

Groundwater Observations

No.	Struck (m)	Date	Observations	Standing (m)
1.	6.2m	9/02/2011		6.2m

Remarks
Borehole positions were surveyed on 16/02/2011 by Harrison Grierson.

Co-ordinates:
NZTM2000
5965011.2mN
1746741.9mE
Elevation: 168.00mRL
Auckland 1946
Inclination: -90°

Log of Investigation

Project: **Puhoi to Warkworth Preliminary Site Investigation**	**Drillhole**
Location: **Redwoods Rd** Project No: **ZB01072**	Hole ID: **BH112**
Client: **NZTA**	Date: **7/02/2011**

R.L. (m)	Depth (m)	Drilling Method	Drilling Flush Return (%)	TCR (%)	RQD	Spacing of Natural Defects (mm)	In-Situ Testing	Sampling	Relative Strength	Weathering Grade	Geology Legend	GroundWater	Description of Strata	Geological Unit
			25 50 75	25 50 75		500 100 50 10 0			EW VW W MS S VS	UW SW MW HW CW RW				
		HQ3		97	13								7.78m: *BF (5°), N, [VIII] Si of low plasticity clay.* 7.79 - 8.2m: *JT (90°), T, [IV] Mc of limonite on joint.* 7.8 - 7.93m: *JT (85°), T, [VII] Mc of limonite on joint.* 8.19 - 8.2m: *JT (15°), T, [IV] C.* 8.2m: A thin (10mm) bed of subhorizontal to gently inclined, thinly laminated carbonaceous material. 8.25m: A thick (850mm) bed of subhorizontal, thinly laminated to very thinly bedded SILTSTONE; weak. 8.28m: *BF (10°), Mn, [VIII] C.* 8.4 - 8.41m: *JT (5°), Vn, [I] C.* 8.45m: *BF (5°), T, [IV] C.* 8.54m: *BF (5°), Vn, [VIII] C.* 8.71m: Bedding becomes irregular with clasts.	
159.5	8.5													
159.0	9.0												9.08 - 9.21m: *JT (85°), T, [IV] Mc of limonite on joint.* 9.23m: *BF (5°), Vn, [VIII] Si of low plasticity clay.* 9.37 - 9.44m: *JT (60°), Vn, [I] C.*	
158.5	9.5												9.5m: *BF (0°), T, [VIII] C.*	
		HQ3		100	53								9.73 - 9.85m: *VN (90°), T, [VII] Mc of 1-2mm calcite vein.* 9.86m: Irregular SILTSTONE bedding.	
158.0	10.0							C2					10.11 - 10.24m: *JT (90°), Vn, [IV] C.* 10.24m: *BF (5°), Vn, [I] C.* 10.31 - 10.46m: *JT (75°), Vn, [I] C.* 10.37m: *BF (5°), Vn, [V] C.*	
157.5	10.5												10.57m: Bedding becomes gently inclined and undulating. 10.71 - 10.84m: With fine to coarse gravel SILTSTONE clasts.	
157.0	11.0												10.91 - 10.92m: *BF (10°), N, [I] C.* 10.95m: Becomes gently inclined, extremely to very closely spaced, thinly laminated bedding. 11.12m: *BF (10°), Vn, [VIII] C.*	
		HQ3		99	100								11.44 - 11.45m: *VN (10°), T, [VII] Mc of 1mm calcite vein.* 11.46m: *BF (5°), Vn, [VIII] C.* 11.61m: Bedding becomes gently inclined and undulating. 11.7m: A thin (10mm) bed of subhorizontal, undulating SILTSTONE. 11.82m: *BF (5°), Vn, [II] C.*	
156.5	11.5													
156.0	12.0													

Started: 7/02/2011
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Log of Investigation

Project: **Puhoi to Warkworth Preliminary Site Investigation**	**Drillhole**
Location: **Redwoods Rd** Project No: **ZB01072**	Hole ID: **BH112**
Client: **NZTA**	Date: **7/02/2011**

R.L. (m)	Depth (m)	Drilling Method	Drilling Flush Return (%)	TCR (%)	RQD	Spacing of Natural Defects (mm)	In-Situ Testing	Sampling	Relative Strength	Weathering Grade	Geology Legend	GroundWater	Description of Strata	Geological Unit
155.5	12.5	HQ3		100	93								12.04m: Bedding becomes irregular. 12.09 - 12.16m: *JT (85°), T, [I] C.* 12.49m: *BF (15°), Vn, [V] C.* 12.65 - 12.81m: *VN (80°), T, [I] Mc of 1mm calcite lens.* 12.81m: *BF (10°), Vn, [IV] C.*	
155.0	13.0													
154.5	13.5												13.5 - 13.6m: *JT (75°), T, [I] C.* 13.83m: A thin (10mm) bed of subhorizontal to gently inclined, thinly laminated carbonaceous material.	
154.0	14.0	HQ3		95	53								14.07m: *BF (5°), Vn, [VIII] Si of low plasticity clay.* 14.2 - 14.34m: *JT (80°), T, [VII] C.* 14.22m: With subhorizontal to gently inclined, extremely closely spaced, thinly laminated bedding.	
153.5	14.5												14.51 - 14.71m: *JT (80°), T, [II] Mc of calcite vein.* 14.61m: *BF (5°), Vn, [VIII] C of fractured along carbonaceous bed.*	
153.0	15.0							C3					15.11m: Becomes brownish grey, medium grained SANDSTONE. 15.19m: *BF (5°), Vn, [V] C.*	
152.5	15.5	HQ3		100	100								15.41m: *BF (10°), Vn, [VIII] Mc of calcite lens.* 15.65m: *BF (10°), Vn, [VII] Mc of calcite lens.* 15.82m: *BF (0°), Vn, [VIII] C.*	
152.0	16.0													

Started: 7/02/2011
Finished: 10/02/2011
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Checked: RGK

Depth Related Remarks

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Groundwater Observations

No.	Struck (m)	Date	Observations	Standing (m)
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Log of Investigation

Project: **Puhoi to Warkworth Preliminary Site Investigation**	**Drillhole**
Location: **Redwoods Rd** Project No: **ZB01072**	Hole ID: **BH112**
Client: **NZTA**	Date: **7/02/2011**

R.L. (m)	Depth (m)	Drilling Method	Drilling Flush Return (%)	TCR (%)	RQD	Spacing of Natural Defects (mm)	In-Situ Testing	Sampling	Relative Strength	Weathering Grade	Geology Legend	GroundWater	Description of Strata	Geological Unit
151.5	16.5												16.17m: *BF (5°), Vn, [V] Si of low plasticity clay.*	
													16.64m: *BF (10°), Vn, [IV] C.*	
													16.79m: A thin (50mm) bed of SILTSTONE, with a gently inclined, very thin, coarse grained SANDSTONE layer. 16.91m: *BF (5°), Vn, [V] C.*	
151.0	17.0													
		HQ3		**100**	93								17.12m: *BF (5°), Vn, [I] C.*	
													17.37m: *BF (5°), Vn, [VIII] C.*	
150.5	17.5												17.51 - 17.57m: *JT (90°), T, [IV] C.* 17.55 - 17.57m: *JT (25°), T, [I] C.* 17.58 - 17.72m: *VN (85°), T, [IV] Mc of 1mm calcite vein.*	
													17.75m: A gently inclined, laminated coarse grained SANDSTONE bed.	
													17.85m: Bedding becomes irregular with fine grained SANDSTONE clasts.	
150.0	18.0													
													18.31m: A thin (50mm) bed of gently inclined, SILTSTONE.	
149.5	18.5												18.48m: A moderately thin (100mm) bed of subhorizontal, thinly laminated to thinly bedded SILTSTONE. 18.55m: A thin (50mm) layer of irregular bedding and clasts of SILTSTONE. 18.59m: *BF (5°), Vn, [VII] C.* 18.6 - 47.69m: Alternating moderately thin to thick (100 to 1000mm) beds of fine grained grading to coarse grained SANDSTONE. 18.7 - 18.97m: *VN (80°), T, [VII] Mc of 1mm calcite vein.* 18.71m: *BF (5°), Vn, [VIII] C.*	
		HQ3		**100**	100									
149.0	19.0												19.18m: *BF (5°), T, [VIII] C.* 19.22m: With rare SILTSTONE clasts. 19.27m: *BF (5°), Vn, [IV] C.*	
													19.42m: A very thin (10mm) bed of light grey SILTSTONE. 19.45m: A thin (40mm) bed of subhorizontal, laminated to very thinly bedded SILTSTONE. 19.59m: A thin (20mm) layer of irregular bedding.	
148.5	19.5												19.69m: A thin (40mm) bed of steeply inclined, laminated to very thinly bedded SILTSTONE. 19.73m: A thin (30mm) bed of irregular, thinly laminated carbonaceous material. 19.79m: *BF (10°), N, [I] C.*	
148.0	20.0													

Started: 7/02/2011
Finished: 10/02/2011
Driller: DCN Drilling
Plant: Morooka MST800
Logged: ME
Checked: RGK

Depth Related Remarks

From	Remarks

Groundwater Observations

No.	Struck (m)	Date	Observations	Standing (m)
1.	6.2m	9/02/2011		6.2m

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Client: **NZTA**	Date: **7/02/2011**

R.L. (m)	Depth (m)	Drilling Method	Drilling Flush Return (%)	TCR (%)	RQD	Spacing of Natural Defects (mm)	In-Situ Testing	Sampling	Relative Strength	Weathering Grade	Geology Legend	GroundWater	Description of Strata	Geological Unit
			25 50 75	25 50 75		500 100 50 10 0			EW VW W MS S VS	UW SW MW HW CW RW				
		HQ3		**100**	86								19.87m: *BF (20°), Vn, [IV] C.* 19.89m: A thin (20mm) bed of subhorizontal to gently inclined, thinly laminated carbonaceous material. 19.98m: *BF (5°), Vn, [II] C.* 20.07 - 20.3m: *VN (80°), T, [VII] Mc of calcite vein.* 20.13m: *BF (0°), Vn, [VII] C.* 20.2m: A thin (30mm) layer of undulated bedding.	
147.5	20.5							C4					20.25m: A moderately thin (100mm) bed of subhorizontal, closely to moderately widely spaced, laminated to very thinly bedded SILTSTONE. 20.33m: *BF (5°), Vn, [VIII] Si of low plasticity clay.* 20.55m: *BF (10°), Vn, [II] C.* 20.56m: A thin (20mm) bed of subhorizontal to gently inclined, thinly laminated carbonaceous material. 20.66m: *BF (5°), Vn, [VIII] C.* 20.69 - 20.84m: *JT (75°), Vn, [I] C.*	
147.0	21.0												21.02m: With fine to coarse gravel sized SILTSTONE clasts.	
		HQ3		**95**	100								21.34m: *BF (10°), Vn, [VIII] C.* 21.46m: *BF (0°), Vn, [IV] C.* 21.54m: *BF (5°), Vn, [VIII] C.* 21.67m: A thin (50mm) layer of undulated bedding. 21.77m: *BF (5°), Vn, [IV] C.* 21.86 - 21.92m: *JT (90°), T, [I] C.*	
146.5	21.5													
146.0	22.0												22.01m: *BF (5°), Vn, [I] C.* 22.02 - 22.19m: *JT (90°), T, [IV] C.*	
145.5	22.5													
145.0	23.0												22.91m: A very thin (10mm) bed of subhorizontal, undulating, laminated, pinkish grey, medium grained SANDSTONE. 22.97m: A moderately thin (100mm) layer of irregular bedding with minor SILTSTONE clasts. 23.04m: *BF (5°), Vn, [V] C.* 23.06m: Becomes fine grained SANDSTONE with subhorizontal, thinly laminated to very thin bedding. 23.24m: *BF (5°), N, [I] C.* 23.31 - 23.39m: *JT (85°), T, [IV] C.* 23.39m: *BF (5°), Vn, [V] C.*	
		HQ3		**97**	100									
144.5	23.5												23.66m: *BF (0°), Vn, [VIII] Si of low plasticity clay.*	
144.0	24.0												23.84m: *BF (5°), N, [I] C.*	

Started: 7/02/2011
Finished: 10/02/2011
Driller: DCN Drilling
Plant: Morooka MST800
Logged: ME
Checked: RGK

Depth Related Remarks

From	Remarks

Groundwater Observations

No.	Struck (m)	Date	Observations	Standing (m)
1.	6.2m	9/02/2011		6.2m

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Log of Investigation

Project: **Puhoi to Warkworth Preliminary Site Investigation**	**Drillhole**
Location: **Redwoods Rd** Project No: **ZB01072**	Hole ID: **BH112**
Client: **NZTA**	Date: **7/02/2011**

R.L. (m)	Depth (m)	Drilling Method	Drilling Flush Return (%)	TCR (%)	RQD	Spacing of Natural Defects (mm)	In-Situ Testing	Sampling	Relative Strength	Weathering Grade	Geology Legend	GroundWater	Description of Strata	Geological Unit
143.5	24.5	HQ3		100	100								24.29m: *BF (5°), Vn, [V] C.* 24.32 - 24.4m: *VN (90°), T, [I] Mc of calcite vein.* 24.39m: A thin (50mm) bed of moderately thin to moderately thickly, irregular bedding with SILTSTONE clasts. 24.7m: *BF (5°), Vn, [VIII] C.* 24.83m: *BF (5°), Vn, [V] C.*	
143.0	25.0							C5					25.04m: *BF (5°), N, [VIII] C.* 25.19m: *BF (10°), Vn, [V] C.*	
142.5	25.5	HQ3		100	53								25.4 - 25.67m: *JT (80°), T, [VII] Mc of limonite on joint.* 25.41 - 25.5m: *JT (85°), T, [VII] Mc of limonite on joint.* 25.73 - 25.83m: *JT (80°), T, [VIII] Mc of limonite on joint.* 25.82 - 25.83m: *JT (10°), Vn, [I] C.*	
142.0	26.0													
141.5	26.5												26.34m: A moderately thick (200mm) bed of fine grained SANDSTONE, with subhorizontal, thinly laminated to very thinly bedded SANDSTONE grading to coarse grained. 26.56m: A moderately thin (100mm), bed of SILTSTONE with irregular bedding. 26.57 - 26.6m: *FR (45°), Vn, [IV] C.* 26.86 - 26.95m: *JT (65°), T, [VII] Mc of limonite on joint.* 26.95m: A thin (50mm) bed of SILTSTONE, with irregular bedding and fine to medium gravel size SANDSTONE clasts.	
141.0	27.0												27.17 - 27.32m: *JT (75°), Vn, [VIII] Mc of limonite on joint.*	
140.5	27.5	HQ3		96	46								27.64 - 27.67m: *JT (35°), Vn, [IV] C.* 27.79m: *BF (5°), Vn, [I] C.* 27.91 - 28.05m: *JT (90°), T, [I] Mc of limonite on joint.*	
140.0	28.0													

Started: 7/02/2011
Finished: 10/02/2011
Driller: DCN Drilling
Plant: Morooka MST800
Logged: ME
Checked: RGK

Depth Related Remarks

From	Remarks

Groundwater Observations

No.	Struck (m)	Date	Observations	Standing (m)
1.	6.2m	9/02/2011		6.2m

Remarks
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NZTM2000
5965011.2mN
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Log of Investigation

Project: **Puhoi to Warkworth Preliminary Site Investigation**	**Drillhole**
Location: **Redwoods Rd** Project No: **ZB01072**	Hole ID: **BH112**
Client: **NZTA**	Date: **7/02/2011**

R.L. (m)	Depth (m)	Drilling Method	Drilling Flush Return (%)	TCR (%)	RQD	Spacing of Natural Defects (mm)	In-Situ Testing	Sampling	Relative Strength	Weathering Grade	Geology Legend	GroundWater	Description of Strata	Geological Unit
139.5	28.5	HQ3		100	40								28.22 - 28.8m: *JT (90°), T, [IV] Mc of limonite on joint.* 28.56m: A moderately thin (100mm) bed of subhorizontal to gently inclined, thinly laminated carbonaceous material. 28.66m: Grades to fine grained SANDSTONE; massive. 28.8m: Becomes dark grey. 28.91 - 29.28m: *JT (80°), Vn, [V] C.* 29.21m: *BF (0°), Vn, [VII] C.* 29.35m: *BF (5°), Vn, [IV] C.* 29.4m: Grades to medium grained SANDSTONE, moderately strong. 29.45m: Becomes pale grey. 29.49m: A thin (30mm) bed of SILTSTONE with irregular bedding.29.49m: *BF (0°), Vn, [VIII] C.* 29.53m: *BF (5°), N, [I] C.*	
139.0	29.0													
138.5	29.5													
138.0	30.0	HQ3		100	100			C6						
137.5	30.5													
137.0	31.0													
136.5	31.5												31.69m: A thin (40mm) bed of subhorizontal, laminated to very thinly bedded SILTSTONE. 31.7m: With irregular bedding and SILTSTONE clasts. 31.73m: A thin (50mm) bed of fine grained SANDSTONE with subhorizontal, very closely spaced, laminated bedding grading to coarse	
136.0	32.0													

Started: 7/02/2011
Finished: 10/02/2011
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Depth Related Remarks

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			25 50 75	25 50 75		500 100 50 10 0			EW VW W MS S	UW SW HW CW RW				
		HQ3		**100**	100								grained SANDSTONE.31.73m: *BF (5°), Vn, [II] C.* 31.79m: A thin (30mm) bed of undulating, thinly laminated carbonaceous material. 31.81m: A 40mm SILTSTONE clast. 32.3m: *BF (5°), Vn, [IV] C.*	
135.5	32.5													
135.0	33.0													
134.5	33.5	HQ3		**93**	100								33.69m: With fine to coarse gravel size SILTSTONE clasts.	
134.0	34.0													
133.5	34.5													
133.0	35.0	HQ3		**96**	100								35.36m: *BF (5°), Vn, [V] C.*	
132.5	35.5							C7					35.56 - 37.5m: A very thick (2000mm) bed of moderately thin to moderately thickly bedded SILTSTONE with gently inclined, very thin SANDSTONE bedding. 35.58m: Bedding becomes irregular.	
132.0	36.0													

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Location: **Redwoods Rd** Project No: **ZB01072**	Hole ID: **BH112**
Client: **NZTA**	Date: **7/02/2011**

R.L. (m)	Depth (m)	Drilling Method	Drilling Flush Return (%)	TCR (%)	RQD	Spacing of Natural Defects (mm)	In-Situ Testing	Sampling	Relative Strength	Weathering Grade	Geology Legend	GroundWater	Description of Strata	Geological Unit
131.5	36.5	HQ3		**100**	100								36.11m: *BF (0°), Vn, [VIII] C.* 36.29m: A very thin (10mm) bed of subhorizontal to gently inclined, thinly laminated carbonaceous material. 36.46m: A thin (50mm) bed of irregularly bedded SILTSTONE and SANDSTONE clasts. 36.6m: *BF (10°), Vn, [V] C.* 36.62m: With subhorizontal, thinly laminated to moderately thin bedding.	
131.0	37.0												37m: *BF (5°), Vn, [VIII] C.*	
130.5	37.5	HQ3		**97**	100								37.82 - 37.91m: *VN (80°), T, [I] Mc of calcite vein.* 37.94m: A thin (40mm) bed of irregularly bedded SILTSTONE clasts. 38.11m: A moderately thin (60mm) bed of pale grey SILTSTONE. 38.12m: *BF (0°), Vn, [V] C.* 38.28 - 38.36m: *VN (80°), T, [IV] Mc of calcite vein.* 38.43m: *BF (5°), Vn, [VIII] C.* 38.62m: *VN (90°), T, [IV] Mc of calcite vein.* 38.75m: *BF (5°), Vn, [V] C.*	
130.0	38.0													
129.5	38.5													
129.0	39.0	HQ3		**100**	83								39.3m: A moderately thin (100mm) bed of SILTSTONE with thinly laminated to very thin beds. 39.35m: *VN (85°), T, [IV] Mc of calcite lens.* 39.41m: *BF (0°), Vn, [VIII] C.* 39.86m: A thin (30mm) bed of SILTSTONE.	
128.5	39.5													
128.0	40.0													

Started: 7/02/2011
Finished: 10/02/2011
Driller: DCN Drilling
Plant: Morooka MST800
Logged: ME
Checked: RGK

Depth Related Remarks

From	Remarks

Groundwater Observations

No.	Struck (m)	Date	Observations	Standing (m)
1.	6.2m	9/02/2011		6.2m

Remarks
Borehole positions were surveyed on 16/02/2011 by Harrison Grierson.

Co-ordinates:
NZTM2000
5965011.2mN
1746741.9mE
Elevation: 168.00mRL
Auckland 1946
Inclination: -90°

Log of Investigation

Project: **Puhoi to Warkworth Preliminary Site Investigation**	**Drillhole**
Location: **Redwoods Rd** Project No: **ZB01072**	Hole ID: **BH112**
Client: **NZTA**	Date: **7/02/2011**

R.L. (m)	Depth (m)	Drilling Method	Drilling Flush Return (%)	TCR (%)	RQD	Spacing of Natural Defects (mm)	In-Situ Testing	Sampling	Relative Strength	Weathering Grade	Geology Legend	GroundWater	Description of Strata	Geological Unit
			25 50 75	25 50 75		500 100 50 10 0			EW VW W MS S	UW SW MW HW CW RW				
127.5	40.5							C8					40.15m: A moderately thin (100mm) bed of SILTSTONE. 40.25 - 40.5m: *VN (85°), T, [IV] Mc of calcite vein.* 40.32 - 40.52m: *JT (80°), T, [IV] C.*	
127.0	41.0	HQ3		**93**	100								40.74m: Bedding becomes undulated and irregular. 41.34 - 41.58m: *F (80°), T, [VII] Mc of calcite lens.*	
126.5	41.5												41.57m: *BF (10°), Vn, [VIII] C.* 41.67m: *BF (5°), T, [I] C.* 41.8m: *BF (5°), Vn, [VIII] Mc of calcite lens.*	
126.0	42.0												42m: A moderately thin (150mm) bed of subhorizontal, undulating, laminated to very thin interbedded SILTSTONE. 42.08 - 42.38m: *JT (80°), T, [VIII] Mc of calcite lens.*	
125.5	42.5	HQ3		**100**	53								42.36 - 42.38m: *JT (30°), Vn, [I] C.* 42.46 - 42.66m: *JT (75°), T, [VIII] Mc of calcite vein.* 42.57m: *BF (10°), Vn, [VIII] Mc of calcite lens.* 42.74m: *BF (10°), N, [VIII] C.*	
125.0	43.0												43.17m: A thin (20mm) bed of gently inclined, laminated to very thinly bedded SILTSTONE.	
124.5	43.5												43.86m: A thin (50mm) bed of laminated, pinkish grey, medium grained SANDSTONE. 43.88m: *BF (5°), Vn, [V] C.*	
124.0	44.0													

Started: 7/02/2011
Finished: 10/02/2011
Driller: DCN Drilling
Plant: Morooka MST800
Logged: ME
Checked: RGK

Depth Related Remarks

From	Remarks

Groundwater Observations

No.	Struck (m)	Date	Observations	Standing (m)
1.	6.2m	9/02/2011		6.2m

Co-ordinates:
NZTM2000
5965011.2mN
1746741.9mE
Elevation: 168.00mRL
Auckland 1946
Inclination: -90°

Remarks
Borehole positions were surveyed on 16/02/2011 by Harrison Grierson.

Log of Investigation

Project: **Puhoi to Warkworth Preliminary Site Investigation**	**Drillhole**
Location: **Redwoods Rd** Project No: **ZB01072**	Hole ID: **BH112**
Client: **NZTA**	Date: **7/02/2011**

R.L. (m)	Depth (m)	Drilling Method	Drilling Flush Return (%)	TCR (%)	RQD	Spacing of Natural Defects (mm)	In-Situ Testing	Sampling	Relative Strength	Weathering Grade	Geology Legend	GroundWater	Description of Strata	Geological Unit
		HQ3		**95**	100								44.45m: *BF (10°), Vn, [V] C.* 44.52m: A thin (40mm) bed of SILTSTONE.	
123.5	44.5													
123.0	45.0													
													45.35m: *BF (5°), Vn, [IV] C.*	
122.5	45.5							C9						
		HQ3		**100**	100								45.75m: *BF (5°), Vn, [II] C.* 45.91m: *BF (10°), Vn, [VIII] C.*	
122.0	46.0													
121.5	46.5													
													46.84m: A very thin (10mm) bed of pale grey SILTSTONE. 46.99m: *BF (5°), Vn, [VIII] C.* 47.12m: A thin (50mm) layer of irregular SILTSTONE bedding with SANDSTONE clasts. 47.21m: *BF (0°), Vn, [VIII] C.*	
121.0	47.0													
		HQ3		**100**	100									
120.5	47.5												47.45m: *BF (5°), Vn, [I] C.* 47.69m: A moderately thin (70mm) irregular bed.	
120.0	48.0													

Started: 7/02/2011
Finished: 10/02/2011
Driller: DCN Drilling
Plant: Morooka MST800
Logged: ME
Checked: RGK

Depth Related Remarks

From	Remarks

Groundwater Observations

No.	Struck (m)	Date	Observations	Standing (m)
1.	6.2m	9/02/2011		6.2m

Remarks
Borehole positions were surveyed on 16/02/2011 by Harrison Grierson.

Co-ordinates:
NZTM2000
5965011.2mN
1746741.9mE
Elevation: 168.00mRL
Auckland 1946
Inclination: -90°

Log of Investigation

Project: **Puhoi to Warkworth Preliminary Site Investigation**	**Drillhole**
Location: **Redwoods Rd** Project No: **ZB01072**	Hole ID: **BH112**
Client: **NZTA**	Date: **7/02/2011**

R.L. (m)	Depth (m)	Drilling Method	Drilling Flush Return (%)	TCR (%)	RQD	Spacing of Natural Defects (mm)	In-Situ Testing	Sampling	Relative Strength	Weathering Grade	Geology Legend	GroundWater	Description of Strata	Geological Unit
			25 50 75	25 50 75		500 100 50 10 0			EW VW W MS S	UW SW MW HW CW RW				
119.5	48.5	HQ3		97	100								48.17m: A thin (50mm) bed of subhorizontal, laminated SILTSTONE. 48.34m: *BF (0°), Vn, [VIII] C.*	
119.0	49.0												48.78m: *BF (10°), Vn, [VIII] C.* 49.04m: *BF (5°), Vn, [VIII] C.* 49.05 - 49.29m: *VN (75°), Vn, [VII] Mc of calcite vein.*	
118.5	49.5	HQ3		100	100								49.36m: *BF (5°), Vn, [I] C.* 49.5 - 49.58m: *VN (85°), T, [IV] Mc of calcite vein.* 49.79 - 50m: *VN (80°), T, [VII] Mc of 3mm calcite vein.*	
118.0	50.0												BH112 terminated at 50.00m. Target Depth	

Started: 7/02/2011
Finished: 10/02/2011
Driller: DCN Drilling
Plant: Morooka MST800
Logged: ME
Checked: RGK

Depth Related Remarks

From	Remarks

Groundwater Observations

No.	Struck (m)	Date	Observations	Standing (m)
1.	6.2m	9/02/2011		6.2m

Remarks
Borehole positions were surveyed on 16/02/2011 by Harrison Grierson.

Co-ordinates:
NZTM2000
5965011.2mN
1746741.9mE
Elevation: 168.00mRL
Auckland 1946
Inclination: -90°

Borehole 112
EOH 50m (Redwoods Rd)
<BH112 Box No.1> 0.0 – 6.28m

<BH112 Box No.2> 6.28 – 9.23m

<BH112 Box No.3> 9.23 – 12.0m

<BH112 Box No.4> 12.0 – 14.62m

<BH112 Box No.5> 14.62 – 17.51m

<BH112 Box No.6> 17.51 – 20.36m

<BH112 Box No.7> 20.36 – 23.24m

<BH112 Box No.8> 23.24 – 26.05m

<BH112 Box No.9> 26.05 – 28.90m

<BH112 Box No.10> 28.90 – 31.73m

<BH112 Box No.11> 31.73 – 34.78m

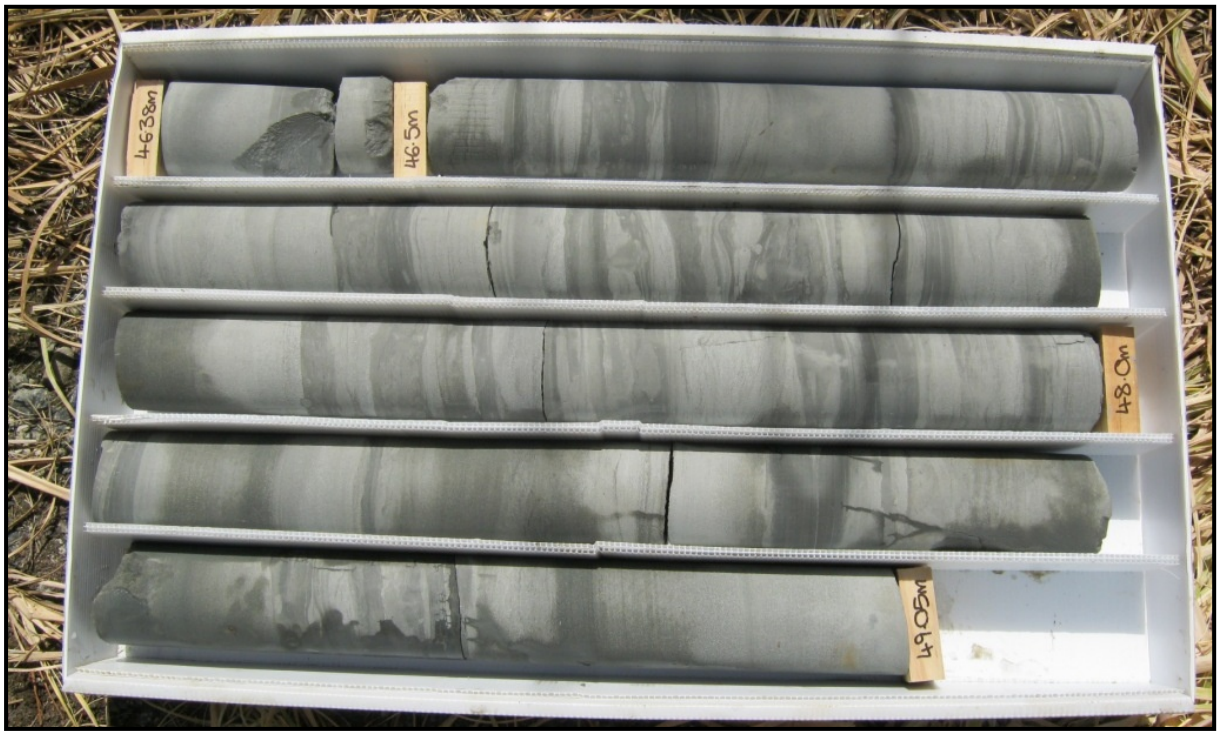
<BH112 Box No.12> 34.78 – 37.50m

<BH112 Box No.13> 37.50 – 40.50m

<BH112 Box No.14> 40.50 – 43.40m

<BH112 Box No.15> 43.40 – 46.38m

<BH112 Box No.16> 46.38 – 49.05m



<BH112 Box No.17> 49.05 – 50.0m

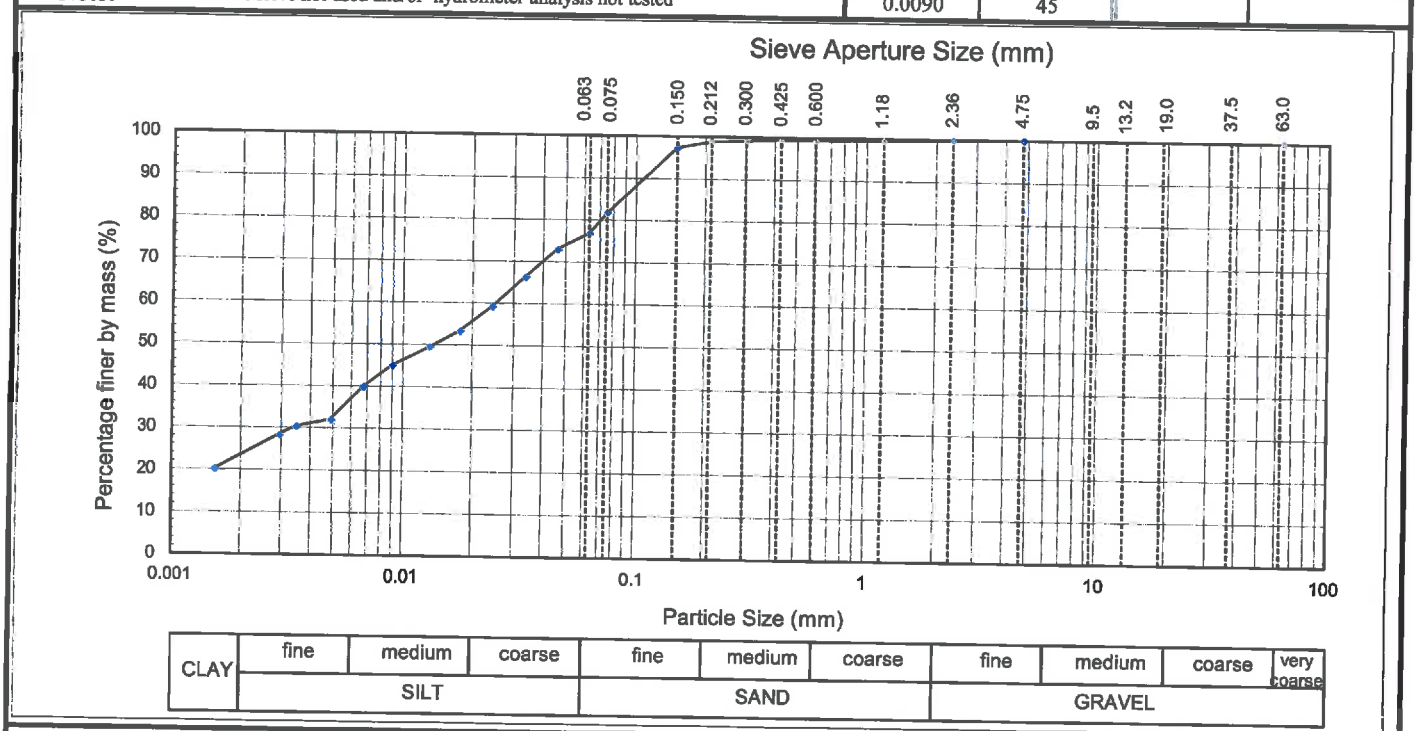
PARTICLE SIZE ANALYSIS (HYDROMETER METHOD) TEST REPORT

OPUS

Project :	**Puhoi to Warkworth Planning Alliance**
Location :	**SH1, Puhoi to Warkworth**
Client :	**Further North Alliance**
Feature:	-
Contractor :	-
BH/TP/Sample ID:	**BH112** Depth: **5.0-5.2 metres**
Sampled by :	**Client**
Date received :	**8/03/13**
Sampling method :	**Core**
Sample condition :	**As received**
Sample description :	**Clayey Sandy SILT**
Solid Particle Density (t/m^3):	**2.70** **Assumed**
Water Content (as received):	**20.1** **%**

Project No:	**2-68357.13**
Lab Ref No:	**13/357/001**
Client Ref:	**ZB01369.401**

Sieve Analysis						Hydrometer Analysis			
Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)
63.0	--	4.75	100	0.300	99	0.0460	73	0.0067	40
37.5	--	2.36	100	0.212	99	0.0335	66	0.0049	32
19.0	--	1.18	100	0.150	97	0.0243	59	0.0035	30
13.2	--	0.600	100	0.075	82	0.0176	53	0.0029	28
9.5	--	0.425	99	0.063	77	0.0130	49	0.0015	20
Note: "--" denotes sieve not used and/or hydrometer analysis not tested						0.0090	45		



Test Methods	Notes
Particle Size Analysis: NZS 4402:1986: Test 2.8.4 (Washed Grading & Hydrometer Method)	Fraction Passing finest sieve is included in Hydrometer test
Water Content: NZS 4402: 1986 Test 2.1	pH of suspension : 8.0 (Whatmans Full Range pH Indicator paper)

Date Tested: 14/03/13

Date Reported: 15/03/13

Testing is covered by IANZ Accreditation

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IANZ Approved Signatory

Designation : Senior Civil Engineering Technician

Date : 15/03/13

csf 2100 (8/02)

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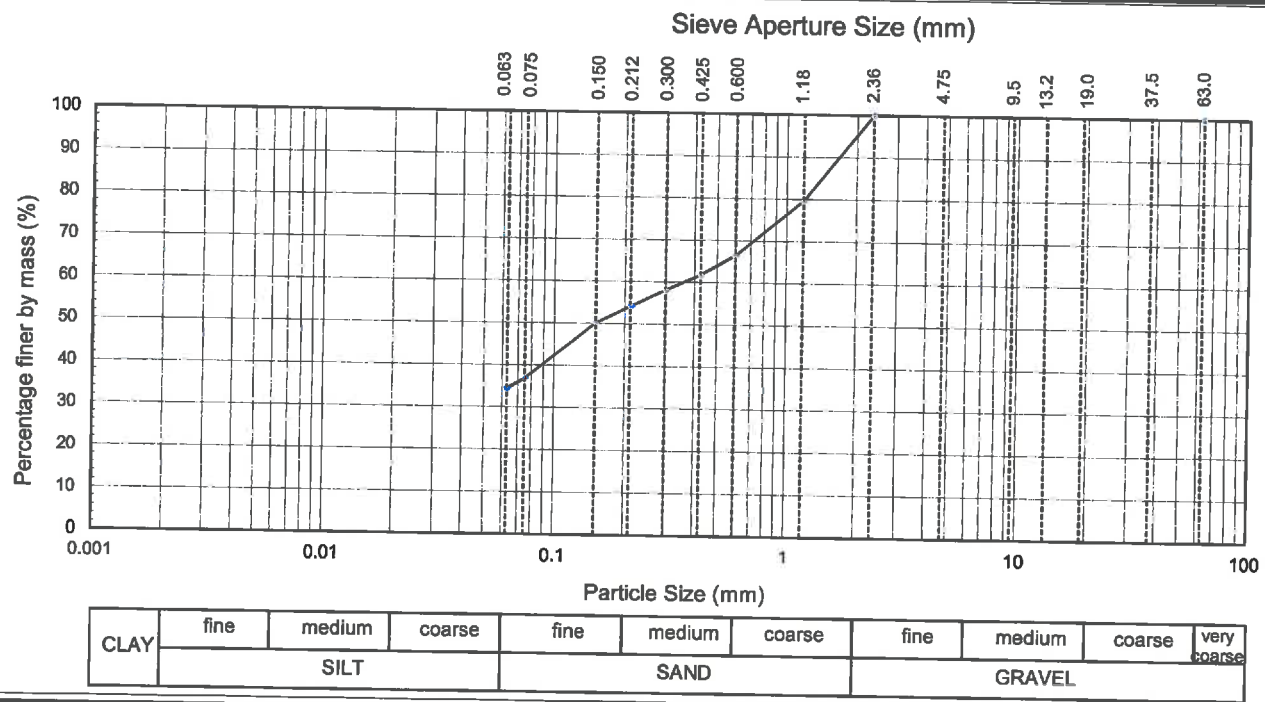
PARTICLE SIZE ANALYSIS (WET SIEVE METHOD) TEST REPORT

OPUS

Project :	**Puhoi to Warkworth Planning Alliance**
Location :	**SH1, Puhoi to Warkworth**
Client :	**Further North Alliance**
Feature:	-
Contractor :	-
BH/TP/Sample ID:	**BH112** Depth: **10.00 metres**
Sampled by :	**Client**
Date received :	**8/03/13**
Sampling method :	**Core**
Sample condition :	**Sample crushed through -2.36mm sieve.**
Sample description :	**Clayey/Silty Sand with minor Gravel**
Solid Particle Density (t/m^3):	**N/A**
Water Content (as received):	**8.1 %**

Project No:	**2-68357.13**
Lab Ref No:	**13/357/001**
Client Ref:	**ZB01369.401**

Sieve Analysis						Hydrometer Analysis			
Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)
63.0	--	4.75	--	0.300	58	--	--	--	--
37.5	--	2.36	100	0.212	54	--	--	--	--
19.0	--	1.18	80	0.150	50	--	--	--	--
13.2	--	0.600	66	0.075	37	--	--	--	--
9.5	--	0.425	62	0.063	34	--	--	--	--
Note: "--" denotes sieve not used and/or hydrometer analysis not tested						--	--		



Test Methods	Notes
Particle Size Analysis: NZS 4402:1986: Test 2.8.1 (Wet Sieve Method)	Fraction Passing finest sieve is by difference
Water Content: NZS 4402: 1986 Test 2.1	pH of suspension : 8.0 (Whatmans Full Range pH Indicator paper)

Date Tested: 15/03/13

Date Reported: 15/03/13

Testing is not covered by IANZ Accreditation

Signatory

Designation : Senior Civil Engineering Technician

Date : 15/03/13

csf 2100 (8/02)

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ORGANIC MATTER CONTENT TEST REPORT

OPUS

Project :	**Puhoi to Warkworth Planning Alliance**
Location :	**SH1, Puhoi to Warkworth**
Client :	**Further North Alliance**
Contractor :	-
Sampled by :	**Client**
Date sampled :	**05/03/13**
Sampling method :	**N/A**
Sample description :	**As Shown**
Sample condition :	**As Received**

Project No :	**2-68357.13**
Lab Ref No :	**13/357/001**
Client Ref No :	**ZB01369.401**

Test Results

Sample No:	BH106	BH112
Sample description:	Brown SILT, some Clay and Sand, minor Gravel	Greyish Brown Clayey Sandy SILT
Depth (m):	3.65	5.0-5.2
Organic Matter (%):	**1**	**1**
Water Content (%):	**15.8**	**20.1**

NOTE 1 of the Test Method states:
While the loss on ignition method will give quantitative oxidation of organic matter, thus avoiding the problem of conversion from organic carbon to organic matter, many inorganic soil constituents are also modified by heating which leads to mass loss in excess of the actual organic content.

For highly organic soils, the method is sufficiently accurate for day to day purposes, but it should not be relied on for organic contents less than about 15%.

Test Method		Notes
Organic Matter	NZS 4402 : 1986, Test 3.1.2 (subsidiary method by ignition)	1) whole soil tested
Water Content :	NZS 4402 : 1986 Test 2.1	

Date tested : 15/03/13

Date reported : 15/03/13

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IANZ Approved Signatory

Designation : Senior Civil Engineering Technician
Date : 15/03/13

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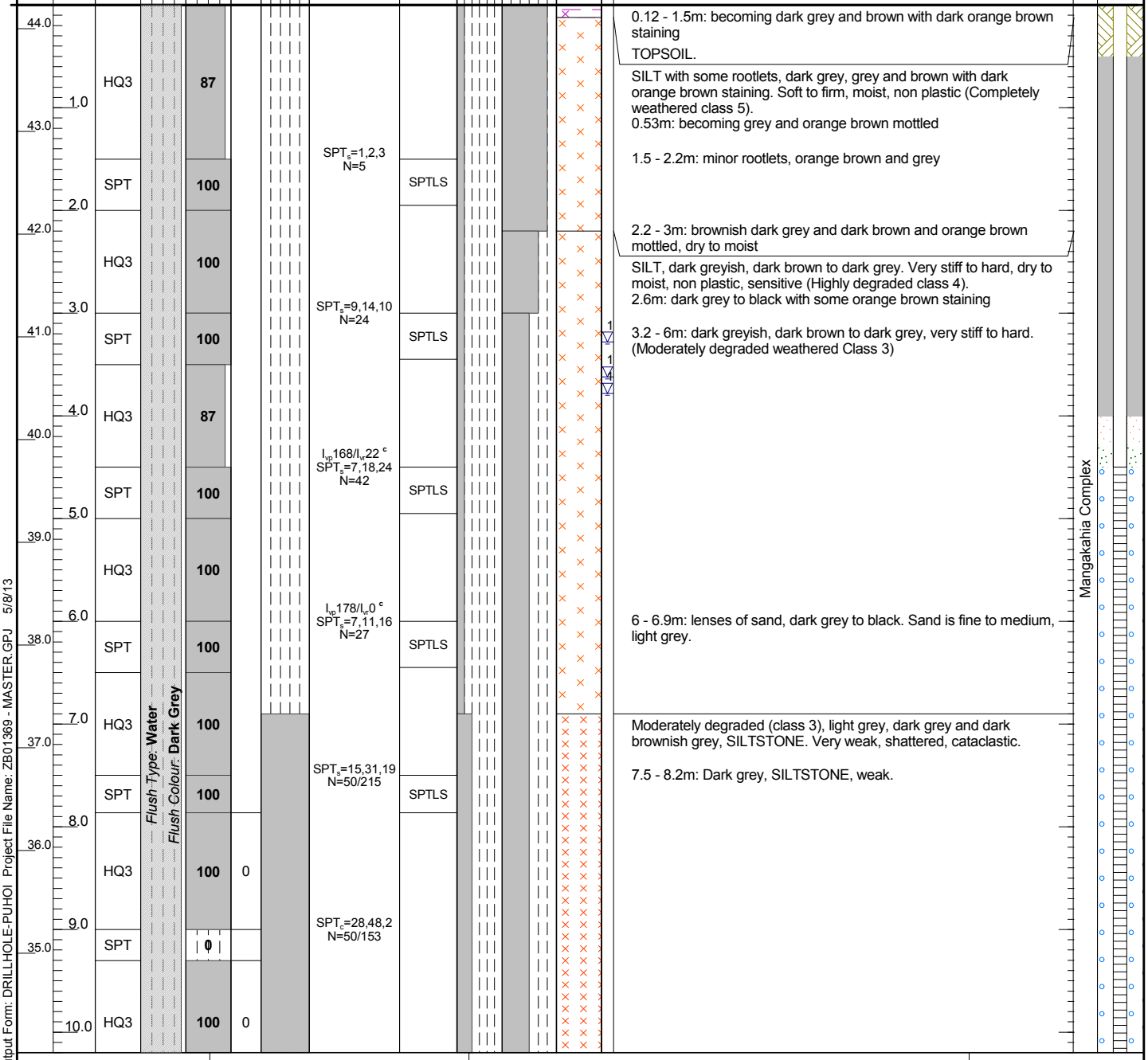
Draft Log of Investigation

Project: **Further North**	**Borehole**
Location: **Schedewys Hill** Project No: **ZB01369**	Hole ID: **BH207**
Client: **NZTA**	Date: **1/03/2013**



Started: 1/03/2013
Finished: 4/03/2013
Driller: McMillan (NI) Drilling
Plant: D&B-8D Track
Logged: SPT
Checked: RGK

Depth Related Remarks

From	Remarks
10.5m	More difficult to drill from here..
15m	Swelling of Onerahi Chaos.

Groundwater Observations

No.	Struck (m)	Date	Observations	Standing (m)
1.	3.3m	11/03/2013		
1.	3.64m	18/03/2013		
1.	3.8m	5/04/2013		

Remarks

Fully Automated SPT used - Calibrated Energy Ratio 66.3% (reported values uncorrected)
Chainage 59640mCh.

Co-ordinates:
NZTM2000
5960372.1mN
1748354.9mE
Elevation: 44.23mRL
Auckland 1946
Inclination: -90°

Draft Log of Investigation

Project: **Further North**	**Borehole**
Location: **Schedewys Hill** Project No: **ZB01369**	Hole ID: **BH207**
Client: **NZTA**	Date: **1/03/2013**

R.L. (m)	Depth (m)	Drilling Method	Drilling Flush Return (%)	TCR (%)	RQD	Spacing of Natural Defects (mm)	In-Situ Testing	Sampling	Relative Strength	Weathering Grade	Geology Legend	GroundWater	Description of Strata	Geological Unit	Backfill / Installation
			25 50 75	25 50 75		500 100 50 10 0			EW VW W MS SS	UW SW HW CW RW					
		SPT		0			SPT_c=34,50 N=50/116								
33.0	11.0	HQ3		87	0			C							
32.0	12.0	SPT		0			SPT_c=27,50 N=50/78								
31.0	13.0	HQ3		100	0									Mangakahia Complex *(Contd.)*	
		SPT		0			SPT_c=40,50 N=50/135								
30.0	14.0	HQ3		100	0										

BH207 terminated at 14.80m. Target Depth

Started: 1/03/2013
Finished: 4/03/2013
Driller: McMillan (NI) Drilling
Plant: D&B-8D Track
Logged: SPT
Checked: RGK

Depth Related Remarks

From	*Remarks*
10.5m	More difficult to drill from here..
15m	Swelling of Onerahi Chaos.

Groundwater Observations

No.	*Struck (m)*	*Date*	*Observations*	*Standing (m)*
1.	3.3m	11/03/2013		
1.	3.64m	18/03/2013		
1.	3.8m	5/04/2013		

Remarks

Fully Automated SPT used - Calibrated Energy Ratio 66.3% (reported values uncorrected)
Chainage 59640mCh.

Co-ordinates:
NZTM2000
5960372.1mN
1748354.9mE
Elevation: 44.23mRL
Auckland 1946
Inclination: -90°

Borehole 207
EOH 14.8m (Schedewys)
<BH207 Box No.1> 0.0 – 2.9m

<BH207 Box No.2 > 2.9 – 5.9m

< BH207 Box No.3 > 5.9 – 8.6m

< BH207 Box No.4 > 8.6 – 11.45m

< BH207 Box No.5 > 11.45 – 14.5m

< BH207 Box No.6 > 14.5 – 14.8m

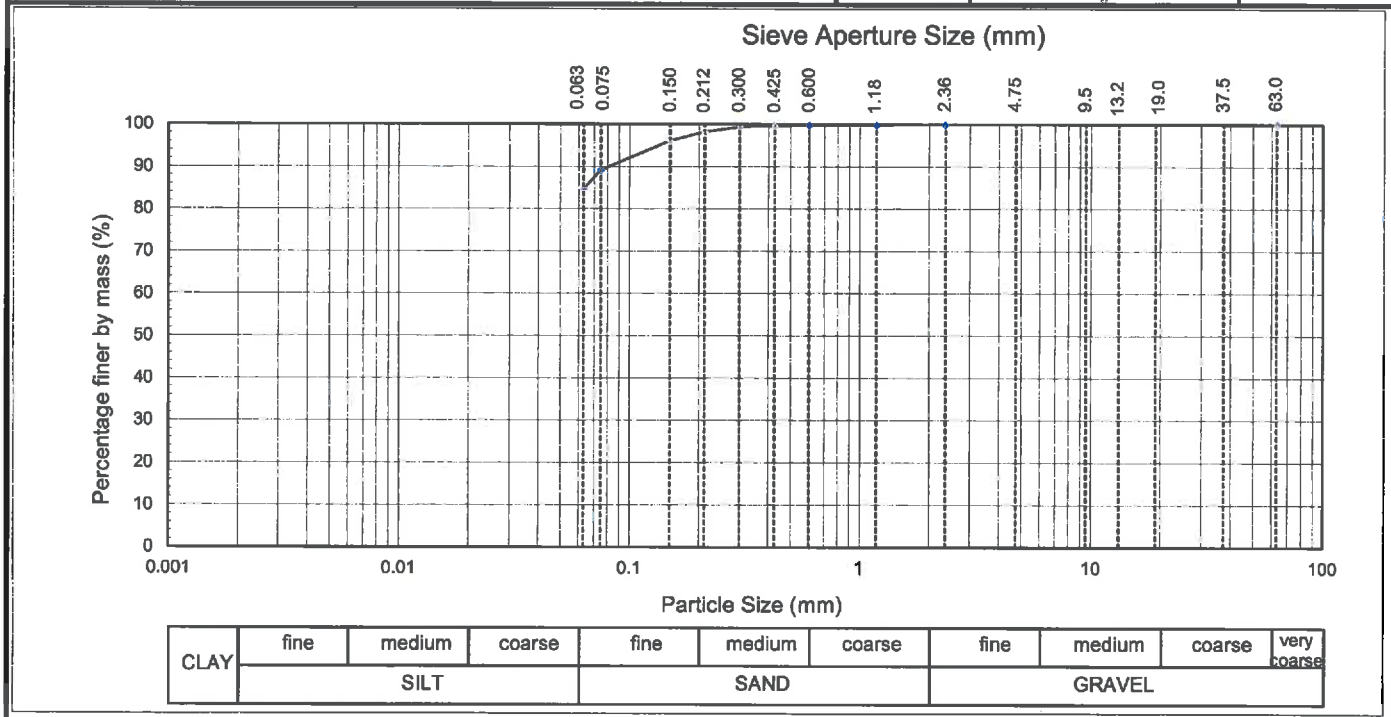
PARTICLE SIZE ANALYSIS (WET SIEVE METHOD)
TEST REPORT

OPUS

Project :	**Puhoi to Warkworth Planning Alliance**
Location :	**SH1, Puhoi to Warkworth**
Client :	**Further North Alliance**
Feature:	-
Contractor :	-
BH/TP/Sample ID:	**BH 207** Depth: **1.5-1.95 metres**
Sampled by :	**Client**
Date received :	**8/03/13**
Sampling method :	**SPT**
Sample condition :	**As received**
Sample description :	**CLAY/SILT with some Sand**
Solid Particle Density (t/m^3):	**NA**
Water Content (as received):	**52.6 %**

Project No:	**2-68357.13**
Lab Ref No:	**13/357/001**
Client Ref:	**ZB01369.401**

Sieve Analysis						Hydrometer Analysis			
Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)
63.0	--	4.75	--	0.300	99	--	--	--	--
37.5	--	2.36	100	0.212	98	--	--	--	--
19.0	--	1.18	100	0.150	96	--	--	--	--
13.2	--	0.600	100	0.075	89	--	--	--	--
9.5	--	0.425	100	0.063	85	--	--	--	--
Note:	"--" denotes sieve not used and/or hydrometer analysis not tested					--	--		



Test Methods	Notes
Particle Size Analysis: NZS 4402:1986: Test 2.8.1 (Wet Sieve Method)	Fraction Passing finest sieve is by difference
Water Content: NZS 4402: 1986 Test 2.1	

Date Tested: 27/03/13

Date Reported: 28/03/13

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IANZ Approved Signatory

Designation : Senior Civil Engineering Technician

Date : 28/03/13

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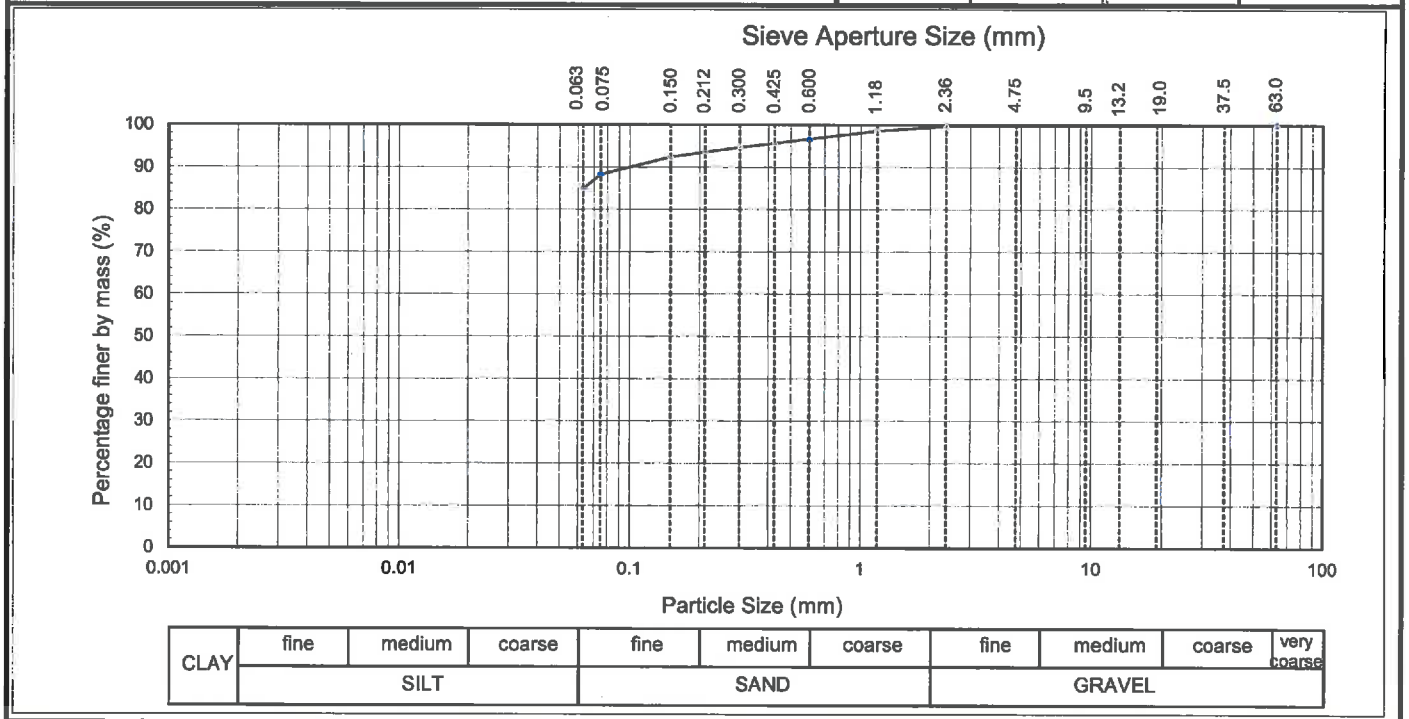
PARTICLE SIZE ANALYSIS (WET SIEVE METHOD)
TEST REPORT

OPUS

Project :	**Puhoi to Warkworth Planning Alliance**
Location :	**SH1, Puhoi to Warkworth**
Client :	**Further North Alliance**
Feature:	-
Contractor :	-
BH/TP/Sample ID:	**BH 207** Depth: **3.0-3.45 metres**
Sampled by :	**Client**
Date received :	**8/03/13**
Sampling method :	**SPT**
Sample condition :	**As received**
Sample description :	**CLAY/SILT with some Sand**
Solid Particle Density (t/m^3):	**NA**
Water Content (as received):	**44.7 %**

Project No:	**2-68357.13**
Lab Ref No:	**13/357/001**
Client Ref:	**ZB01369.401**

Sieve Analysis						Hydrometer Analysis			
Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)
63.0	--	4.75	--	0.300	95	--	--	--	--
37.5	--	2.36	100	0.212	94	--	--	--	--
19.0	--	1.18	99	0.150	92	--	--	--	--
13.2	--	0.600	97	0.075	88	--	--	--	--
9.5	--	0.425	96	0.063	85	--	--	--	--
Note: "--" denotes sieve not used and/or hydrometer analysis not tested						--	--		



Test Methods	Notes
Particle Size Analysis: NZS 4402:1986: Test 2.8.1 (Wet Sieve Method)	Fraction Passing finest sieve is by difference
Water Content: NZS 4402: 1986 Test 2.1	

Date Tested: 28/03/13

Date Reported: 28/03/13

Testing is covered by IANZ Accreditation

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IANZ Approved Signatory

Designation : Senior Civil Engineering Technician

Date : 28/03/13

csf 2100 (8/02)

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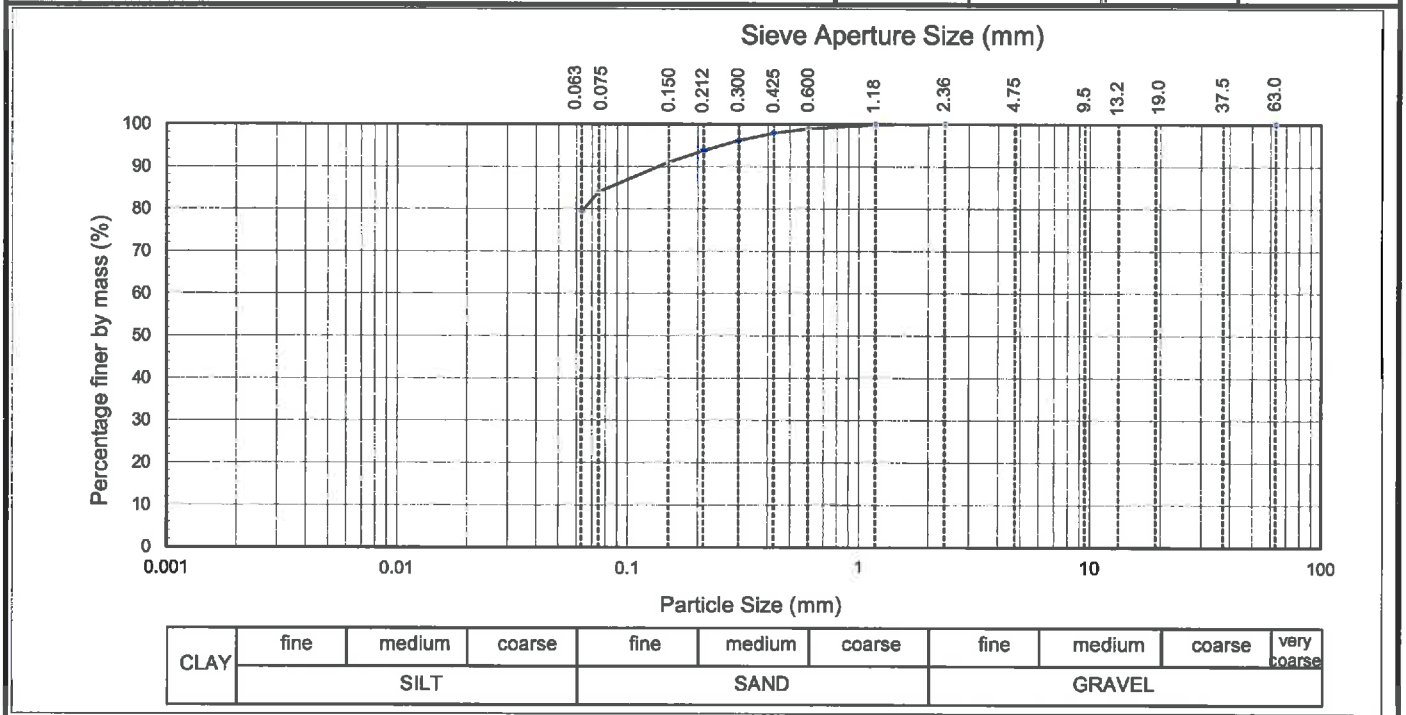
PARTICLE SIZE ANALYSIS (WET SIEVE METHOD) TEST REPORT

OPUS

Project :	**Puhoi to Warkworth Planning Alliance**
Location :	**SH1, Puhoi to Warkworth**
Client :	**Further North Alliance**
Feature:	-
Contractor :	-
BH/TP/Sample ID:	**BH 207** Depth: **4.5-4.95 metres**
Sampled by :	**Client**
Date received :	**8/03/13**
Sampling method :	**SPT**
Sample condition :	**As received**
Sample description :	**Sandy CLAY/SILT**
Solid Particle Density (t/m^3):	**NA**
Water Content (as received):	**27.4 %**

Project No:	**2-68357.13**
Lab Ref No:	**13/357/001**
Client Ref:	**ZB01369.401**

Sieve Analysis						Hydrometer Analysis			
Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)
63.0	--	4.75	--	0.300	96	--	--	--	--
37.5	--	2.36	100	0.212	94	--	--	--	--
19.0	--	1.18	100	0.150	91	--	--	--	--
13.2	--	0.600	99	0.075	84	--	--	--	--
9.5	--	0.425	98	0.063	79	--	--	--	--
Note:	"--" denotes sieve not used and/or hydrometer analysis not tested					--	--		



Test Methods	Notes
Particle Size Analysis: NZS 4402:1986: Test 2.8.1 (Wet Sieve Method)	Fraction Passing finest sieve is by difference
Water Content: NZS 4402: 1986 Test 2.1	

Date Tested: 28/03/13

Date Reported: 28/03/13

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IANZ Approved Signatory

Designation : Senior Civil Engineering Technician

Date : 28/03/13

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PLASTICITY INDEX FOR SOILS TEST REPORT

OPUS

Project :	**Puhoi to Warkworth Planning Alliance**
Location :	**SH1, Puhoi to Warkworth**
Client :	**Further North Alliance**
Sampled by :	**Client**
Date received :	**8/03/13**
Sampling method :	**Bag/Shoe/SPT**
Sample condition :	**As Received**

Project No :	**2-68357.13**
Lab Ref No :	**13/357/001**
Client Ref No :	**ZB01369.401**

Test Results

Sample ID :	BH202	BH207	BH207
Depth (m) :	1.30-1.80	1.50-1.95	4.50-4.95
Soil Fraction Tested:	Whole soil	Whole soil	Whole soil
Liquid Limit :	54	93	70
Plastic Limit :	33	31	32
Plasticity Index :	**21**	**62**	**38**
Natural Water Content (%):	**46.3**	**52.6**	**27.4**

Sample Description : **BH202 1.30-1.80m :** SILT with some sand and some clay.
BH207 1.50-1.95m: CLAY/SILT with some sand.
BH207 4.50-4.95m: Sandy CLAY/SILT.

Test Methods		Notes
Water Content	NZS 4402 : 1986, Test 2.1	
Liquid Limit	NZS 4402 : 1986, Test 2.2	
Plastic Limit	NZS 4402 : 1986, Test 2.3	
Plasticity Index	NZS 4402 : 1986, Test 2.4	

Date tested : 27/03-03/04/13
Date reported : 05/04/13

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IANZ Approved Signatory

Designation : *Senior Civil Engineering Technician*
Date : 05/04/13

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CSF 2004 (22/08/03)

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