



**MILLWATER - PRECINCT 2  
STAGE 3A**

**Geotechnical Completion Report**

Prepared for  
WFH Properties Ltd

Prepared by  
Tonkin & Taylor Ltd

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## Executive summary

Tonkin + Taylor Ltd (T+T) was engaged by WFH Properties Ltd to monitor and provide earthworks certification for the 35 No. Residential Lots contained within Stage 3A of Precinct 2 in the Millwater Subdivision in Silverdale. Stage 3A comprises residential Lots 331 to 341, 344 to 354 and 373 to 385 inclusive as shown on the Woods Final Contour As-Built Plan (Woods Ref 33210-03A-AB-100) in Appendix A1. This Geotechnical Completion Report contains information required for subdivisional earthworks completion reporting, as well as outlining geotechnical design issues that need to be considered for subsequent building design and construction on each residential Lot.

Previous geotechnical investigation work across the subdivision was undertaken by T+T and reported in:

- a 2000 and 2001 Preliminary feasibility reporting (Ref. [1] and [2]).
- b 2003 Major reconnaissance report covering land in the Silverdale North and Orewa West areas (Ref. [3]).
- c 2004 Geotechnical Investigation Report for the Wainui Road Subdivision (Ref. [4]), updated in October 2005 following scheme modifications (Ref. [5]).
- d 2006 Investigation report following purchase of Westlake property (Ref. [6]).
- e May 2014 Geotechnical Investigation Report for Precinct 2 (Ref. [7]).

Woods Ltd (Woods) undertook the engineering design for this stage and the overall subdivision.

Bulk earthworks commenced on site in 2007, temporarily ceased in late 2008, recommenced in 2013, and were completed by February 2016. Earthworks comprised the following:

- a Stripping of vegetation, organic materials and topsoil to stockpile.
- b Installation of gully and subsoil drains.
- c Construction of 1 No. Shear Key (SK03) as shown on T+T Drawing 21854.001-P2S3A-101 in Appendix A2.
- d Cut to fill earthworks across the entire site, incorporating construction of 4 No. reinforced earth slopes (i.e. RE 601 to RE 604), as shown on T+T Drawing 21854.001-P2S3A-101 in Appendix A2.

Civil earthworks commenced on site in February 2016 and were completed by July 2016, and comprised the following:

- a Minor cut to fill earthworks across parts of the site as part of final Lot development, as shown on the Woods Cut/Fill Contour As-Built Plan Earthworks Surface – Final Surface (Woods Ref 33210-03A-AB-111) in Appendix A1.
- b Installation of roading and services.

Overall subdivisional soil types are moderately expansive (Class M), based on laboratory testing undertaken in accordance with AS 2870:2011 (Ref. [9]). Due to this classification, soils lie outside the definition of good ground within NZS 3604:2011 (Ref. [10]). Building foundations will require either specific foundation design for expansive soils or foundation design in accordance with AS 2870:2011 (Ref. [9]). Subject to design issues outlined in Section 3, and CSIRO recommendations outlined in the appendices relating to expansive soils foundation design and home owner maintenance, each residential Lot is considered to have a building platform area generally suitable for domestic residential development subject to specific geotechnical assessment and foundation design due to the presence of expansive soils and where Lots contain, or are adjacent to, land with slopes steeper than 1 in 4 (V:H).

Foundation design for residential development should proceed in accordance with Sections 6.5 to 6.10 of this report.



# 1 Introduction

## 1.1 General

Tonkin + Taylor Ltd (T+T) was engaged by WFH Properties Ltd to monitor and provide earthworks certification for the 35 No. Residential Lots contained within Stage 3A of Precinct 2 in the Millwater Subdivision in Silverdale. Stage 3A comprises residential Lots 331 to 341, 344 to 354 and 373 to 385 inclusive as shown on the Woods Final Contour As-Built Plan (Woods Ref 33210-03A-AB-100) in Appendix A1.

Previous geotechnical investigation work across the subdivision was undertaken by T+T and reported in:

- a 2000 and 2001 Preliminary feasibility reporting (Ref. [1], [2]).
- b 2003 Major reconnaissance report covering land in the Silverdale North and Orewa West areas (Ref. [3]).
- c 2004 Geotechnical Investigation Report for the Wainui Road Subdivision (Ref. [4]), updated in October 2005 following scheme modifications (Ref. [5]).
- d 2006 Investigation report following purchase of Westlake property (Ref. [6]).
- e May 2014 Geotechnical Investigation Report for Precinct 2 (Ref. [7]).

The preliminary (Ref. [1], [2]) and investigation (Ref. [3], [4], [5], [6], [7]) reports noted the presence of existing instability comprising landsliding, soil creep and shallow slope movement across much of Precinct 2. These features were proposed to be stabilised, and/or undercut and replaced with engineered fill, during development works. Stability analyses further indicated that shear keys and geotechnical remediation works were also required to achieve satisfactory factors of safety against instability for the finished development of Stage 3A.

Earthworks compaction control, in terms of minimum shear strengths and maximum air voids, was recommended, and, along with other recommendations, has been incorporated into our control of the works and, where applicable, included in completion reporting.

The scope of work covered by this completion report includes:

- a Review of geotechnical investigation reporting for the site;
- b Monitoring and certification of earthworks operations in compliance with NZS 4431:1989 (Ref. [8]);
- c Monitoring and certification of construction of 4 No. reinforced earth slopes;
- d Assessment of soils for expansive conditions in accordance with AS 2870:2011 (Ref. [9]);
- e Certification of completed Lots for residential development in accordance with NZS 3604:2011 (Ref. [10]).

Woods Ltd (Woods) undertook subdivision engineering design and civil works construction observations. As-built plans showing final contours and cut and fill depths have been prepared by Woods and are attached in Appendix A1.

## 1.2 Description of Subdivision

The Millwater subdivision is situated to the north of the Silverdale Township, and west of the Metro Park East reserve area, and comprises approximately 260 hectares. The subdivision is bound to the south and west by Wainui Road, to the north by the Orewa Estuary and to the east by the Orewa Estuary and Millwater Parkway. The original site comprised a mix of farm properties and associated dwellings and existing residential developments.

The Precinct 2, Stage 3A area of the Millwater subdivision is located within what is known as Precinct 2 in the Silverdale North Structure Plan.

The Precinct 2 area is bound by Manuel Road to the northwest, Old Mill Road to the east, Wainui Road to the south and west, and Precinct 3 to the northeast. The overall Precinct 2 and Stage 3A areas are shown on T+T Drawing 21854.001-P2S3A-100 in Appendix A2.

Pre-development gradients within the Stage 3A area were gentle to moderately steep (1 in 15 to 1 in 3 (V:H)) with an overall fall to the south east.

Post-development gradients within the Stage 3A area remain gentle to moderately steep (1 in 15 to 1 in 3 (V:H)) and generally fall to the south east as before. In order to form more level building platforms, 4 No. reinforced earth slopes of between 1 in 1.5 and 1 in 2 (V:H) have been constructed along some Lot boundaries as shown on T+T Drawing 21854.001-P2S3A-101.

Stage 3A is presently accessed from the existing Manuel Road.

### 1.3 Geological Setting

Published geological mapping and information indicates the Precinct 2 area is underlain by Northland Allochthon materials. In addition to the Northland Allochthon, our investigations identified the presence of overlying alluvial materials on site.

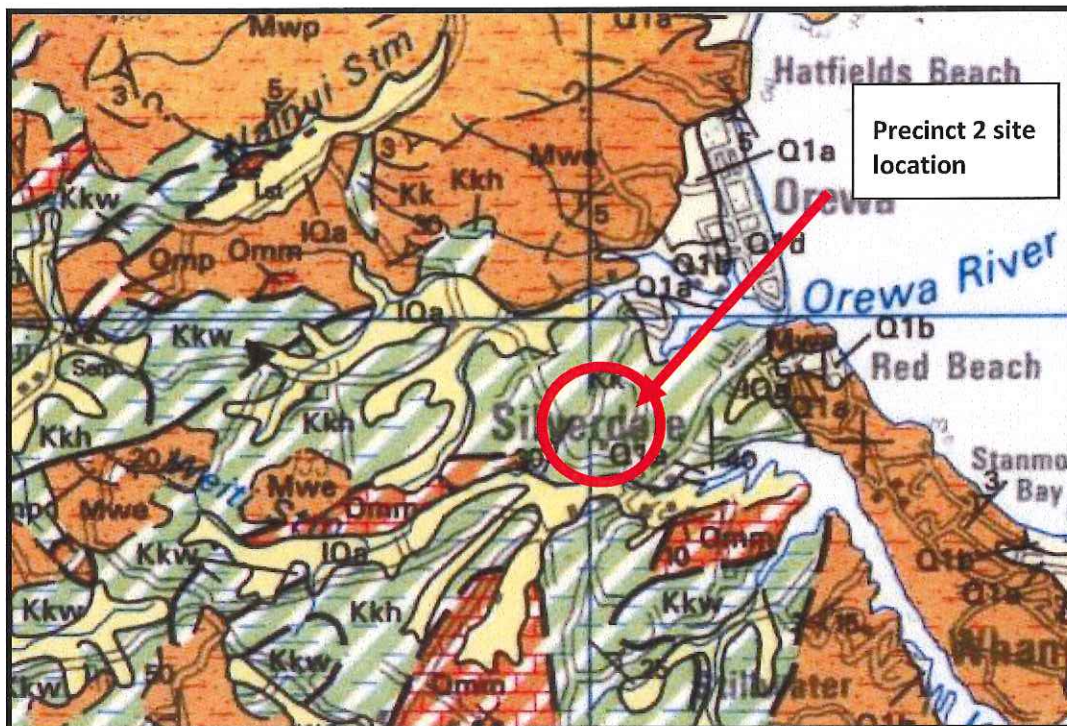


Figure 1 - Local Geology (from Edbrooke)

Land south of the Orewa River is located on an area of extensively deformed and sheared mudstones and muddy to sandy limestones described as Onerahi Chaos – Northland Allochthon material. Recent stream alluvium and slope colluvium derived from residual Northland Allochthon material is mapped towards the base of the gullies at the bottom of the slopes. Recent stream alluvium and discontinuous areas of older Pleistocene Age alluvium are also likely to be present overlying the Northland Allochthon.

Summary descriptions of geological units in Wainui/Manuel Roads area (after Kermode 1991) are as follows:

**a**     **Northland Allochthon**

Deformed sediments, commonly known as Onerahi Chaos - Northland Allochthon: forms hummocky rolling hills covering more than 100 km<sup>2</sup> west of Whangaparaoa Peninsula. Mixture of undifferentiated deposits of various and widely sized (cm-km), randomly oriented blocks comprising conglomerate limestone, mudstone, alternating sandstone and mudstone, and serpentinite in a matrix of closely fractured and crushed, moderately soft, grey, brown, and greenish grey mudstone and some sandstone (calcareous or siliceous). Some of the large blocks, especially of limestone, have been mapped individually.

**b**     **Pleistocene Age Alluvium**

Up to 20 m thick and from 3 to 10 m above present base level: forms higher coastal and valley terraces throughout the map area; in places locally discontinuous or absent. These alluvial deposits are typically very thinly to very thickly bedded, yellow-grey to orange-brown, angular to well rounded, mixed sizes (usually graded, coarse becoming fine upwards) of mud, sand and gravel, comprising rock fragments and weathered rock residue from the hinterland. They include some beds of black, humus-rich clay and white, pumice silt.

Geological cross-sections through the Precinct 2, Stage 3A area are enclosed as Drawing Number 21854.001-P2S3A-103 to -104 in Appendix A2. Borehole logs from the post-earthworks investigations are enclosed in Appendix E.

Fill material placed across the site to form the final design profile typically comprised site-won Northland Allochthon.

## **2 Earthworks Operations**

### **2.1 Plant**

Bulk earthworks were undertaken by Hick Bros Civil Construction Ltd (HBCCL) from early 2013 through to early 2016. Civil works have been completed by Hopper Construction Ltd (HCL). Various earthworks equipment was used to undertake the works, comprising D6 and D8 bulldozers and scoops, motor scrapers, tractors and discs, sheepsfoot compactors, padfoot rollers, and a number of 12 to 35 tonne excavators. This plant generally carried out all construction earthworks.

Specialist contractors and plant were brought on site for pavement construction. Certification of the pavement construction is beyond the scope of this report.

### **2.2 Construction Programme**

Subdivisional earthworks were undertaken by HBCCL from early 2013 through to early 2016. Final civil earthworks and construction for the residential Lots were under HCL's control and were undertaken progressively from February 2016 through to completion in July 2016.

Key Stage 3A earthworks components included:

- a Stripping of vegetation, organic materials and topsoil to stockpile.
- b Installation of gully and subsoil drains.
- c Construction of 1 No. Shear Key (SK03) as shown on T+T Drawing 21854.001-P2S3A-101 in Appendix A2.
- d Cut to fill earthworks across the entire site, incorporating construction of 4 No. reinforced earth slopes (i.e. RE 601 to RE 604), as shown on T+T Drawing 21854.001-P2S3A-101 in Appendix A2.

Key Stage 3A civil works components included:

- a Minor cut to fill earthworks across parts of the site as part of final Lot development, as shown on the Woods Cut/Fill Contour As-Built Plan Earthworks Surface – Final Surface (Woods Ref 33210-03A-AB-111) in Appendix A1.
- b Installation of roading and services.

The earthworks, undercuts and subsoil drainage as-built plans are included in Appendix A1 (Woods Drawings 33210-03A-AB-100, 110 to 112 and 120), and show the earthworks undertaken across the site.

## 2.3 Compaction Control

Compaction control criteria, consisting of maximum allowable air voids and minimum allowable shear strengths, were used for cohesive fill control. The Technical Specification included in our Geotechnical Investigation Report (Ref. [4],[5],[6],[7]) included the following requirement for the subdivisional earthworks:

### Minimum Shear Strength and Maximum Air Voids Method

**Minimum Undrained Shear Strength** (Measured by insitu vane – IANZ calibrated)

#### General fills:

Average value not less than 140 kPa

Minimum single value 110 kPa

#### High Strength Structural fills (Reinforced Earth Fill Slopes):

Average value not less than 150 kPa

Minimum single value 120 kPa

### Maximum Air Voids Percentage (as defined in NZS 4402:1986)

#### General fills:

Average value not more than 10%

Maximum single value 12%

#### High Strength Structural fills (Reinforced Earth Fill Slopes):

Average value not more than 8%

Minimum single value 10%

The average corrected shear strength value was determined over any ten consecutive tests.

Regular in situ density, strength and water content tests were carried out on the filling at, or in excess of, the frequency recommended by NZS 4431:1989 (Ref. [8]). Test results are contained in Appendix E.

Quality Control (QC) testing showed that the results for the filling were consistently meeting the required undrained shear strength and air voids criteria, demonstrating that the water content of placed fill was consistently at, or close to, optimum. To the best of our knowledge, any problems encountered were rectified, where required, by close monitoring of the selection of borrow materials, discing and remixing of the available soil types, and minor reworking.

### 3 Geotechnical Development Works

#### 3.1 Subsoil Drainage

A network of subsoil drains has been installed within the original gully alignments across Precinct 2 during the original bulk earthworks, in addition to those drains installed as part of the shear key and reinforced earth slope construction.

The subsoil drains installed within the original gullies and shear keys were excavated into the underlying rock to intercept groundwater and springs. The subsoil drains comprised 600mm to 1m wide trenches, installed in the base of the mucked out gully alignments, prior to placement of up to 6m of fill, and backfilled with:

- a 160mm diameter, Hiway grade, perforated Nexus pipes along the base of the trench.
- b SAP50 scoria over the top of the Nexus pipe to within 1m of the ground surface (at time of construction).
- c Bidim A19 geotextile filter-cloth over the top of the scoria.
- d Compacted, engineered fill within the top metre of the trench.

Subsoil drains installed as part of reinforced earth slope construction comprised the following:

- a 160mm diameter, Hiway grade, perforated Nexus pipes along the base of the rear of the reinforced soil block.
- b SAP50 scoria over the top of the Nexus pipe and up the back face of the reinforced soil block, to within 2.0 metres of the ground surface (at time of construction).
- c Bidim A19 geotextile filter-cloth over the top of the scoria prior to placement of the reinforced soil.

The gully and shear key drains discharge into the main downslope gully that runs centrally through Precinct 2. The reinforced earth slope drains were connected to the reticulated stormwater system.

The subsoil drainage system and connections are shown on the Woods Shear Key, Undercuts & Subsoil Drains As-Built Plan (Woods Ref 33210-03A-AB-120) in Appendix A1, and on T+T Drawing 21854.001-P2S3A-102 in Appendix A2.

#### 3.2 Shear Keys

Based on stability analyses undertaken as part of the investigation reporting, a shear key was identified as being required across Precinct 2 to provide satisfactory factors of safety against instability for the finished development of Stage 3A.

1 No. Shear Key (i.e. SK 03) was excavated within Stage 3A during the recent bulk earthworks in the location shown on the T+T Drawing 21854.001-P2S3A-101, included in Appendix A2. Excavations for the Shear Key were inspected and mapped by an Engineering Geologist to check that the key base had been extended sufficiently into the underlying more competent Northland Allochthon rock materials, and that there were no apparent adverse structural features or lower strength materials exposed within the base of the excavation. Any areas of suspect ground, including areas of identified landslippage, were removed under the instruction of our site Geologist and replaced with well compacted engineered fill, placed in accordance with the bulk earthworks specification (Section 2.3 above).

The shear key long-section for SK 03 was developed based on the mapping undertaken and is included in Appendix A2 (Drawing 21854.001-P2S3A-107). This section shows the materials exposed within the side of the shear key excavation and relevant geological structural information mapped during our inspections.



Following completion of the shear key excavation, drainage blankets were placed along the rear face of the key, and comprised the following:

- a 160mm diameter perforated Hiway grade Nexus drain pipe: This was run along the base of the rear of the excavation and connected to the gully subsoil drainage in several locations (as per the Woods As-Built plan 33210-03A-AB-120). Additional Nexus drain pipes were also installed along mid-height benches where appropriate and connected into the key drainage outlet system.
- b SAP50 scoria: A layer of minimum 300mm thickness of SAP 50 was placed across the entire rear face, and extended to within 1.0m of the top of the key. It should be noted that the top of the key at this stage generally coincided with the original ground surface.
- c Bidim A19 geotextile filtercloth: This was placed over the surface of the SAP 50 scoria to prevent contamination of the drainage aggregate with overlying bulk earthworks materials.

The rear face drainage blanket was extended up to at least 1 metre above the soil / rock interface to intercept perched groundwater flows which typically flows along this interface.

Ground conditions exposed during shear key construction were generally as anticipated from the design stage of the development. The slope stability analysis results from the original design phase are discussed in Section 4.

### 3.3 Reinforced Earth Slope

Four reinforced earth (RE) slopes (i.e. RE 601 to RE 604) were constructed during the recent bulk earthworks within Stage 3A.

The slopes comprise biaxial geogrids placed at 0.5m (vertical) intervals within the well compacted engineered fill, placed in accordance with the bulk earthworks specification (Section 2.3 above). The grids extend up to within 1.5m (vertical) of the slope crest. They have been placed at various lengths, starting at the face of the slope.

Typical cross-sections through the RE slopes are shown on T+T Drawing 21854.001-P2S3A-105 in Appendix A2.

The placement of the geogrid allows steeper finished gradients than is typically possible with unreinforced bulk fills, and minimises the risk of instability across the face of the slope, particularly where finished gradients across the slopes are up to 1 in 1.5 (V:H).

Construction of the RE slopes comprised the following:

- a Foundation preparation;
- b Placement and compaction of fill to the required levels;
- c Placement of the geogrid layers, ensuring that the grid is held tightly in place;
- d Spreading of fill across the surface of the geogrid with lightweight plant;
- e Compaction and placement of further fill up to the level of the next grid layer;
- f Installation of Enkamat across the face of any slopes steeper than 1 in 2 (V:H) to assist in retention of the topsoil facing while vegetation is established.

The fill was placed and compacted beyond the limit of the final slope face and then trimmed back to ensure full compaction of the slope face was achieved, taking care not to damage the geogrid.

As noted in Section 3.1, a drainage blanket was installed at the rear of the reinforced block of soil and comprised a minimum of 300mm thickness of SAP50 scoria, covered in Bidim A19 geotextile filtercloth and a cap of cohesive fill 2.0m in thickness. A 160mm diameter perforated Nexus pipe at the base of

the drainage blanket provides a discharge outlet for any groundwater captured in the drainage blanket. The drainage pipe is connected into the stormwater system.

This slope has been designed to accommodate construction of a lightweight structure of up to 10kPa distributed load at the crest of the slope.

The reinforced earth slope drainage system is also shown on the T+T As-Built plans in Appendix A2.

### **3.4 Undercuts**

Earthworks operations across Lots 344 to 354 and 331 to 341 resulted in exposure of the underlying Northland Allochthon rock materials. The Northland Allochthon rock has been undercut by 1m and replaced with engineered, compacted fill, placed in accordance with the bulk earthworks specification (Section 2.3 above). The rock undercut has been undertaken to seal off the underlying rock from ingress of surface water flows, to reduce the potential effects of expansive soils as the Northland Allochthon rock weathers, and to allow for ease of construction of domestic service connections.

The extent of the undercut areas is shown on the Woods Shear Key, Undercuts & Subsoil Drains As-Built Plan (Woods Ref 33210-03A-AB-120) in Appendix A1.

## 4 Stability Analyses

As noted in Section 1, slope stability analyses undertaken during the investigation stage of the project identified the need for shear keys to be constructed across Precinct 2 so as to provide acceptable factors of safety against slope instability for the finished development of Stage 3A.

During excavation of Shear Key 03, the excavated faces were mapped to confirm the key had been extended sufficiently into the underlying rock materials and to check for any apparent adverse oriented geological structure or other features exposed within the lower part of the key.

We are satisfied that the design stability analyses remain valid for the completed works on the following basis:

- a the exposed ground conditions generally conform to those assumed for design;
- b the as-built profiles match design levels;
- c the earthworks monitoring shows compliance with specified criteria, upon which fill properties have been based.

## 5 Project Evaluation / Building Design Considerations

### 5.1 General

Ground conditions within Precinct 2, Stage 3A straddle a range of “design conditions” including cut ground, filled ground, expansive soils and constructed slopes up to 1 in 1.5 (V:H). The following sections set out relevant geotechnical design issues.

### 5.2 Bearing capacity for building foundations

All filled and natural ground within the influence of conventional residential shallow strip and pad foundation loads is assessed as generally having a geotechnical ultimate bearing capacity of 300kPa, as required by NZS 3604:2011 (Ref. [10]). This corresponds to a factored (Ultimate Limit State) bearing capacity of 150kPa and working (Serviceability Limit State) bearing capacity of 100kPa.

Due to the presence of expansive soils, foundation conditions fall outside the definition of “good ground” contained in NZS 3604:2011 (Ref. [10]). In terms of AS 2870:2011 (Ref. [9]), the soils present are considered to lie within Site Class M (moderately expansive) with characteristic surface movements anticipated to be in the range of 20mm to 40mm. Due allowance should be made for expansive soils, as discussed in Section 5.12.

Where a geotechnical ultimate bearing capacity greater than 300kPa is required to support any dwelling constructed outside the scope of NZS 3604:2011 (Ref. [10]), further specific site investigation and design of foundations will be required.

### 5.3 Building Limitation Zones

Steep slopes (steeper than 1 in 4 (V:H)) are present within, or immediately adjacent to, a number of the Lots in the Stage 3A area.

The steep slopes comprise reinforced earth slopes with face gradients of between 1 in 1.5 and 1 in 2 (V:H), and are located in Lots 331 to 341, 344 to 354 and 373 to 385. Construction within the flatter parts of these Lots is intended, and a Building Restriction Zone (“No Build Zone”) has been developed across the steeper areas of the Lots so as to ensure that the reinforcement of the slopes is not detrimentally affected by future development. The extent of the Building Restriction Zone associated with the reinforced earth slopes is shown on T+T Drawing 21854.001–P2S3A–110 (Building Limitation Plan) in Appendix A2. Excavation, fill placement and/or construction within this zone is not permitted.

Vegetation on slopes that are 1 in 4 (V:H) or steeper is recommended to reduce the potential for shallow slope instability and to minimise surface erosion. Where gradients are 1 in 4 (V:H) or steeper, there is potential for minor shallow creep of the topsoil layer. However, such creep is considered unlikely to detrimentally affect the global stability of the slope.

### 5.4 Settlement

From our inspections during earthworks operations, and the results of compaction quality control testing, we consider that differential settlement induced by self-weight of engineered fill should now be largely complete. Further settlements should be within normally accepted design tolerances of 25mm, as outlined in NZS 3604:2011 (Ref. [10]), with respect to conventional building development.

In order to minimise the risk of ground settlements exceeding 25 mm, NZS 3604:2011 (Ref. [10]) allows a maximum fill surcharge of 600 mm over the building platform during future development. Filling in excess of this thickness should be subject to specific foundation design and assessment.

## 5.5 Retaining walls

Due to the shallow grades across most of the Stage 3A Lots, it is not anticipated that significant retaining walls will be required as part of any Lot development. However, if walls are required, then retaining wall design will be dependent on the site specific requirements. For preliminary design we recommend the use of the following geotechnical design parameters:

$$\gamma = 18 \text{ kN/m}^3,$$

$$c' = 0 \text{ kPa},$$

$$\phi' = 30^\circ,$$

$$K_a = 0.30,$$

$$K_p = 3.33,$$

“Su” of 50kPa for the embedment soil (subject to confirmation during construction).

These values are based on level ground above and below the wall and will require appropriate amendment to allow for slope, traffic and other surcharges or toe slopes and the specific lot geometry and development requirements, as applicable.

All retaining walls should include a layer of free draining granular fill (with geotextile over the top) immediately behind the wall covered with a 0.3m thick (minimum) compacted clay fill cap, with intercepted groundwater seepage piped into the reticulated stormwater system.

Any walls greater than 1.5m retained height will require a geotechnical assessment, as a minimum, to check and confirm that the stability of the subject (or adjacent) Lot is not detrimentally affected. Retaining walls downslope of the RE slopes shall also take into account the load imposed by these slopes.

## 5.6 Subsoil Drainage

Following gully muckouts and reinforced earth slope construction during initial bulk earthworks, groundwater drainage was installed using Nexus drains covered in geotextile cloth to permanently handle ground water flows.

The extent of the subsoil drainage systems are shown on the Woods Shear Key, Undercuts & Subsoil Drains As-Built Plan (Woods Ref 33210-03A-AB-120) in Appendix A1, and on T+T Drawing 21854.001-P2S3A-102 in Appendix A2.

This drainage system is relatively deep and located so that it is unlikely to be encountered during future residential site development and is expected to be maintenance free. Any deep excavations should take account of the presence of these drains nonetheless. If a drain is encountered, damaged, or identified as defective, repairs should be observed by a Chartered Professional (Geotechnical) Engineer familiar with this report, and notified to Auckland Council.

The subsoil drains running along the boundary of Lots 331, 333/334, 336/337 and 339/340 are relatively shallow (approximately 1m below current ground surface) and will need to be taken into account when undertaking residential design and construction on these properties. Piling of foundations to below a 45 degree line extending up from the invert of the drains will be required in proximity to the drain in these Lots, to avoid surcharging the drain.

The Woods Shear Key, Undercuts & Subsoil Drains As-Built Plan (Woods Ref 33210-03A-AB-120) shows the location and invert of the subsoil drainage through this Stage.

## 5.7 Post Earthworks Investigations

Following the completion of earthworks operations, T+T have undertaken supplementary fieldwork to confirm the consistency of the natural subsoils and engineered fill. From the investigations, we confirm that the subsoils are considered to have a geotechnical ultimate bearing capacity of 300kPa, as required by NZS 3604:2011 (Ref. [10]). This corresponds to a factored (Ultimate Limit State) bearing capacity of 150kPa and working (Serviceability Limit State) bearing capacity of 100kPa. Associated borehole logs and site plan (T+T Drawing 21854.001–P2S3A–111) are attached in Appendix E.

## 5.8 Stormwater

Public stormwater services have been installed within the Precinct 2, Stage 3A. Stormwater and runoff from roofs, decks and paved areas, together with discharges from retaining wall drains and other subsoil drains must be connected directly into the public stormwater drainage network.

## 5.9 Service lines

Trench backfill has been compacted to minimise potential for future settlements. However, where building envelopes lie adjacent to or across service lines, all foundations should extend and be founded below the 45 degree zone of influence line from pipe inverts. This requirement is to avoid excessive pipe surcharges, and to allow for future maintenance of the system without detrimentally affecting adjacent structures. Subject to approval from Auckland Council, foundations may extend and bridge over service lines provided specific foundation design is undertaken.

A copy of the stormwater as-built plan (Woods Stormwater Drainage As-Built Overall Layout Plan, Woods Ref 33210–3A–AB–300) is included in Appendix A1.

## 5.10 Road subgrades

Based on the fill monitoring and site observations during development, filled and natural ground within the road and vehicle access Lots is considered generally suitable for the proposed residential pavements. Subgrade strength testing was carried out following excavation to formation levels along the road alignments. These subgrade test results were passed on to Woods for use in their pavement design. All road subgrades have been lime and cement stabilised to assist in pavement strengths, and to minimise the impact of expansive soils on road pavements.

For future road construction in other parts of the Precinct 2 Stage 3A development, within natural ground, a design CBR of 2% is considered appropriate while, within engineered fill areas, a design CBR of 7% is appropriate.

## 5.11 Topsoil

Following completion of topsoil spreading and grassing, topsoil depths were measured in each of the Lots and these are shown on T+T Drawing 21854.001–P2S3A–112 attached in Appendix E. Due to variations in placement depths and earth worked surface levels, topsoil depths may vary from those recorded.

## 5.12 Expansive soils

Expansive soils (or “reactive soils” using Australian terminology) are clay soils that undergo appreciable volume change upon changes in moisture content. The reactivity and the typical range of movement that could be expected from soils underlying any given building site depend on the amount of clay present, clay mineral type, and proportion, depth and distribution of clay throughout the soil profile. Moisture changes tend to occur slowly in clays and produce swelling upon wetting and shrinkage upon drying.



Apart from seasonal moisture changes (wet winters / dry summers) other factors that can influence soil moisture content include:

- a Influence of garden watering and site drainage;
- b The presence of large trees (especially fast growing Australian species such as eucalyptus) close to building envelopes, and;
- c Initial soil moisture conditions at construction time.

Visually, the surfaces of expansive soils are noted for developing extensive cracking during dry periods (especially late summer through autumn in Auckland) and can be locally identified by this feature when sites are excavated and left for a week or two to dry out. Further information on expansive soils is given in Appendices C and D of this report.

In order to assess for the presence of expansive soils within this stage of the development, representative soil samples were retrieved from near surface strata and tested by Geotechnics Ltd to determine soil shrinkage characteristics in accordance with AS 1289.7.1.1.

Based on the laboratory results (attached in Appendix E), the foundation soils on this stage of the subdivision lie outside the definition of 'good ground' as outlined in NZS 3604:2011 (Ref. [10]).

In terms of AS 2870:2011 (Ref. [9]), the soils present are considered to lie within Site Class M (moderately expansive) with characteristic surface movements anticipated to be in the range of 20mm to 40mm.

Accordingly, building foundations on this stage of the subdivision will need to be subject to specific foundation design by a Chartered Professional Engineer familiar with the contents of this report and responsible for design of structural elements (including foundations) of the building. Reference should be made to AS 2870:2011 (Ref. [9]) for assistance.

## 6 Statement of Professional Opinion as to the Suitability of Land for Building Development

I, Mr C.J. Freer of Tonkin + Taylor Ltd, P O Box 5271, Wellesley St, Auckland, hereby confirm that:

- 6.1 I am a Chartered Professional Engineer experienced in the field of geotechnical engineering and an authorised representative of Tonkin + Taylor who was retained by WFH Properties Ltd as the Geotechnical Engineer on Precinct 2 Stage 3A (comprising residential Lots 331 to 341, 344 to 354 and 373 to 385 inclusive) of the Millwater Residential Subdivision Development off the Millwater Parkway in Silverdale. Inspection and observation of the works have been carried out during construction by either myself or staff acting under my direction.
- 6.2 The extents of preliminary investigations are described in Tonkin + Taylor Ltd Precinct 2 Geotechnical Investigation Report Ref No. 21854.001 dated May 2014. The conclusions and recommendations of those documents have been re-evaluated in the preparation of this report. Details of all earthworks control tests performed are enclosed (Appendix E).
- 6.3 The Contractors have confirmed that the work undertaken has been completed in accordance with the drawings, specifications and any variations issued and is consistent with the inspections and observations carried out by Tonkin + Taylor Ltd. Complete Construction Certificates have been provided by the Contractors and are presented in Appendix B. Tonkin + Taylor Ltd accepts no liability for any errors or omissions represented by those documents.
- 6.4 On the basis of our observations and inspections together with the information supplied by others, including the Contractor's Construction Certificates, it is my professional opinion, not to be construed as a guarantee that:
  - 6.4.1 The earth fills shown on the attached Woods drawings, Project No 33210, Millwater, Precinct 2, Stage 3A, Drawing Numbers 33210-03A-AB-100, -110 to -112 and -120, have been generally placed in compliance with NZS 4431:1989 (Ref. ([8])).
  - 6.4.2 The completed earthworks give due regard to land slope and foundation stability considerations.
- 6.5 **For Lots 331 to 341, 344 to 354 and 373 to 385 inclusive:**
  - 6.5.1 These Lots contain a "Building Line Restriction" relating to the reinforced earth slopes which form the 1 in 1.5(V:H) slopes along the Lot boundaries. The restriction zone is shown on T+T Drawing 21854.001-P2S3A-110 in Appendix A2. Excavation, filling and/or construction within this zone is not to be undertaken, to ensure stability of the slope is not compromised.
  - 6.5.2 The presence of geogrids within the reinforced earth slopes is brought to the attention of future building and services designers. The topmost grid is located between 1 to 2 metres below the surface at the top of the slope, and does not generally extend more than 2 metres back from the crest of the slope. It is not expected that the grids will be encountered during future development of these Lots, however, the presence of the grids should be recognized. Any exposure and/or damage and subsequent repair to the grids during any future development must be observed and certified by a Chartered Professional Engineer (Geotechnical) familiar with the contents of this report.

Design of the reinforced earth slope has assumed a maximum distributed load of 10kPa (dead plus live loads) up to the edge of the Building Limitation Line.

- 6.5.3 Any cut or fill walls greater than 1.5m retained height, or of any height within 2m of the building restriction lines shown on T+T Drawing 21854.001–P2S3A–110 in Appendix A2, will require a geotechnical assessment, as a minimum, to ensure stability of the subject or adjacent Lot is not detrimentally affected. Any earthworks involving fills in excess of 600mm depth will also require a geotechnical assessment.

#### 6.5.4 Foundation design

The filled and natural ground within residential Lot boundaries is considered generally suitable for the erection thereon of light timber framed, flexibly clad residential buildings subject to clauses 6.5.2 to 6.5.5.

#### 6.5.5 Bearing capacity

Foundation design for these Lots should limit geotechnical ultimate bearing capacity to 300 kPa (factored (ULS) 150 kPa, working (SLS) 100 kPa). This is as specified in NZS 3604:2011 (Ref. [10]).

#### 6.5.6 Expansive soils

Due to the presence of expansive clay soils, foundation soils lie outside the definition of 'good ground' in NZS 3604:2011 (Ref. [10]). Soils are considered to lie in Site Class M (moderately expansive) as defined in AS 2870:2011 (Ref. [9]) with anticipated characteristic surface ground movements of 20mm to 40mm. Clause 6.5.6.1 of this Geotechnical Completion Report may be used for expansive soil foundation design on this subdivision:

##### 6.5.6.1 Specific foundation design for expansive soils

Specific foundation design should be undertaken by a Chartered Professional Engineer familiar with the contents of this report and responsible for design of structural elements (including foundations) of the building.

The minimum specific design requirements set for expansive soils within this clause are:

- i) Minimum foundation embedment of 600 mm following topsoil removal and benching of building platform areas to finished ground levels
- ii) Four bar steel reinforcing cages should be used
- iii) For buildings having brittle exterior cladding, for example brick veneer, stucco plaster, solid plaster, block work, styrofoam type cladding or sprayed plaster over harditex systems etc, the potential effects of seasonal ground movements need to be considered by the building designer.

The above minimum requirements within this clause may be superceded if individual engineers are able to demonstrate their specific design solutions are applicable to site soil conditions to the satisfaction of Auckland Council. Specific design may be undertaken by first principles or by reference to AS 2870:2011 (Ref. [9]), Section 4 and related documents.

#### 6.5.7 Floor Slab Construction

Slab on grade construction is expected to be relatively straightforward across the subdivision, but problems can occur with slab construction on shrink/swell sensitive

soils. In soils which become desiccated in summer, subsequent capillary moisture rise may cause dry soils to wet up and swell, causing slab uplift and building distress. Alternatively, construction during winter may result in subgrade soils with high moisture contents drying out through summer, with subsequent soil shrinkage and possible building deformation.

The structural engineer should take likely construction timeframes into account and confirm that their design and construction methodologies will accommodate the soil shrinkage or swelling that may occur.

The Contractor should ensure that the ground beneath the floor slab areas is suitably conditioned to ensure that the subgrade is neither too dry nor too wet prior to hardfill placement and concrete pouring to avoid undue shrink or swell movements.

#### 6.5.8 Building maintenance - Owners responsibility

The owner is responsible for maintenance of the building and site and should be familiar with the performance and maintenance requirements set out in CSIRO sheet BTF18 Foundation Maintenance and Footing Performance: A Home Owners Guide. A copy of this sheet is included in Appendix D.

#### 6.5.6 Retaining walls / Earthworks

No retaining wall construction in excess of 1.5 metres height and no earthworks involving fills in excess of 600mm depth should take place on these Lots unless endorsed by a suitable design undertaken by a Chartered Professional (Geotechnical) Engineer familiar with the contents of this report and responsible for design of structural elements of the building.

#### 6.6 Underfill (Subsoil) drainage

Underfill (Subsoil) drains have been installed during subdivisional development in the locations shown on the Woods Shear Key, Undercuts & Subsoil Drains As-Built Plan (Woods Ref 33210-03A-AB-120) in Appendix A1, and on T+T Drawing 21854.001-P2S3A-102 in Appendix A2. These drains are considered to be maintenance free. This drainage system is relatively deep and located so that it is unlikely to be encountered during future residential site development. Although future works are unlikely to encounter the drains, their location should be considered prior to designing deep foundations and, if damaged, repairs should be observed by a Chartered Professional (Geotechnical) Engineer familiar with this report, and notified to Auckland Council.

The subsoil drains running along the boundary of Lots 331, 333/334, 336/337 and 339/340 are relatively shallow (approximately 1m below current ground surface) and will need to be taken into account when undertaking residential design and construction on this property. Piling of foundations to below a 45 degree line extending up from the invert of the drains will be required in proximity to the drain in these Lots, to avoid surcharging the drain.

The Woods Shear Key, Undercuts & Subsoil Drains As-Built Plan (Woods Ref 33210-03A-AB-120) shows the location and invert of the subsoil drains through these Lots.

#### 6.7 Stormwater and Sanitary Sewer Lines

Where building envelopes lie adjacent to or across service lines, all foundations should extend and be founded below the 45 degree zone of influence line extending from pipe inverts. This requirement is to avoid excessive pipe surcharges, and to allow for future maintenance of the system without detrimentally affecting adjacent structures. Subject to approval from Auckland Council, foundations may extend and bridge over service lines provided specific

foundation design is undertaken. A copy of the stormwater as-built plans are included in Appendix A1.

#### 6.8 Road and Access Lots

Based on the fill monitoring and site observations undertaken during site development, the filled and natural ground within Precinct 2, Stage 3A is considered generally suitable for residential road and accessway construction. Scala penetrometer testing should be undertaken when road subgrades have been prepared to confirm subgrade strengths. Subject to such subgrade testing, for future road construction in other parts of the Precinct 2 Stage 3A development, within natural ground, a design CBR of 2% is considered appropriate, while within engineered fill areas, a design CBR of 7% is appropriate.

#### 6.9 Unexpected ground conditions

Our assessment is based on interpolation between borehole positions, site observations and periodic earthworks control visits. Local variations in ground conditions may occur. Although unlikely, unfavourable ground conditions may be encountered during site benching and footing excavations. It is important that we be contacted in this eventuality, or in the event that any variation in subsoil conditions from those described in the report are found. Design assistance is available as required to accommodate any unforeseen ground conditions present.

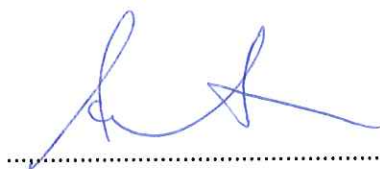
## 7 Applicability

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

It does not remove the necessity for the normal inspection of foundation conditions at the time of erection of any dwelling, especially in cases where concrete blockwork and/or brick veneer or stucco plaster buildings are sited partly on fill or partly on natural ground, or where they are entirely sited on filling whose depth changes significantly across the building platform.

Tonkin & Taylor Ltd

Report prepared by:



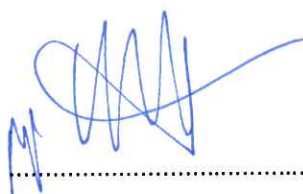
Andrew Linton  
Senior Geotechnical Engineer

Technical review by:



Andrew Stiles  
Senior Geotechnical Engineer

Authorised for Tonkin & Taylor Ltd by:



Chris Freer  
Project Director BE (Civil), MIPENZ, C.P. Eng.

JXXL

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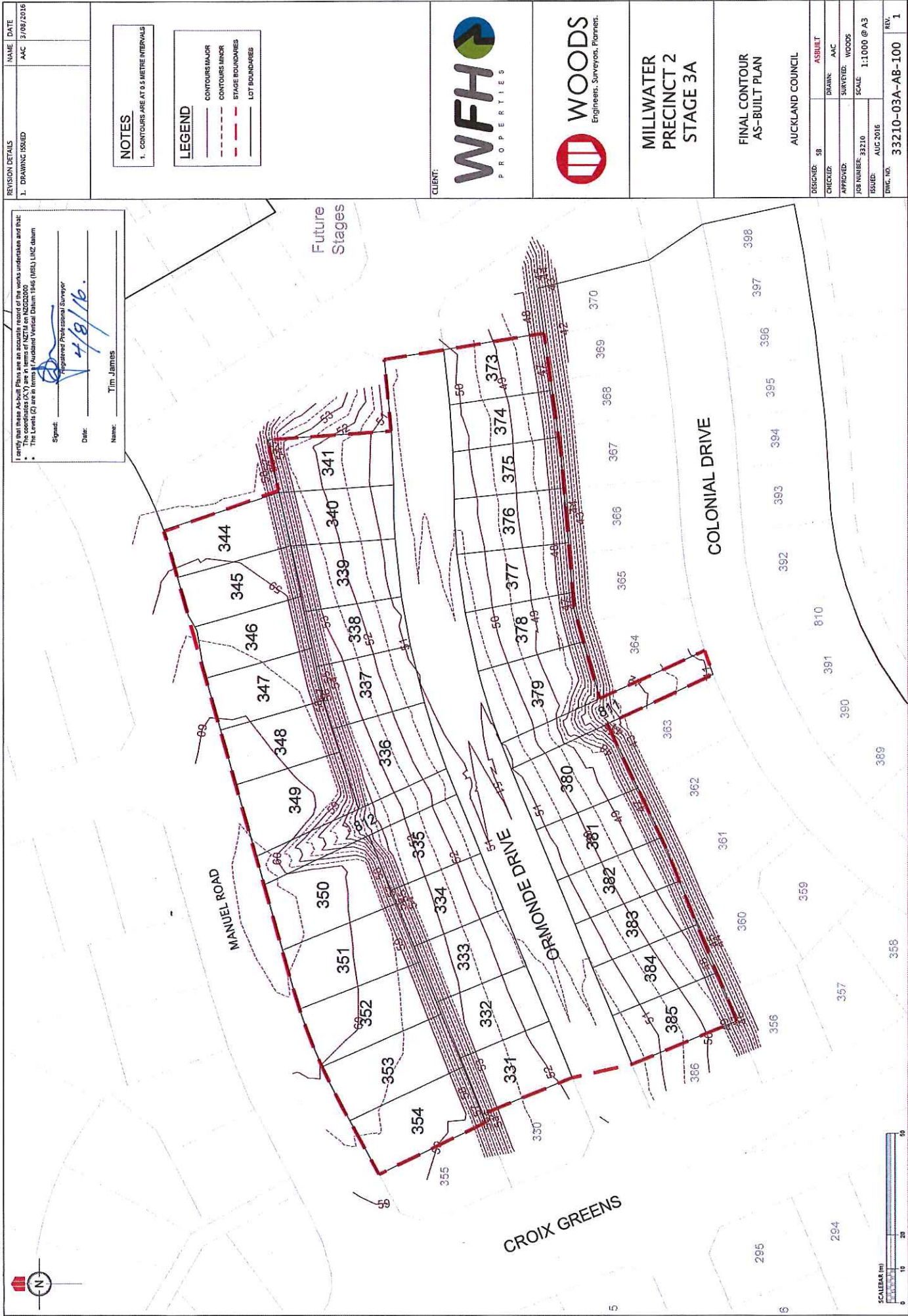
## 8 References

- [1] Tonkin & Taylor Ltd., October 2001. *Stoney Block*, T+T Ref. 18214.
- [2] Tonkin & Taylor Ltd., May 2001. *Silverdale Blocks, Silverdale, Geotechnical Issues – Future Medium Density Development*, T+T Ref. 18213.
- [3] Tonkin & Taylor Ltd., November 2003. *Silverdale North and Orewa West Blocks, Silverdale, Geotechnical Issues – Future Medium Density Development*, T+T Ref. 20914.
- [4] Tonkin & Taylor Ltd., November 2004. *Wainui Road Subdivision, Silverdale, Geotechnical Investigation Report*, T+T Ref. 21854.
- [5] Tonkin & Taylor Ltd., October 2005. *Wainui Road Subdivision, Silverdale, Geotechnical Investigation Report – Scheme Plan 7*, T+T Ref. 21854.
- [6] Tonkin & Taylor Ltd., March 2006. *Silverdale North – Westlake Block, Geotechnical Investigation Report*, T+T Ref. 21854.
- [7] Tonkin & Taylor Ltd., June 2014. *Millwater – Precinct 2, Geotechnical Investigation Report*. T+T Ref. 21854.001
- [8] New Zealand Standards, 1989. *NZS 4431:1989 Code of Practice for Earth Fill for Residential Development*.
- [9] Standards Australia, 2011. *AS 2870:2011 Residential slabs and footings*.
- [10] New Zealand Standards, 2011. *NZS 3604:2011 Timber Framed Buildings*.

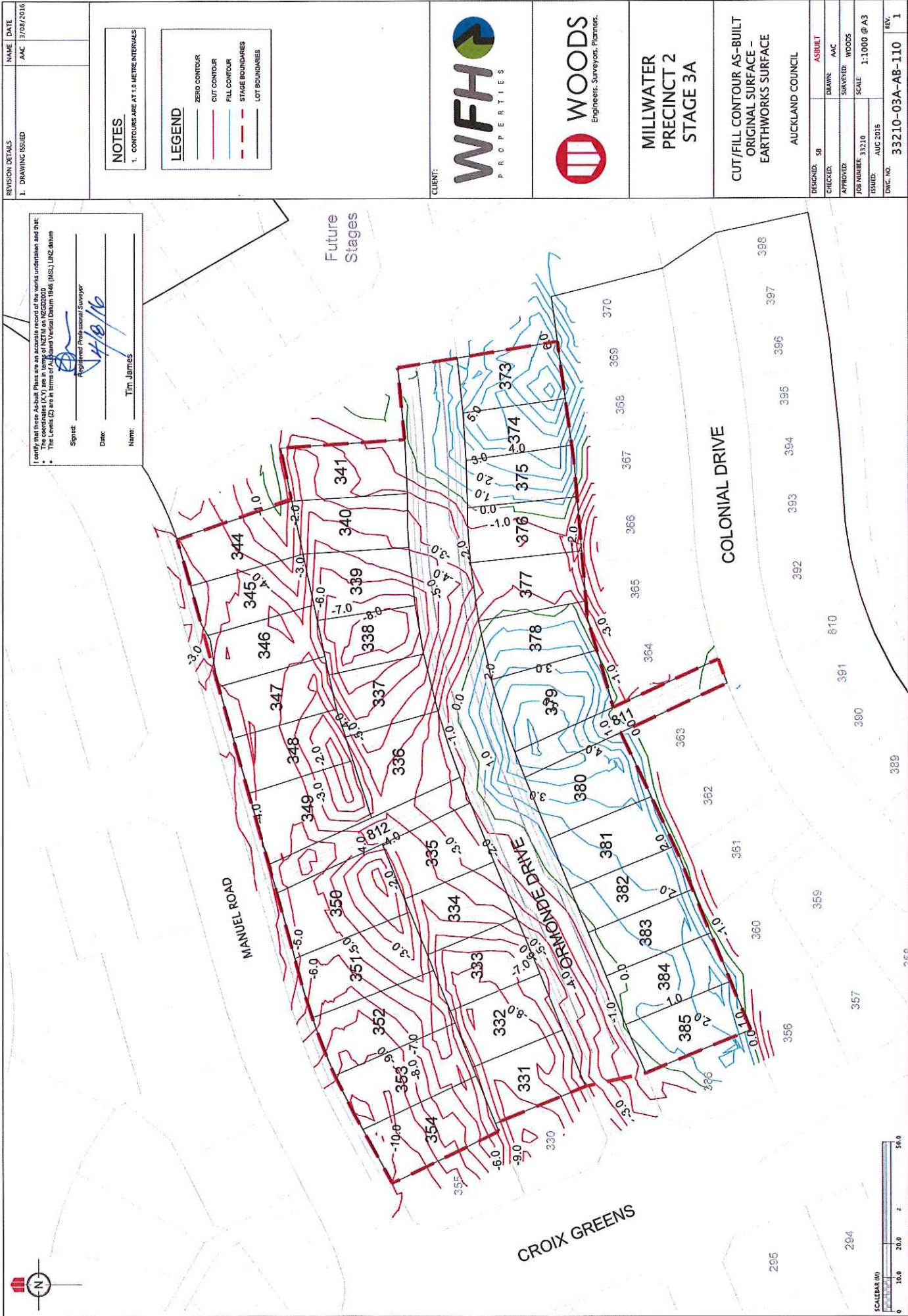
## Appendix A1: Woods Drawings

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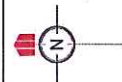
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- 33210-03A-AB-111 Cut/Fill Contour As-Built Plan Earthworks Surface – Final Surface
- 33210-03A-AB-112 Cut/Fill Contour As-Built Plan Original Surface – Final Surface
- 33210-03A-AB-120 Shear Key, Undercuts & Subsoil Drains As-Built Plan
- 33210-3A-AB-300 to 303 Stormwater Drainage As-Built Plans











I certify that these As-built Plans are an accurate record of the works undertaken and that:  
• The coordinates (X,Y) are in terms of NZTM on NGC2009  
• The Levels (Z) are in terms of New Zealand Vertical Datum 1949 (NZVD) UNZ datum

Signed:  Registered Professional Surveyor

Date: 4/8/16

Name: Tim James

MANUEL ROAD

CROIX GREENS

COLONIAL DRIVE

Futur Stage

### NOTES

1. CONTOURS ARE AT 0.25 METRE INTERVALS

### LEGEND

- ZERO CONTOUR
- CUT CONTOUR
- FILL CONTOUR
- STAGE BOUNDARIES
- LOT BOUNDARIES

CLIENT:



**WOODS**  
Engineers, Surveyors, Planners.

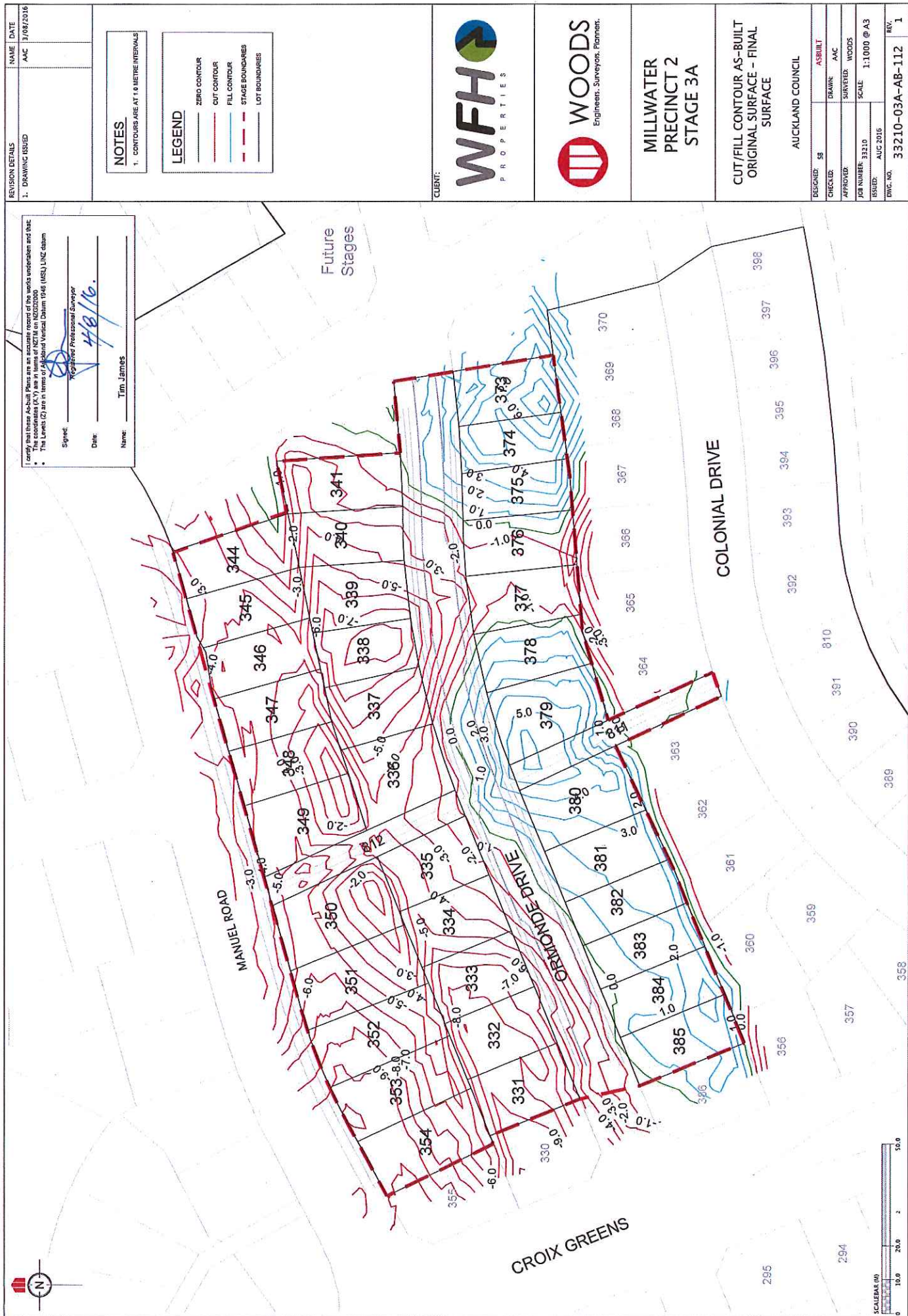
MILLWATER  
PRECINCT 2  
STAGE 3A

CUT/FILL CONTOUR AS-BUILT  
EARTHWORKS SURFACE - FINAL  
SURFACE

AUCKLAND COUNCIL

DESIGNED	58	ASBUILT
CHECKED		DRAWN: AAC
APPROVED		SURVEYED: WOODS
JOB NUMBER	33210	SCALE 1:1000 @ A3
ISSUED	AUG 2016	
DWG. NO.	33210-03A-AB-111	REV. 1





Consent and Resource Authorisation Plans are to be submitted to the Council for approval. The consented (R) is in terms of the Resource Management Act 1991. The Levels (Z) are in terms of Mean Sea Level (MSL) datum.

Signed: Tim James  
Date: 4/8/16  
Name: Tim James  
Professional Surveyor

REVISION DETAILS		NAME	DATE
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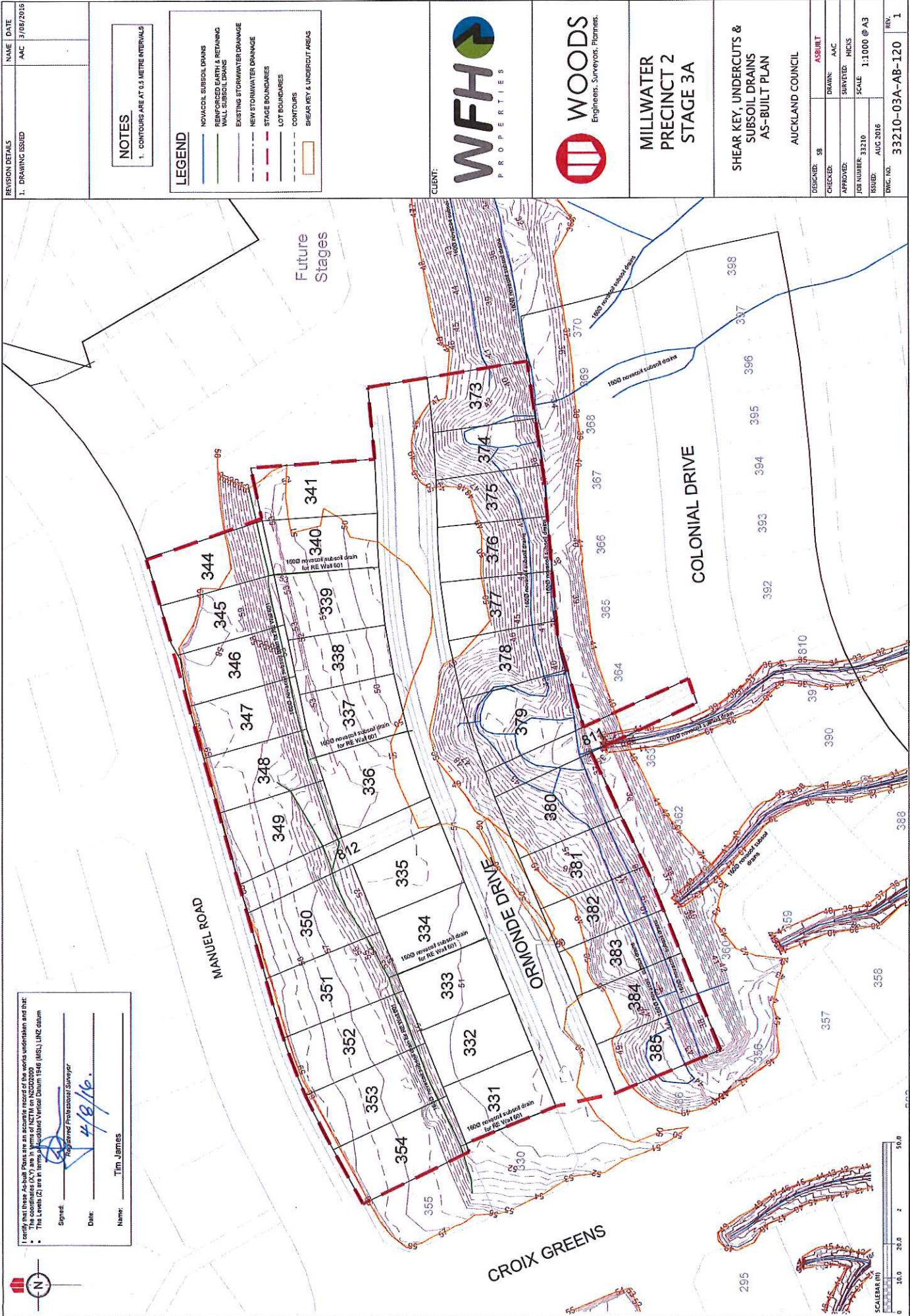
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	LOT BOUNDARIES

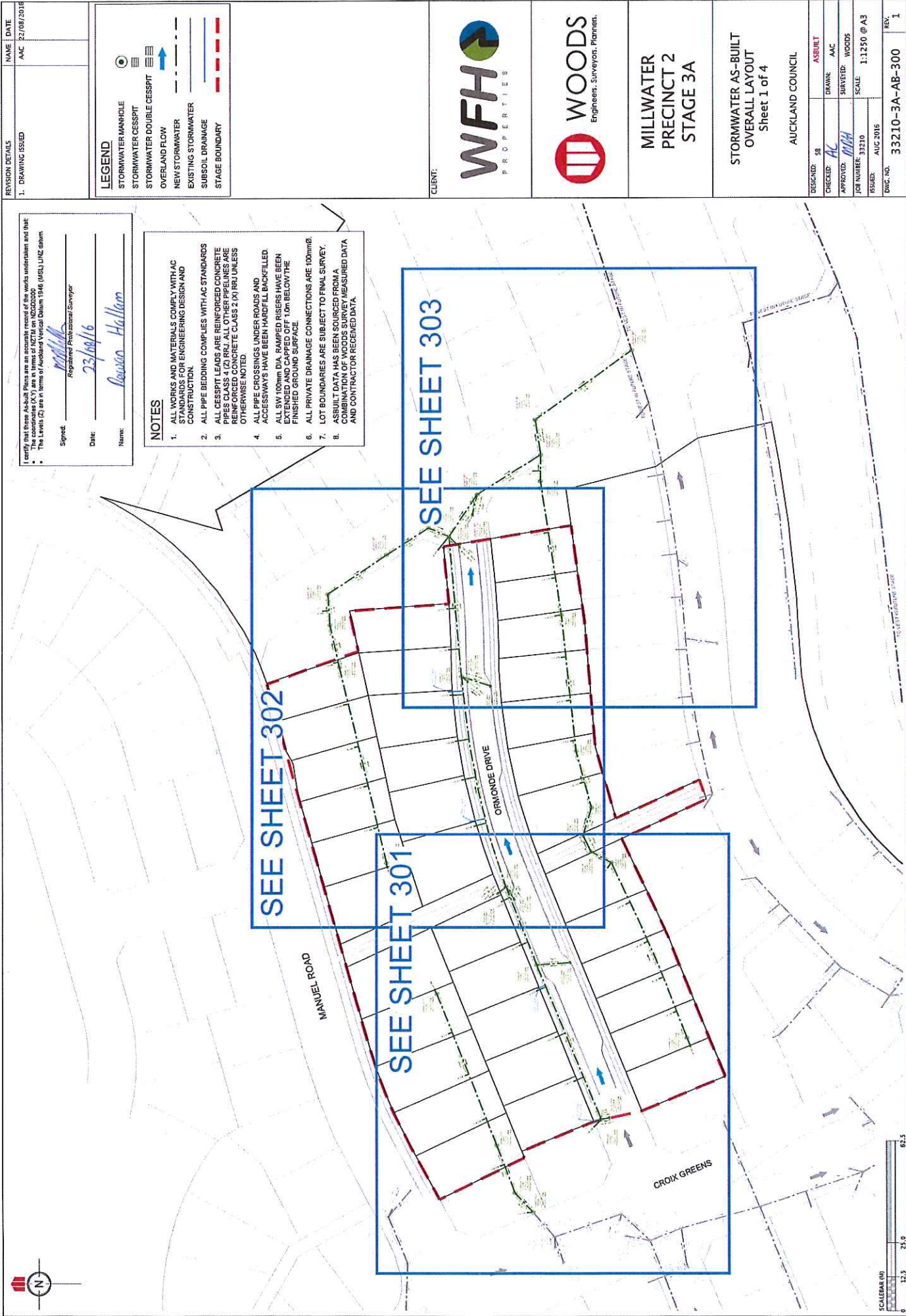
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AUCKLAND COUNCIL	

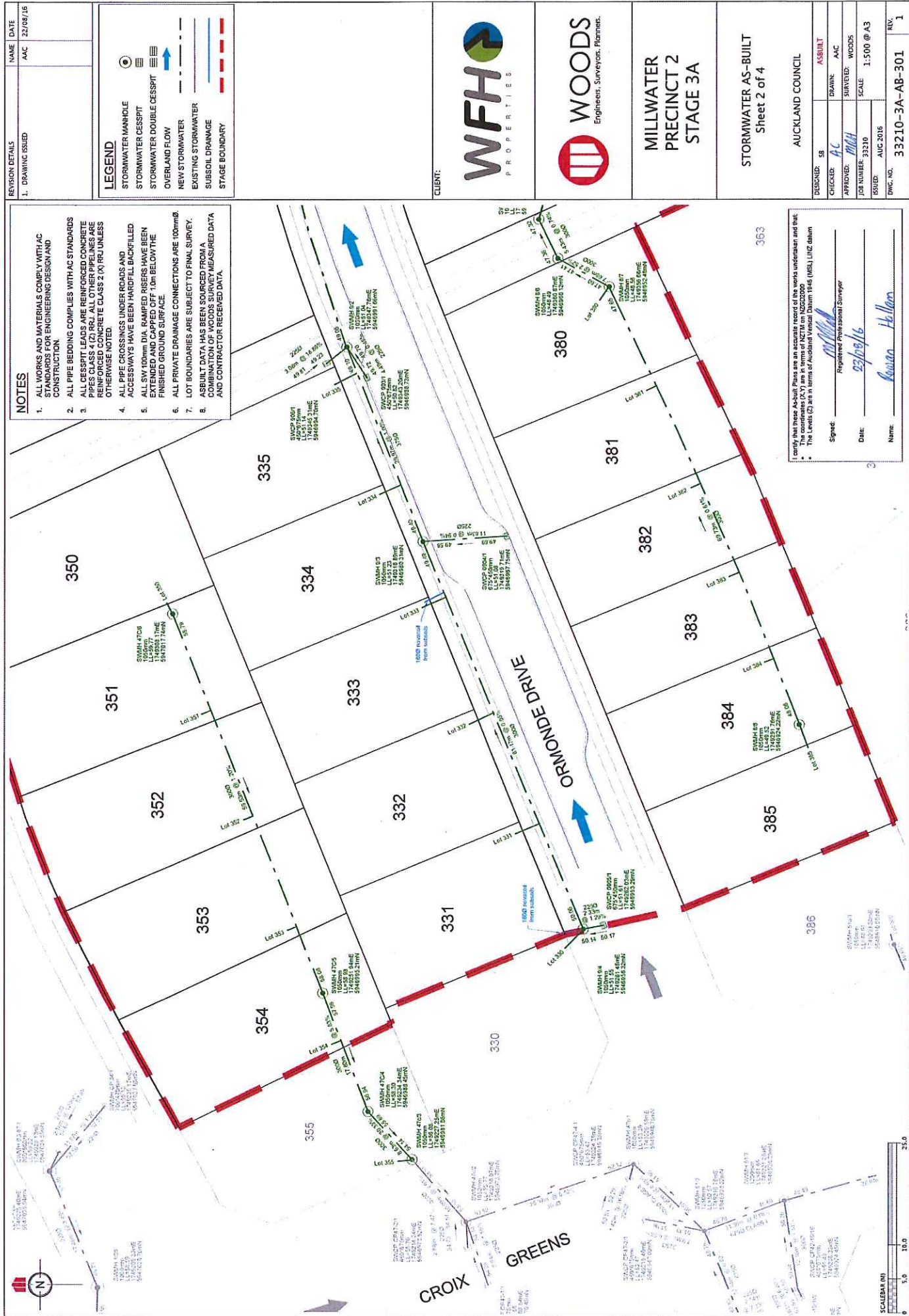
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ISSUED: AUG 2016	
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## **Appendix A2: T+T Drawings**

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- 21854.001-P2S3A-100 Drawing List and Site Location Plan
- 21854.001-P2S3A-101 Geotechnical Works Plan
- 21854.001-P2S3A-102 Geotechnical Works Subsoil Drain Plan
- 21854.001-P2S3A-103 Geological Cross Section 3
- 21854.001-P2S3A-104 Geological Cross Section 4
- 21854.001-P2S3A-105 Typical Reinforced Earth Slope Details
- 21854.001-P2S3A-106 Shear Key 03 Plan
- 21854.001-P2S3A-107 Shear Key 03 Longsection
- 21854.001-P2S3A-108 Geology Legend and Definition of Terms
- 21854.001-P2S3A-110 Building Limitation Plan



WHF PROPERTIES LTD  
RESIDENTIAL SUBDIVISION  
MILLWATER-PRECINCT 2 (STAGE 3A)  
Completion Report Issue

DRAWING Rev Title

GENERAL	
• 21854.001-P2S3A-100	1 Drawing List and Site Location Plan
• 21854.001-P2S3A-101	1 Geotechnical Works Plan
• 21854.001-P2S3A-102	1 Geotechnical Works Subsoil Drain Plan
• 21854.001-P2S3A-103	1 Geological Cross Section 3
• 21854.001-P2S3A-104	1 Geological Cross Section 4
• 21854.001-P2S3A-105	1 Typical Reinforced Earth Slope Details
• 21854.001-P2S3A-106	1 Shear Key 03 Plan
• 21854.001-P2S3A-107	1 Shear Key 03 Longsection
• 21854.001-P2S3A-108	1 Geology Legend and Definition of Terms
• 21854.001-P2S3A-110	1 Building Limitation Plan

APPENDIX E

• 21854.001-P2S3A-111	1 Post Earthworks Investigation Plan
• 21854.001-P2S3A-112	1 Topsoil Depths Plan
• 21854.001-P2S3A-113	1 Earthworks Testing Location Plan

• Denotes drawing this issue: 8/09/2016



Street map sourced from Land Information New Zealand data (Crown Copyright Reserved).

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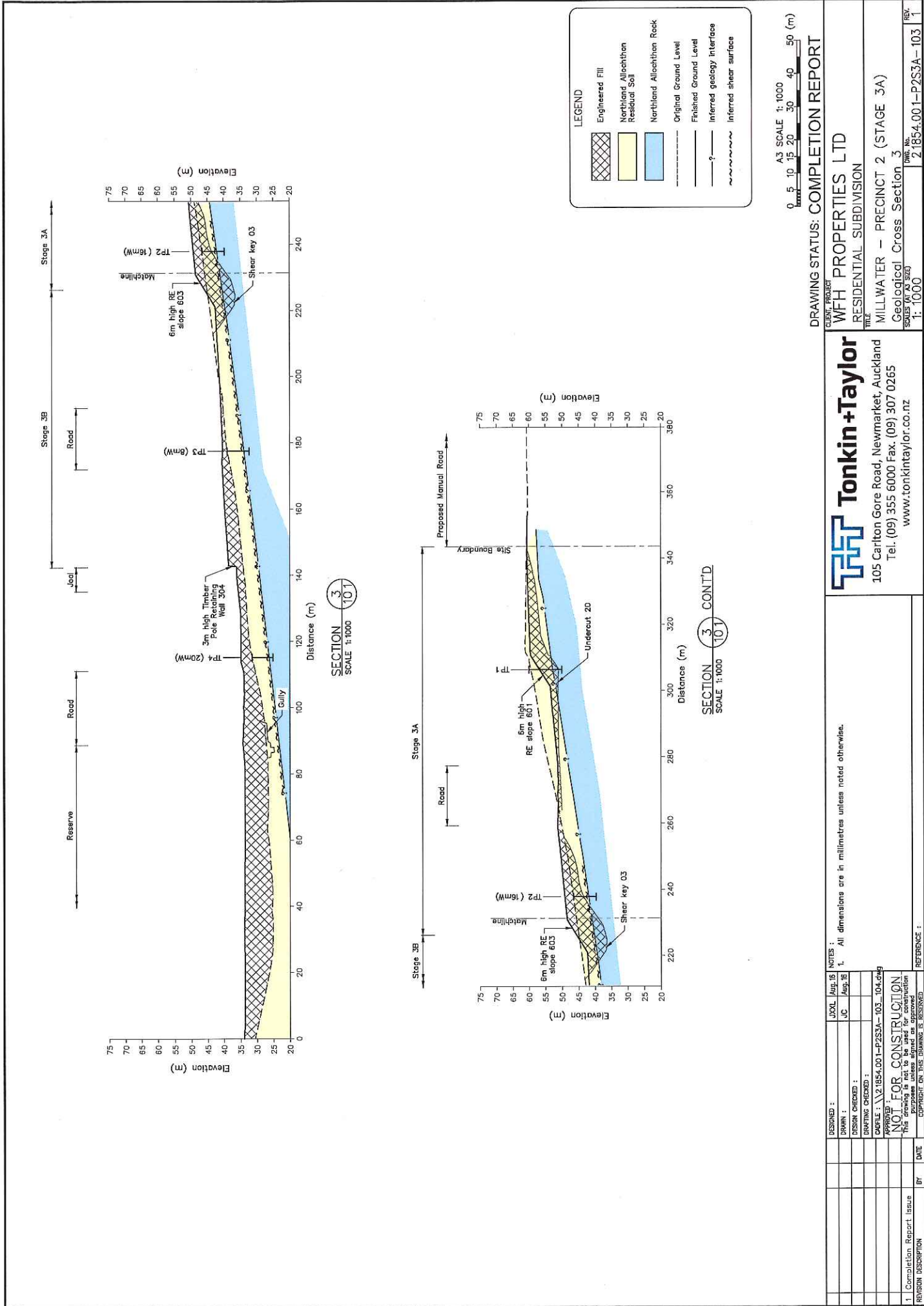
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MILLWATER - PRECINCT 2 (STAGE 3A)		MILLWATER - PRECINCT 2 (STAGE 3A)	
Drawing List and Site Location Plan		Drawing List and Site Location Plan	
21854.001-P2S3A-100		21854.001-P2S3A-100	
AS SHOWN		AS SHOWN	
105 Carlton Gore Road, Newmarket, Auckland Tel. (09) 355 6000 Fax. (09) 307 0265 www.tonkintaylor.co.nz		105 Carlton Gore Road, Newmarket, Auckland Tel. (09) 355 6000 Fax. (09) 307 0265 www.tonkintaylor.co.nz	
Tonkin+Taylor		Tonkin+Taylor	
105 Carlton Gore Road, Newmarket, Auckland Tel. (09) 355 6000 Fax. (09) 307 0265 www.tonkintaylor.co.nz		105 Carlton Gore Road, Newmarket, Auckland Tel. (09) 355 6000 Fax. (09) 307 0265 www.tonkintaylor.co.nz	
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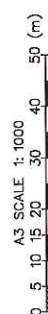
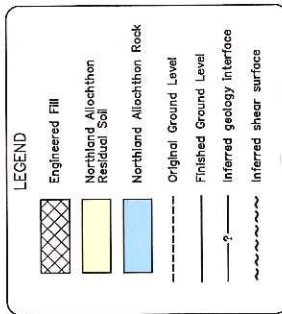
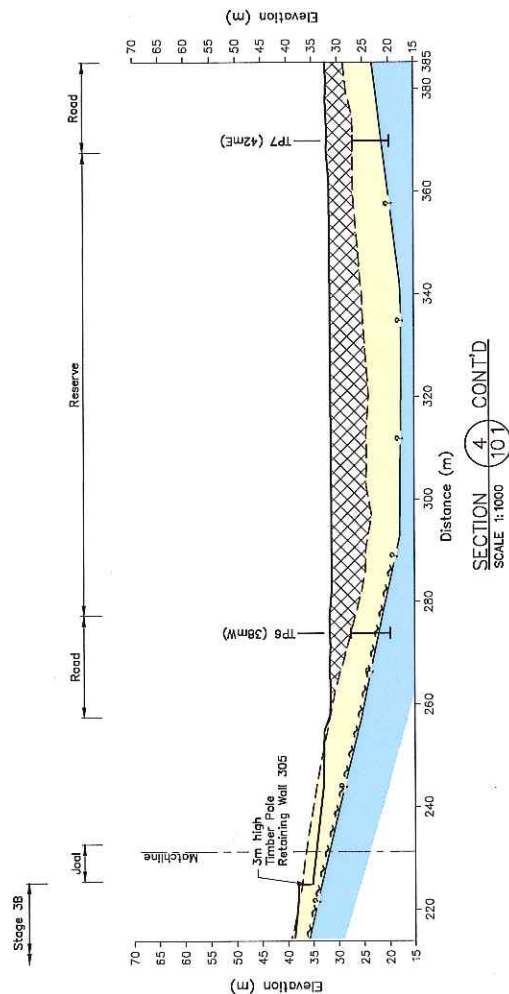
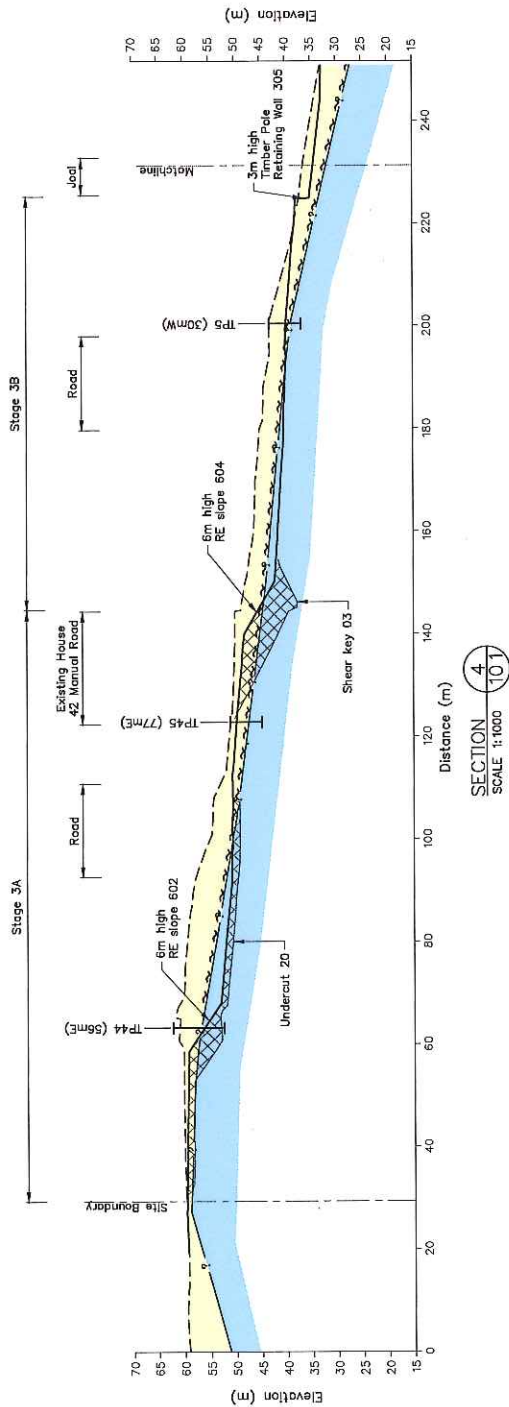
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TITLE: MILLWATER - PRECINCT 2 (STAGE 3A)  
Geological Cross Section 3  
DWG. No. 2.1854.001-P2S3A-103  
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APPROVED :			REV.	1
1. Completion Report issue				
REVISION DESCRIPTION	BY	DATE		

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SHEAR KEY 03 PLAN  
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ORIGINAL IN COLOUR

REVISION	DESCRIPTION	BY	DATE
1	Completion Report Issue		

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NOT FOR CONSTRUCTION		
This drawing is not to be used for construction		
COPYRIGHT ON THIS DRAWING IS RESERVED		

NOTES :  
1. All dimensions are in metres unless noted otherwise.  
2. As-built plan supplied by WOODS, reference file name "33211-03A-AB-100 FINAL CONTOURS.dwg" dated 4 Aug 2016.  
3. Undercuts, shearkey & subsoil drains supplied by WOODS, reference file name "33211-03A-AB-120 SK UC & SUBSOIL.dwg" dated 4 Aug 2016.  
4. Coordinate Datum: NZGD2000, New Zealand Transverse Mercator (NZTM2000). Level Datum: LINZ (MSL) Auckland Vertical Datum 1946

DRAWING STATUS: COMPLETION REPORT

**Tonkin+Taylor**  
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CLIENT PROJECT  
**WFH PROPERTIES LTD**  
RESIDENTIAL SUBDIVISION

TITLE  
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Shear Key 03 Plan

DWG. NO.  
21854.001-P253A-106

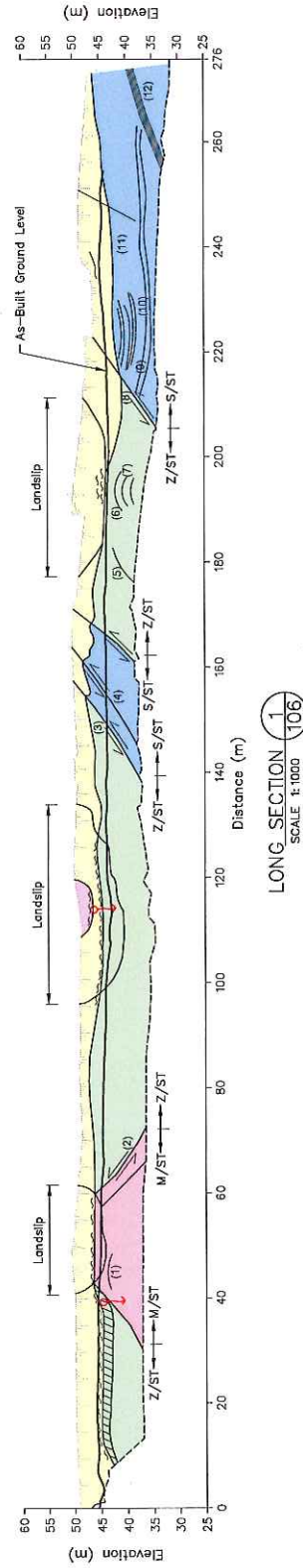
REV.  
1

Note: Refer Dwg. No. 21854-001-P2S3A-108 for  
Geology Legend and Definition of Terms

A3 SCALE 1:1000



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- (5) B 15°/337' UN, SM, VT, CN
- (6) B 20°/285' PL, SM, VT, CN
- (7) B 21°/0'12' PL, SM, VT, CN
- (8) F 12°/336' PL, SL, T, CV
- (9) B 15°/334' UN, RO, T, CN
- (10) B 6°/253' UN, RO, T, CN
- (11) B 11°/285' PL, RO, VT, CN
- (12) SZ 14°/260' UN, SL, T, CV



DRAWING STATUS: COMPLETION REPORT





DESIGNED : JXXL Aug 16		NOTES :	
DRAWN : JJC Aug 16		1. All dimensions are in metres unless noted otherwise.	
DESIGN CHECKED :		2. As-built plan supplied by WOODS, reference file name "33211-03A-AB-100 FINAL CONTOURS.dwg" dated 4 Aug 2016.	
DRAFTING CHECKED :		3. Undercuts, shearkey & subsoil drains supplied by WOODS, reference file name "33211-03A-AB-120 SK UC & SUBSOIL.dwg" dated 4 Aug 2016.	
DATEFILE : \\21854-001-P2S3A-108_107.dwg			
APPROVED :			
NOT FOR CONSTRUCTION			
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COPYRIGHT ON THIS DRAWING IS RESERVED			
REVISION DESCRIPTION	BY	DATE	REFERENCE :
1. Completion Report Issue			
CLIENT: PROJECT			
WFH PROPERTIES LTD			
RESIDENTIAL SUBDIVISION			
TITLE			
MILLWATER - PRECINCT 2 (STAGE 3A)			
Shear Key 03 Longsection			
SCALE (AT A3 SIZE)			
1: 1000			
DWG. No.			
21854.001-P2S3A-107			
REV.			
1			





















**3. TYPICAL EXAMPLE:**

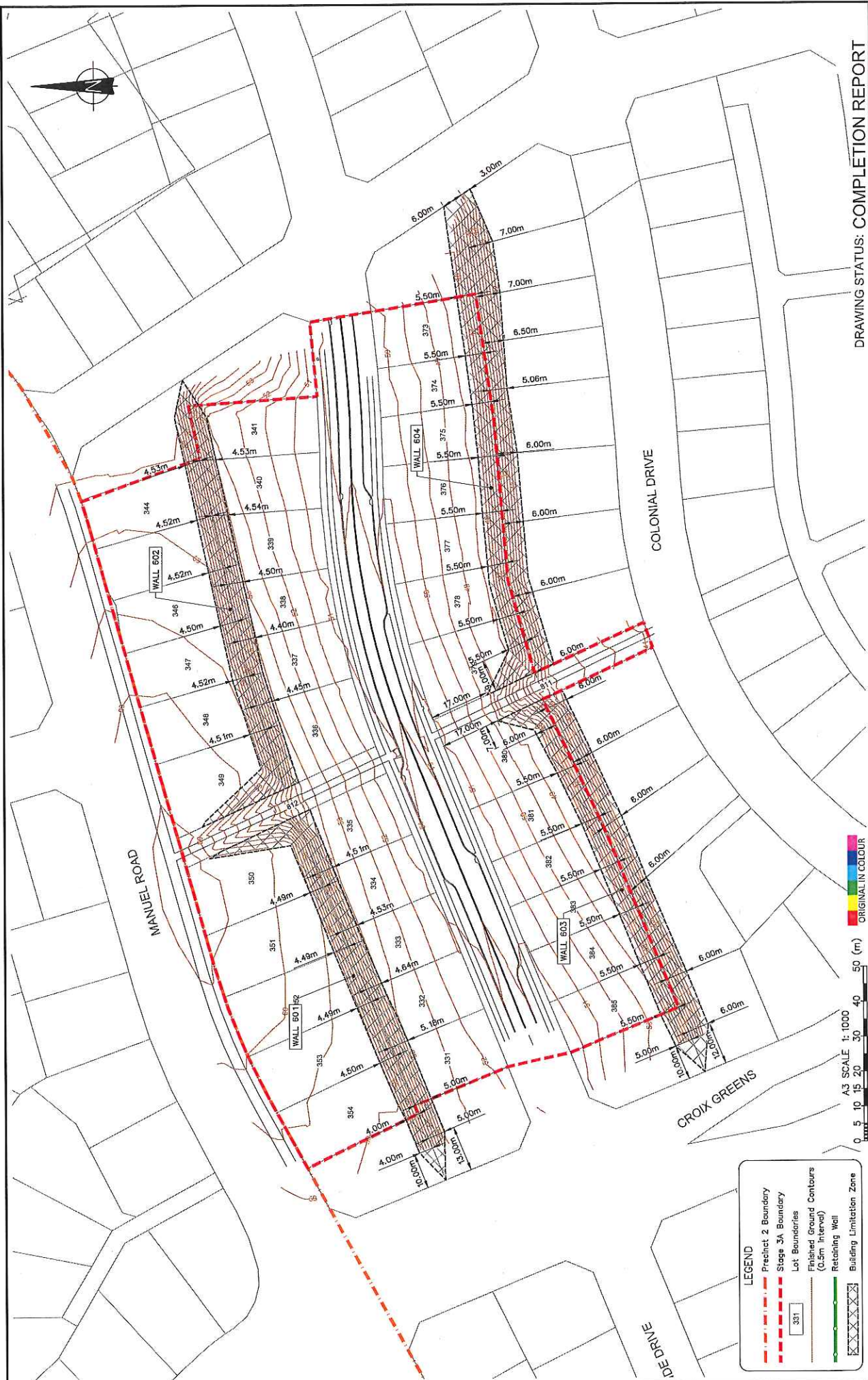
No. in defect set	→
Dip angle	→
Dip direction	→
Shape	→
Roundness	→
Aperture	→
Grinding/Cooling Type	→
Infilling Description (per Soil Description)	→

60/62, PL SL, 1. CV, stiff green CLAY

TYPE	TERM	CODE	SYMBOL
	Bedding	B	
	Joint	J	
	Shear zone	SZ	
	Fault trace	F	

LONNSECCTION MATERIAL LEGEND	
	Alluvium Silty Clay and Clayey Silt, firm to stiff, moist to wet, light grey to white, organic layers, generally thinly bedded (siltarozaria)
	Colluvium Clayey Silt, firm to stiff, moist, light grey mottled orange/brown
	East Coast Bay Formation Sills Stiff to very stiff Silty Clay, Clayey Silt and minor Silty Sand, moist to wet, light yellow to light grey
	MW East Coast Bays Formation Moderately Weathered EGBF Silty Clay and Clayey Silt, minor Silty Sand, very stiff, wet, dark grey, thinly bedded
	SW-LW East Coast Bays Formation Slightly to unweathered EGBF Interbedded Sandstone, Siltstone and Mudstone. Sandstone, Silty, very weak, dark grey. Siltstone and Mudstone, extremely weak to very weak, dark grey
	Northland Allochthon residual soil, stiff to very stiff silts and clays, moist, moderately to highly plastic, light yellow grey
	Northland Allochthon "softened zone" Moderate to Slightly weathered siltstones and/or mudstone, extremely to very weak, grey, red/brown and black, highly plastic, many silty layers, many polished surfaces. Some green grey and black beds.
	NORTHLAND ALLOCHTHON Siltstone, highly weathered to moderately weathered, dark grey and light brown, fractured, common minor polished surfaces at various orientations, generally dry
	NORTHLAND ALLOCHTHON Mudstone, highly weathered, grey and red/brown, fractured, common minor polished surfaces at various orientations, dry to damp
	NORTHLAND ALLOCHTHON Sandstone, highly weathered to moderately weathered, grey/brown and light green/grey, fractured, generally dry
	Engineered Fill
	Saturated Zone
	Concretion Typically moderately strong, Sandstone units
	Groundwater seepage
	Shear Surface
	Existing Ground Level
	Undercut Level

ORIGINAL IN COLOUR		DRAWING STATUS: COMPLETION REPORT																													
<table><tr><td>DESIGNED :</td><td>JJOL</td><td>Aug. 16</td></tr><tr><td>DRAWN :</td><td>JC</td><td>Aug. 16</td></tr><tr><td>DESIGN CHECKED :</td><td></td><td></td></tr><tr><td>DRAFTING CHECKED :</td><td></td><td></td></tr><tr><td>CADFILE :</td><td colspan="2">\\21854.001-P253A-108.dwg</td></tr><tr><td>APPROVED :</td><td colspan="2">NOT FOR CONSTRUCTION</td></tr><tr><td colspan="3">This drawing is unissue signed or approved</td></tr><tr><td colspan="3">COPYRIGHT ON THIS DRAWING IS RESERVED</td></tr></table>		DESIGNED :	JJOL	Aug. 16	DRAWN :	JC	Aug. 16	DESIGN CHECKED :			DRAFTING CHECKED :			CADFILE :	\\21854.001-P253A-108.dwg		APPROVED :	NOT FOR CONSTRUCTION		This drawing is unissue signed or approved			COPYRIGHT ON THIS DRAWING IS RESERVED			<table><tr><td colspan="2">NOTES :</td></tr><tr><td colspan="2">1. All dimensions are in millimetres unless noted otherwise.</td></tr></table>		NOTES :		1. All dimensions are in millimetres unless noted otherwise.	
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 <b>Tonkin + Taylor</b> 105 Carlton Gore Road, Newmarket, Auckland Tel. (09) 355 6000 Fax. (09) 307 0265 www.tonkintaylor.co.nz		<table><tr><td colspan="2">CLIENT PROJECT</td></tr><tr><td colspan="2">WFH PROPERTIES LTD</td></tr><tr><td colspan="2">RESIDENTIAL SUBDIVISION</td></tr><tr><td colspan="2">TITLE</td></tr><tr><td colspan="2">MILLWATER — PRECINCT 2 (STAGE 3A)</td></tr><tr><td colspan="2">Geology Legend and Definition of Terms</td></tr><tr><td>SCALE (Vertical)</td><td>1:100</td></tr><tr><td>AS SHOWN</td><td>21854.001-P253A-108 1</td></tr></table>		CLIENT PROJECT		WFH PROPERTIES LTD		RESIDENTIAL SUBDIVISION		TITLE		MILLWATER — PRECINCT 2 (STAGE 3A)		Geology Legend and Definition of Terms		SCALE (Vertical)	1:100	AS SHOWN	21854.001-P253A-108 1												
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NO.	REVISION DESCRIPTION	BY	DATE																												
1	Completion Report Issue																														



**LEGEND**

- Precinct 2 Boundary
- Stage 3A Boundary
- Lot Boundaries
- Finished Ground Contours (0.5m Interval)
- Retaining Wall
- Building Limitation Zone



DESIGNED :		JXC	Aug. 16
DRAWN :		JJC	Aug. 16
DESIGN CHECKED :			
DRAFTING CHECKED :			
CAPFILE :		\\21854.001-P2S3A-110.dwg	
APPROVED :		NOT FOR CONSTRUCTION	
1. Completion Report Issue		DATE	BY
REVISION DESCRIPTION		COPYRIGHT ON THIS DRAWING IS RESERVED	

NOTES :

- All dimensions are in metres unless noted otherwise.
- As-built plan supplied by WOODS, reference file name "33211-03A-AB-100 FINAL CONTOURS.dwg" dated 4 Aug 2016.
- Undercuts, shearkey & subsoil drains supplied by WOODS, reference file name "33211-03A-AB-120 SK UC & SUBSOIL.dwg" dated 4 Aug 2016.
- Coordinate Datum: NZGD2000, New Zealand Transverse Mercator (NZTM2000). Level Datum: LINZ (MSL) Auckland Vertical Datum 1946

**Tonkin+Taylor**  
105 Carleton Gore Road, Newmarket, Auckland  
Tel. (09) 355 6000 Fax. (09) 307 0265  
www.tonkintaylor.co.nz

**DRAWING STATUS: COMPLETION REPORT**

CLIENT: PROJECT  
**WFH PROPERTIES LTD**  
RESIDENTIAL SUBDIVISION

TITLE  
**MILLWATER - PRECINCT 2 (STAGE 3A)**  
Building Limitation Plan

SCALE: (AT A3 SIZE)  
1:1000

WKS NO:  
21854-001-P2S3A-110

REV:  
1



## **Appendix B: Contractors Certificates**

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- **Hick Bros Ltd – Sixth Schedule (Bulk Earthworks)**
- **Hopper Construction Ltd – Sixth Schedule (Civil Earthworks)**
- **FGS Group Ltd – Producer Statement 3 (Pool Fence Installation for RE Slopes)**

**PS3 - FORM OF PRODUCER STATEMENT- CONSTRUCTION**

**ISSUED BY:** HICK BROS CIVIL CONSTRUCTION LIMITED

**TO:** WFH PROPERTIES

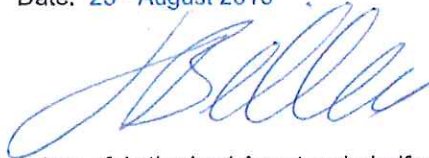
**IN RESPECT OF:** MILLWATER PRECINT 2 STAGE 3 GEOTECHNICAL REMEDIATION AND BULK EARTHWORKS

**AT:** PRECINCT 2 STAGE 3 CONTRACT 33213 - 01

HICK BROS CIVIL CONSTRUCTION LTD has contracted to WFH PROPERTIES to carry out and complete certain building works in accordance with a contract, titled MILLWATER PRECINT 2 STAGE 3 GEOTECHNICAL REMEDIATION AND BULK EARTHWORKS ("the contract")

I JAMES BILKEY a duly authorized representative of HICK BROS CIVIL CONSTRUCTION LIMITED believe on reasonable grounds that HICK BROS CIVIL CONSTRUCTION LIMITED has carried out and completed part only as specified in the attached particulars of the contract works in accordance with the contract.

Date: 23<sup>rd</sup> August 2016



*(Signature of Authorized Agent on behalf of)*

HICK BROS CIVIL CONSTRUCTION LIMITED  
*(Contractor)*

42 FORGE ROAD, SILVERDALE  
*(Address)*

Attachments:

- 1) List detailing works carried out

ATTACHMENT 1

**MILLWATER PRECINT 2 STAGE 3 GEOTECHNICAL REMEDIATION AND BULK EARTHWORKS**

LIST OF WORK CARRIED OUT:

- 1) All the earthworks within Stage 3
- 2) Construction of Reinforced Earth Wall 601 including drainage
- 3) Construction of Reinforced Earth Wall 602 including drainage
- 4) Construction of Reinforced Earth Wall 603 including drainage
- 5) Construction of Reinforced Earth Wall 604 including drainage
- 6) Construction of Reinforced Earth Wall 605 including drainage
- 7) Construction of Reinforced Earth Wall 606 including drainage
- 8) Construction of Reinforced Earth Wall 404 including drainage
- 9) Construction of Reinforced Earth Wall 405 including drainage
- 10) Subsoil drainage as instructed and asbuilt

JB

## Schedule 6 – Form of Producer Statement – Construction

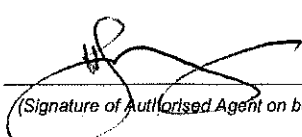
ISSUED BY	Hopper Construction Limited	(Contractor)
TO	WFH Properties Ltd	(Principal)
IN RESPECT OF	Millwater Precinct 2 Stage 3A contract 33210-01	(Description of Contract Works)
AT	Manuel Road Millwater	(Address)

Hopper Construction Ltd (Contractor) has contracted to WFH Properties Ltd (Principal) to carry out and complete certain building works in accordance with a Contract titled Millwater P2 stage 3A ('the Contract')

I Howard Jury (Duly Authorised Agent) a duly authorised representative of Hopper Construction Ltd (Contractor) believe on reasonable grounds that Hopper Construction Ltd (Contractor) has carried out and completed:

- ☒ All
- ☐ Part only as specified in the attached particulars of the contract works in accordance with the Contract

*Click to enter details of attached particulars*

  
(Signature of Authorised Agent on behalf of)

Hopper Construction Limited

(Contractor)

17 Forge Road, Silverdale

(Address)

Date 25 July 2016

# Producer statement construction (PS3) General construction work



All sections of this form must be completed

## TO BE COMPLETED BY THE PERSON WHO HAS UNDERTAKEN THE BUILDING WORK

Author name: Troy Wilton Building consent No: R.62477

Author company: FLS Group Author Registration No: N/A

Description of building work:

Fence to top of battered wall.

Legal description:

Lot 1 DP 67675, Lot 1 DP 121041, Lot 2 DP 354443  
Lot 1 DP 340986, part allot 60 PSH of Waiwera, Lot 4  
dp 67675, Lot 2 dp 206067, Lot 1 dp 86940, Lot 1  
dp 308959 part Lot 2 dp 308959, Section 10 SP 364653,  
Sec 3 SO 457160, Sec 4 SO 457160, Pt allot 335 PSH of Waiwera  
Lot 1 dp 42190, Lot 1001 dp 472234

Site address:

Precinct 2 Silverdale North

NZBC clauses:  
(circle as applicable)

B1	B2	C1	C2	C3	C4	D1	D2	E1	E2	E3	F1
F2	F3	<u>F4</u>	F5	F6	F7	F8	G1	G2	G3	G4	G5
G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	H1	

I have sighted the above building consent and read the attached conditions of consent and confirm that I have undertaken the building work described above in accordance with the consented plans and specifications.

I understand that Council will rely upon this producer statement, for the purposes of establishing compliance with the above building consent.

Signature:

Troy Wilton

Date:

25/07/2016

Tradesperson's contact details:

Address:

135 Foundry rd. Silverdale

Postcode: 0944

Business:

09 377 - 8778

Fax:

Mobile:

Email

admin@fys.co.nz

## COUNCIL USE ONLY

☐ Central ☐ Henderson ☐ Manukau ☐ Orewa ☐ Papakura ☐ Pukekohe ☐ Takapuna

Received by:

Register checked:

YES

NO

Signature:

Registration current:

YES

NO

Producer statement accepted as establishing compliance with the consented plans:

YES

NO

## **Appendix C: NZS 3604:2011 Expansive Soils (Extract)**

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### **NZS 3604:2011 Expansive Soils (Extract)**

Expansive soils tend to be moderately to highly plastic clays that undergo appreciable volume change upon changes in moisture content. Technically, they are defined in NZS 3604:2011 as those soils having a liquid limit of more than 50% and a linear shrinkage of more than 15%. Where soils are quite silty or sandy, shrink and swell is less of a problem, due to the lower clay contents.

Building damage resulting from expansive soil movement can range from relatively minor brick veneer cracking and internal cracking on wall corners and wall ceiling corners with attendant door and windows jamming, through to extensive cracking of foundation block framework, extensive internal visual cracking and significant warping of building frames. Damage is dependent on building construction and materials and is rarely of structural concern.

NZS 3604:2011 "Timber Framed Buildings" defines good ground as follows:

*"Any soil or rock capable of permanently withstanding an ultimate bearing capacity of 300 kPa (i.e. an allowable bearing pressure of 100 kPa using a factor of safety of 3.0), but excludes:*

- a) Potentially compressible ground such as topsoil, soft soils such as clay which can be moulded easily in the fingers, and uncompacted loose gravel which contains obvious voids;*
- b) Expansive soils being those that have a liquid limit of more than 50% when tested in accordance with NZS 4402 Test 2.2, and a linear shrinkage of more than 15% when tested in accordance with NZS 4402 Test 2.6, and*
- c) Any ground which could foreseeably experience movement of 25 mm or greater for any reason including one or a combination of: land instability, ground creep, subsidence, seasonal swelling and shrinking, frost heave, changing ground water level, erosion, dissolution of soil in water, and effects of tree roots."*

Foundations on expansive soils are outside the scope of NZS 3604:2011 as an acceptable solution to the New Zealand Building Code (NZBC). Specific engineering design of foundation elements is involved where expansive soils are present with a recommendation that AS 2870:2011 is used for building design. While not mandatory, AS 2870 designs will allow for a non-specific design foundation to be used without resorting to further ongoing investigation or design.

This geotechnical completion report has classified the soils present on this subdivision to be in Site Class M as per the requirements of AS 2870:2011. Descriptions of the various site classes, together with characteristic surface ground movements are outlined below.

Allowing for some correlation with NZS 3604, the various site classes applicable to NZ conditions are considered to be:

Characteristic Surface Movements	Site Class	Description
a) 20 mm (Note NZS 3604:2011 assumes movement of 25 mm as part of underlying design.	Class A (sand) and/or Class S (Silts) Equivalent to NZS 3604:2011 "Good Ground" sites	Poor to slightly expansive
b) 20 mm – 40 mm	Class M	Moderately expansive
c) 40 mm – 60 mm	Class H1	Highly expansive
d) 60 mm – 75mm	Class H2	Highly expansive
e) > 75 mm	Class E	Extremely expansive

AS 2870 uses a range of factors to assess characteristic soil movement including:

- i. Building distress due to ground movement visible on adjacent structures,
- ii. Known soil properties and site specific testing to determine the shrink / swell index of a soil (Test 7.1.1 in AS 1289 – Methods of Testing Soils for Engineering Purposes).

AS 2870 is based on defining soil types into various hazard classes based on expected surface movement and depth of desiccation that could occur. It then applies various foundation designs and embedment depths based on the form of building construction (slab on ground, strip footing, stiffened raft, stiffened slab with deep edge beams, etc). AS2870 uses more reinforcing steel than NZ designs generally would to create stiffer foundations that are better able to tolerate ground movement.

The Australian approach also regards expansive soil to a considerable extent being a home owner maintenance issue and significant emphasis is put into ensuring that people understand the influence that trees and dry summers etc may have on foundation performance. See Appendix D.



**Appendix D: CSIRO – BTF18 – Foundation  
Maintenance and Footing  
Performance: A Homeowners Guide**

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# Foundation Maintenance and Footing Performance: A Homeowner's Guide



BTF 18  
replaces  
Information  
Sheet 10/91

Buildings can and often do move. This movement can be up, down, lateral or rotational. The fundamental cause of movement in buildings can usually be related to one or more problems in the foundation soil. It is important for the homeowner to identify the soil type in order to ascertain the measures that should be put in place in order to ensure that problems in the foundation soil can be prevented, thus protecting against building movement.

This Building Technology File is designed to identify causes of soil-related building movement, and to suggest methods of prevention of resultant cracking in buildings.

## Soil Types

The types of soils usually present under the topsoil in land zoned for residential buildings can be split into two approximate groups – granular and clay. Quite often, foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Clay soils are subject to saturation and swell/shrink problems.

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870, the Residential Slab and Footing Code.

## Causes of Movement

### Settlement due to construction

There are two types of settlement that occur as a result of construction:

- Immediate settlement occurs when a building is first placed on its foundation soil, as a result of compaction of the soil under the weight of the structure. The cohesive quality of clay soil mitigates against this, but granular (particularly sandy) soil is susceptible.
- Consolidation settlement is a feature of clay soil and may take place because of the expulsion of moisture from the soil or because of the soil's lack of resistance to local compressive or shear stresses. This will usually take place during the first few months after construction, but has been known to take many years in exceptional cases.

These problems are the province of the builder and should be taken into consideration as part of the preparation of the site for construction. Building Technology File 19 (BTF 19) deals with these problems.

### Erosion

All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay with a sand component of say 10% or more can suffer from erosion.

### Saturation

This is particularly a problem in clay soils. Saturation creates a bog-like suspension of the soil that causes it to lose virtually all of its bearing capacity. To a lesser degree, sand is affected by saturation because saturated sand may undergo a reduction in volume – particularly imported sand fill for bedding and blinding layers. However, this usually occurs as immediate settlement and should normally be the province of the builder.

### Seasonal swelling and shrinkage of soil

All clays react to the presence of water by slowly absorbing it, making the soil increase in volume (see table below). The degree of increase varies considerably between different clays, as does the degree of decrease during the subsequent drying out caused by fair weather periods. Because of the low absorption and expulsion rate, this phenomenon will not usually be noticeable unless there are prolonged rainy or dry periods, usually of weeks or months, depending on the land and soil characteristics.

The swelling of soil creates an upward force on the footings of the building, and shrinkage creates subsidence that takes away the support needed by the footing to retain equilibrium.

### Shear failure

This phenomenon occurs when the foundation soil does not have sufficient strength to support the weight of the footing. There are two major post-construction causes:

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.
- In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

## GENERAL DEFINITIONS OF SITE CLASSES

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes
H	Highly reactive clay sites, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

### Tree root growth

Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation soil movement in two ways:

- Roots that grow under footings may increase in cross-sectional size, exerting upward pressure on footings.
- Roots in the vicinity of footings will absorb much of the moisture in the foundation soil, causing shrinkage or subsidence.

## Unevenness of Movement

The types of ground movement described above usually occur unevenly throughout the building's foundation soil. Settlement due to construction tends to be uneven because of:

- Differing compaction of foundation soil prior to construction.
- Differing moisture content of foundation soil prior to construction.

Movement due to non-construction causes is usually more uneven still. Erosion can undermine a footing that traverses the flow or can create the conditions for shear failure by eroding soil adjacent to a footing that runs in the same direction as the flow.

Saturation of clay foundation soil may occur where subfloor walls create a dam that makes water pond. It can also occur wherever there is a source of water near footings in clay soil. This leads to a severe reduction in the strength of the soil which may create local shear failure.

Seasonal swelling and shrinkage of clay soil affects the perimeter of the building first, then gradually spreads to the interior. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Swelling gradually reaches the interior soil as absorption continues. Shrinkage usually begins where the sun's heat is greatest.

## Effects of Uneven Soil Movement on Structures

### Erosion and saturation

Erosion removes the support from under footings, tending to create subsidence of the part of the structure under which it occurs. Brickwork walls will resist the stress created by this removal of support by bridging the gap or cantilevering until the bricks or the mortar bedding fail. Older masonry has little resistance. Evidence of failure varies according to circumstances and symptoms may include:

- Step cracking in the mortar beds in the body of the wall or above/below openings such as doors or windows.
- Vertical cracking in the bricks (usually but not necessarily in line with the vertical beds or perpend).

Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

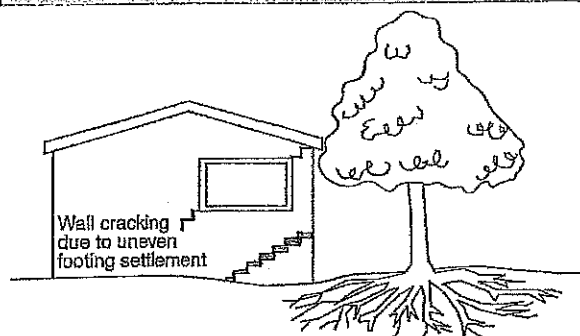
### Seasonal swelling/shrinkage in clay

Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the external footings are pushed higher than the internal ones.

The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally there may be visible dish of the hip or ridge lines.

As the moisture absorption process completes its journey to the innermost areas of the building, the internal footings will rise. If the spread of moisture is roughly even, it may be that the symptoms will temporarily disappear, but it is more likely that swelling will be uneven, creating a difference rather than a disappearance in symptoms. In buildings with timber flooring supported by bearers and joists, the isolated piers will rise more easily than the strip footings or piers under walls, creating noticeable doming of flooring.

Trees can cause shrinkage and damage



As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dish, but other cracks open up. The roof lines may become convex.

Doming and dishing are also affected by weather in other ways. In areas where warm, wet summers and cooler dry winters prevail, water migration tends to be toward the interior and doming will be accentuated, whereas where summers are dry and winters are cold and wet, migration tends to be toward the exterior and the underlying propensity is toward dishing.

### Movement caused by tree roots

In general, growing roots will exert an upward pressure on footings, whereas soil subject to drying because of tree or shrub roots will tend to remove support from under footings by inducing shrinkage.

### Complications caused by the structure itself

Most forces that the soil causes to be exerted on structures are vertical – i.e. either up or down. However, because these forces are seldom spread evenly around the footings, and because the building resists uneven movement because of its rigidity, forces are exerted from one part of the building to another. The net result of all these forces is usually rotational. This resultant force often complicates the diagnosis because the visible symptoms do not simply reflect the original cause. A common symptom is binding of doors on the vertical member of the frame.

### Effects on full masonry structures

Brickwork will resist cracking where it can. It will attempt to span areas that lose support because of subsided foundations or raised points. It is therefore usual to see cracking at weak points, such as openings for windows or doors.

In the event of construction settlement, cracking will usually remain unchanged after the process of settlement has ceased.

With local shear or erosion, cracking will usually continue to develop until the original cause has been remedied, or until the subsidence has completely neutralised the affected portion of footing and the structure has stabilised on other footings that remain effective.

In the case of swell/shrink effects, the brickwork will in some cases return to its original position after completion of a cycle, however it is more likely that the rotational effect will not be exactly reversed, and it is also usual that brickwork will settle in its new position and will resist the forces trying to return it to its original position. This means that in a case where swelling takes place after construction and cracking occurs, the cracking is likely to at least partly remain after the shrink segment of the cycle is complete. Thus, each time the cycle is repeated, the likelihood is that the cracking will become wider until the sections of brickwork become virtually independent.

With repeated cycles, once the cracking is established, if there is no other complication, it is normal for the incidence of cracking to stabilise, as the building has the articulation it needs to cope with the problem. This is by no means always the case, however, and monitoring of cracks in walls and floors should always be treated seriously.

Upheaval caused by growth of tree roots under footings is not a simple vertical shear stress. There is a tendency for the root to also exert lateral forces that attempt to separate sections of brickwork after initial cracking has occurred.

The normal structural arrangement is that the inner leaf of brickwork in the external walls and at least some of the internal walls (depending on the roof type) comprise the load-bearing structure on which any upper floors, ceilings and the roof are supported. In these cases, it is internally visible cracking that should be the main focus of attention, however there are a few examples of dwellings whose external leaf of masonry plays some supporting role, so this should be checked if there is any doubt. In any case, externally visible cracking is important as a guide to stresses on the structure generally, and it should also be remembered that the external walls must be capable of supporting themselves.

#### Effects on framed structures

Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation cause a footing to fall away, this can double the span which a wall must bridge. This additional stress can create cracking in wall linings, particularly where there is a weak point in the structure caused by a door or window opening. It is, however, unlikely that framed structures will be so stressed as to suffer serious damage without first exhibiting some or all of the above symptoms for a considerable period. The same warning period should apply in the case of upheaval. It should be noted, however, that where framed buildings are supported by strip footings there is only one leaf of brickwork and therefore the externally visible walls are the supporting structure for the building. In this case, the subfloor masonry walls can be expected to behave as full brickwork walls.

#### Effects on brick veneer structures

Because the load-bearing structure of a brick veneer building is the frame that makes up the interior leaf of the external walls plus perhaps the internal walls, depending on the type of roof, the building can be expected to behave as a framed structure, except that the external masonry will behave in a similar way to the external leaf of a full masonry structure.

### Water Service and Drainage

Where a water service pipe, a sewer or stormwater drainage pipe is in the vicinity of a building, a water leak can cause erosion, swelling or saturation of susceptible soil. Even a minuscule leak can be enough to saturate a clay foundation. A leaking tap near a building can have the same effect. In addition, trenches containing pipes can become watercourses even though backfilled, particularly where broken rubble is used as fill. Water that runs along these trenches can be responsible for serious erosion, interstrata seepage into subfloor areas and saturation.

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.

Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.

- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

### Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870.

AS 2870 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

### Prevention/Cure

#### Plumbing

Where building movement is caused by water service, roof plumbing, sewer or stormwater failure, the remedy is to repair the problem. It is prudent, however, to consider also rerouting pipes away from the building where possible, and relocating taps to positions where any leakage will not direct water to the building vicinity. Even where gully traps are present, there is sometimes sufficient spill to create erosion or saturation, particularly in modern installations using smaller diameter PVC fixtures. Indeed, some gully traps are not situated directly under the taps that are installed to charge them, with the result that water from the tap may enter the backfilled trench that houses the sewer piping. If the trench has been poorly backfilled, the water will either pond or flow along the bottom of the trench. As these trenches usually run alongside the footings and can be at a similar depth, it is not hard to see how any water that is thus directed into a trench can easily affect the foundation's ability to support footings or even gain entry to the subfloor area.

#### Ground drainage

In all soils there is the capacity for water to travel on the surface and below it. Surface water flows can be established by inspection during and after heavy or prolonged rain. If necessary, a grated drain system connected to the stormwater collection system is usually an easy solution.

It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

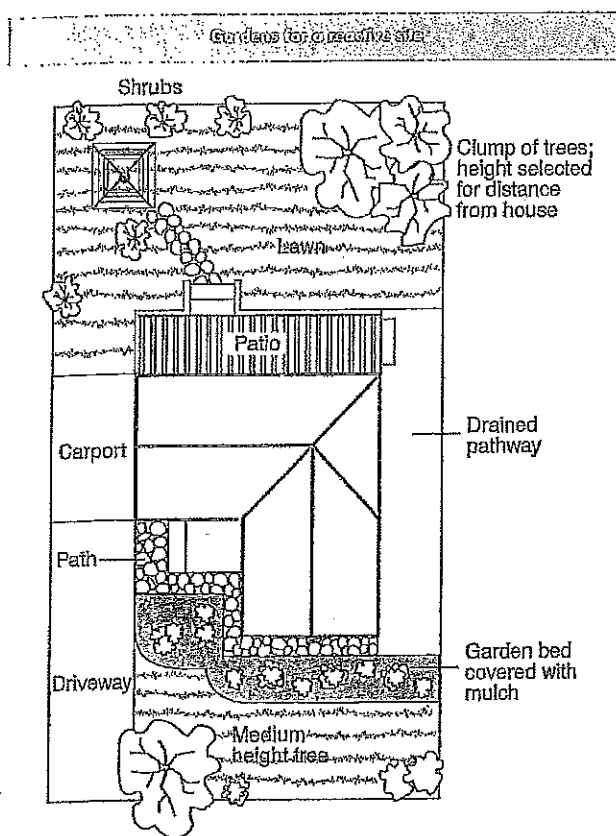
#### Protection of the building perimeter

It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving

### CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

Description of typical damage and required repair	Approximate crack width limit (see Note 3)	Damage category
Hairline cracks	<0.1 mm	0
Fine cracks which do not need repair	<1 mm	1
Cracks noticeable but easily filled. Doors and windows stick slightly	<5 mm	2
Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weathertightness often impaired	5-15 mm (or a number of cracks 3 mm or more in one group)	3
Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted	15-25 mm but also depend on number of cracks	4



should extend outwards a minimum of 900 mm (more in highly reactive soil) and should have a minimum fall away from the building of 1:60. The finished paving should be no less than 100 mm below brick vent bases.

It is prudent to relocate drainage pipes away from this paving, if possible, to avoid complications from future leakage. If this is not practical, earthenware pipes should be replaced by PVC and backfilling should be of the same soil type as the surrounding soil and compacted to the same density.

Except in areas where freezing of water is an issue, it is wise to remove taps in the building area and relocate them well away from the building—preferably not uphill from it (see BTF 19).

It may be desirable to install a grated drain at the outside edge of the paving on the uphill side of the building. If subsoil drainage is needed this can be installed under the surface drain.

#### Condensation

In buildings with a subfloor void such as where bearers and joists support flooring, insufficient ventilation creates ideal conditions for condensation, particularly where there is little clearance between the floor and the ground. Condensation adds to the moisture already present in the subfloor and significantly slows the process of drying out. Installation of an adequate subfloor ventilation system, either natural or mechanical, is desirable.

**Warning:** Although this Building Technology File deals with cracking in buildings, it should be said that subfloor moisture can result in the development of other problems, notably:

- Water that is transmitted into masonry, metal or timber building elements causes damage and/or decay to those elements.
- High subfloor humidity and moisture content create an ideal environment for various pests, including termites and spiders.
- Where high moisture levels are transmitted to the flooring and walls, an increase in the dust mite count can ensue within the living areas. Dust mites, as well as dampness in general, can be a health hazard to inhabitants, particularly those who are abnormally susceptible to respiratory ailments.

#### The garden

The ideal vegetation layout is to have lawn or plants that require only light watering immediately adjacent to the drainage or paving edge, then more demanding plants, shrubs and trees spread out in that order.

Overwatering due to misuse of automatic watering systems is a common cause of saturation and water migration under footings. If it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

#### Existing trees

Where a tree is causing a problem of soil drying or there is the existence or threat of upheaval of footings, if the offending roots are subsidiary and their removal will not significantly damage the tree, they should be severed and a concrete or metal barrier placed vertically in the soil to prevent future root growth in the direction of the building. If it is not possible to remove the relevant roots without damage to the tree, an application to remove the tree should be made to the local authority. A prudent plan is to transplant likely offenders before they become a problem.

#### Information on trees, plants and shrubs

State departments overseeing agriculture can give information regarding root patterns, volume of water needed and safe distance from buildings of most species. Botanic gardens are also sources of information. For information on plant roots and drains, see Building Technology File 17.

#### Excavation

Excavation around footings must be properly engineered. Soil supporting footings can only be safely excavated at an angle that allows the soil under the footing to remain stable. This angle is called the angle of repose (or friction) and varies significantly between soil types and conditions. Removal of soil within the angle of repose will cause subsidence.

#### Remediation

Where erosion has occurred that has washed away soil adjacent to footings, soil of the same classification should be introduced and compacted to the same density. Where footings have been undermined, augmentation or other specialist work may be required. Remediation of footings and foundations is generally the realm of a specialist consultant.

Where isolated footings rise and fall because of swell/shrink effect, the homeowner may be tempted to alleviate floor bounce by filling the gap that has appeared between the bearer and the pier with blocking. The danger here is that when the next swell segment of the cycle occurs, the extra blocking will push the floor up into an accentuated dome and may also cause local shear failure in the soil. If it is necessary to use blocking, it should be by a pair of fine wedges and monitoring should be carried out fortnightly.

**This BTF was prepared by John Lewer FAIB, MIAMA, Partner, Construction Diagnosis.**

The information in this and other issues in the series was derived from various sources and was believed to be correct when published.

The information is advisory. It is provided in good faith and not claimed to be an exhaustive treatment of the relevant subject.

Further professional advice needs to be obtained before taking any action based on the information provided.

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## **Appendix E: Test Results**

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- 21854.001–P2S3A–111 Post Earthworks Investigation Plan
- 21854.001–P2S3A–112 Topsoil Depths Plan
- 21854.001–P2S3A–113 Earthworks Testing Location Plan
- Soil Expansion Test Results
- Post Earthworks Investigation Borehole Logs (HA1 to HA11)
- Earthworks Test Results





DRAWING STATUS: COMPLETION REPORT

CLIENT PROJECT	WFH PROPERTIES LTD RESIDENTIAL SUBDIVISION
TITLE	MILLWATER - PRECINCT 2 (STAGE 3A) Post Earthworks Investigation Plan
DWG. NO.	21854.001-P2S3A-111
SCALE (AT A3 SIZE)	1:1000
REV.	1

**Tonkin+Taylor**  
105 Carlton Gore Road, Newmarket, Auckland  
Tel. (09) 355 6000 Fax. (09) 307 0265  
www.tonkintaylor.co.nz

DESIGNED :	JULY 15
DRAWN :	JULY 15
CHECKED :	JULY 15
DATE :	JULY 15
PROJECT :	21854.001-P2S3A-111
FILE :	21854.001-P2S3A-111.dwg
NOT FOR CONSTRUCTION	
REVISION	DESCRIPTION
1	Completion Report Issue

NOTES	1. All dimensions are in metres unless noted otherwise. 2. As-built plan supplied by WOODS, reference file name "33211-03A-AB-100 FINAL CONTOURS.dwg" dated 4 Aug 2016. 3. Undercuts, shearkey & subsoil drains supplied by WOODS, reference file name "33211-03A-AB-120 SK UC & SUBSOIL.dwg" dated 4 Aug 2016. 4. Coordinate Datum: NZGD2000, New Zealand Transverse Mercator (NZTM2000). 5. Level Datum: LINZ (NZL) Auckland Vertical Datum '1946
REFERENCE :	

**LEGEND**

- Precinct 2 Boundary
- Stage 3A Boundary
- Lot Boundaries
- Finished Ground Contours (0.5m interval)
- Fill Contours
- Zero Contours
- Cut Contours
- Proposed Retaining Wall
- RE Wall Extent
- Expansive soil test samples @ 0.5m and 1.0m depth
- Hand Auger to 3m depth (fully logged)

**HA 1**

**E6**

A3 SCALE 1:1000 0 5 10 15 20 30 40 50 (m)

ORIGINAL IN COLOUR





DRAWING STATUS: COMPLETION REPORT

CLIENT PROJECT	WFH PROPERTIES LTD RESIDENTIAL SUBDIVISION
TITLE	MILLWATER - PRECINCT 2 (STAGE 3A)
Topsoil Depths Plan	
DWG. No.	21854.001-P2S3A-112
REV.	1

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DESIGNED :	JUXL	Aug.16
DRAWN :	JJC	Aug.16
DRAFTING CHECKED :		
DESIGN CHECKED :		
APPROVED :		
CADFILE :	21854.001-P2S3A-112.dwg	
NOT FOR CONSTRUCTION		
1. Completion Report Issue		
REVISION DESCRIPTION	BY	DATE

**LEGEND**

- Precinct 2 Boundary
- Stage 3A Boundary
- Lot Boundaries
- Finished Ground Contours (0.5m interval)
- Proposed Retaining Wall
- RE Wall Extent
- Undercut Extent
- Shear key
- Topsoil depth (mm) taken at centre of each lot

331

250

0 5 10 15 20 30 40 50 (m)

A3 SCALE 1:1000

ORIGINAL IN COLOUR

- NOTES :
- All dimensions are in metres unless noted otherwise.
  - Topsoil depths are based on reference file name "33211-03A-AB-100 FINAL" and applied by Aug 2016.
  - Undercuts, shearkey & subsoil drains supplied by WOODS, reference file name "33211-03A-AB-120 SK UC & SUBSOIL.dwg" dated 4 Aug 2016.
  - Coordinate Datum: NZGD2000, New Zealand Transverse Mercator (NZTM2000). Level Datum: LINZ (MSL) Auckland Vertical Datum 1946

REFERENCE :









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GEOTECHNICS

Page 1 of 3

Site: Precinct 2, Stage 3A, Millwater

Page 1 of 3

Your Job No: 21854.001

Our Job No: 61830.002

Test Method Used: AS 1289.7.1.1 - 2003 Determination of the Shrink - Swell Index

### SUMMARY OF SHRINK - SWELL TEST RESULTS

Lot No.:	*331	331	335	337	337	341	341	345
DEPTH	(m)	0.4 - 0.6	0.4 - 0.6	0.4 - 0.6	0.4 - 0.6	0.4 - 0.6	0.4 - 0.6	0.4 - 0.6
Applied Pressure	(kPa)	55	55	55	55	55	55	55
SWELL TEST	Initial Water Content (%)	10.6	14.8	19.5	42.1	21.8	18.7	38.7
	Bulk Density (t/m <sup>3</sup> )	2.10	2.06	2.05	1.78	1.99	2.07	1.77
	Dry Density (t/m <sup>3</sup> )	1.90	1.79	1.72	1.25	1.63	1.74	1.28
	Final Water Content (%)	12.6	16.7	22.2	44.8	23.9	20.4	40.5
	Swelling Strain (%)	0.06	0.46	0.58	0.29	0.18	0.26	0.04
SHRINKAGE TEST	Initial Water Content (%)	15.1	27.2	18.8	22.5	27.5	24.1	28.6
	Estimated Shrinkage Limit (%)	4.4	6.2	4.9	5.4	9.1	7.4	12.6
	Shrinkage Strain (%)	2.5	3.2	2.4	2.6	4.1	5.2	2.3
	Inert Material Estimate in the Soil Specimen (%)	0	0	0	0	0	0	0
	Soil Crumbling During Shrinkage	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Cracking of the Shrinkage Specimen		Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
SHRINK - SWELL INDEX (%)		1.4	1.9	1.5	1.5	2.3	3.0	1.3

1) Shrinkage Test: \*Lot 331\_0.4-0.6m: Sample height to diameter ratio is less than the required 1.5. We have advised the engineer and it was decided to continue with the testing.

Therefore the test results reported are not IANZ accredited.

Entered by: ST

Date: 20/06/2016

Checked by: MP

Date: 20/06/2016



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**GEOTECHNICS**

File: 102302010003\_Millwater\_3A\_Swell\_Index\_2016.pdf

Site: Precinct 2, Stage 3A, Millwater

Page 2 of 3

Your Job No: 21854.001

Our Job No: 616830.002

Test Method Used: AS 1289.7.1.1 - 2003 Determination of the Shrink - Swell Index

### SUMMARY OF SHRINK - SWELL TEST RESULTS

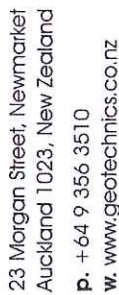
Lot No.:		345	348	348	352	352	373	373	376
DEPTH	(m)	0.9 - 1.1	0.4 - 0.6	0.9 - 1.1	0.4 - 0.6	0.9 - 1.1	0.4 - 0.6	0.9 - 1.1	0.4 - 0.6
Applied Pressure	(kPa)	55	55	55	55	55	55	55	55
SWELL TEST	Initial Water Content (%)	30.1	30.4	28.4	24.6	29.7	27.9	15.6	30.5
	Bulk Density (t/m <sup>3</sup> )	1.80	1.84	1.87	1.92	1.85	1.89	2.04	1.93
	Dry Density (t/m <sup>3</sup> )	1.38	1.41	1.46	1.54	1.43	1.48	1.76	1.48
	Final Water Content (%)	31.7	32.1	30.0	27.4	32.0	29.0	17.5	31.5
	Swelling Strain (%)	0.01	0.09	0.04	0.19	0.10	0.14	0.25	0.34
SHRINKAGE TEST	Initial Water Content (%)	28.9	29.0	26.1	21.8	22.6	19.7	18.5	27.1
	Estimated Shrinkage Limit (%)	9.8	10.4	9.3	7.3	8.0	6.2	6.3	7.7
	Shrinkage Strain (%)	1.8	2.2	2.8	2.6	2.4	2.6	1.9	5.4
	Inert Material Estimate in the Soil Specimen (%)	0	0	0	0	0	0	0	0
	Soil Crumbling During Shrinkage	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Cracking of the Shrinkage Specimen		Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
SHRINK - SWELL INDEX (%)		1.0	1.3	1.6	1.5	1.4	1.5	1.1	3.1

Entered by: ST

Date: 20/06/2016

Checked by: MP

Date: 20/06/2016



Page 3 of 3

**Your Job No: 21854.001**

**Our Job No: 616830.002**

Test Method Used: AS 1289.7.1.1 - 2003 Determination of the Shrink - Swell Index

## SUMMARY OF SHRINK - SWELL TEST RESULTS

Lot No.:		376	379	379	382	382	
DEPTH		(m)	0.9 - 1.1	0.4 - 0.6	0.9 - 1.1	0.4 - 0.6	
Applied Pressure		(kPa)	55	55	55	55	
SWELL TEST	Initial Water Content	(%)	17.7	18.2	23.2	31.4	30.3
	Bulk Density	(t/m³)	2.14	2.06	1.95	1.84	1.85
	Dry Density	(t/m³)	1.82	1.74	1.58	1.40	1.42
	Final Water Content	(%)	18.7	19.9	25.2	33.0	33.0
	Swelling Strain	(%)	0.46	0.46	0.16	0.16	0.39
SHRINKAGE TEST	Initial Water Content	(%)	20.4	19.9	18.9	24.6	28.2
	Estimated Shrinkage Limit	(%)	6.2	5.8	5.7	8.5	9.9
	Shrinkage Strain	(%)	4.8	1.3	1.5	1.9	4.0
	Inert Material Estimate in the Soil Specimen	(%)	0	0	0	0	0
	Soil Crumbling During Shrinkage		Nil	Nil	Nil	Nil	Nil
Cracking of the Shrinkage Specimen		Moderate	Moderate	Moderate	Moderate	Moderate	
SHRINK - SWELL INDEX		(%)	2.8	0.9	0.9	1.1	2.4

Entered by: ST

Date: 20/06/2016

Checked by:

Date: 20/06/2016



# BOREHOLE LOG

BOREHOLE No.: **BH5**

Hole Location: lot 376

SHEET: 1 OF 1

PROJECT: Millwater		LOCATION: Precinct 2 Stage 3A		JOB No.: 21854.001	
CO-ORDINATES: (NZTM 2000)		DRILL TYPE:		HOLE STARTED: 12/05/2016	
R.L.:		DRILL METHOD: HA		HOLE FINISHED: 12/05/2016	
DATUM:		DRILL FLUID:		DRILLED BY: BZZB	
				LOGGED BY: BZZB/TAJ	
				CHECKED:	

GEOLOGICAL		ENGINEERING DESCRIPTION																
GEOLOGICAL UNIT, GENERIC NAME, ORIGINS, MATERIAL COMPOSITION	FLUID LOSS (%)	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION	WEATHERING	STRENGTH CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSION STRENGTH (kPa)	DEFECT SPACING (mm)	Description and Additional Observations
Fill						● >196 kPa				X		M	VSI					0.0m: clayey SILT; orange and grey. Very stiff, moist, low plasticity.
										X								
										X								
										X								
										X								
										X								
										X								
										X								
										X								
										X								
						● >196 kPa				X								2.4m: SILT; grey. Very stiff, dry, non to low plasticity.
						● >196 kPa				X								2.6m: clayey SILT; orange and grey. Very stiff, moist, low plasticity.
						● >196 kPa				X								3m: Target depth

COMMENTS:

Hole Depth 3m

Scale 1:20







# BOREHOLE LOG

BOREHOLE No: HA331

Hole Location: LOT 331

SHEET 1 OF 1

PROJECT: Stage 2C			LOCATION: Millwater Precinct 2			JOB No: 21854.001												
CO-ORDINATES:			DRILL TYPE: 50mm HA			HOLE STARTED: 29/4/16												
R.L.:			DRILL METHOD: HA			HOLE FINISHED: 29/4/16												
DATUM:			DRILL FLUID:			LOGGED BY: rbe												
CHECKED:																		
GEOLOGICAL			ENGINEERING DESCRIPTION															
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION	WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION  Soil type, minor components, plasticity or particle size, colour.  ROCK DESCRIPTION  Substance: Rock type, particle size, colour, minor components.  Defects: Type, inclination, thickness, roughness, filling.
TOPSOIL FILL														H				SILT, non plastic, moist, dark brown (topsoil)
FILL						• UTP												SILT, non plastic, moist, grey and yellowish brown
						• >202kPa			0.5									-grey and reddish brown, minor yellowish inclusions
						• >202kPa												-grey and yellowish brown
						• 176/46kPa			1.0				VSt					
						• UTP			1.5					H				clayey SILT, low plasticity, moist, yellowish brown, with grey inclusions
						• UTP												SILT, non plastic, moist, grey, with minor yellowish brown inclusions
WEATHERED NORTHLAND ALLOCHTHON						• UTP												SILT, non plastic, moist, grey, dry to moist from 1.8m, hard to auger
						• UTP			2.0									sandy SILT, non plastic, dry, grey
																		END OF BOREHOLE 2m (very hard to auger)
									2.5									
									3.0									
									4									


















# BOREHOLE LOG

BOREHOLE No: HA337

Hole Location: LOT 337

SHEET 1 OF 1

PROJECT: Stage 2C			LOCATION: Millwater Precinct 2			JOB No: 21854.001													
CO-ORDINATES:			DRILL TYPE: 50mm HA			HOLE STARTED: 29/4/16													
R.L.:			DRILL METHOD: HA			HOLE FINISHED: 29/4/16													
DATUM:			DRILL FLUID:			DRILLED BY: geotechnics													
						LOGGED BY: rbe													
						CHECKED:													
GEOLOGICAL			ENGINEERING DESCRIPTION																
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.			FLUID LOSS WATER CORE RECOVERY (%) METHOD CASING	TESTS SAMPLES R.L. (m) DEPTH (m)	GRAPHIC LOG CLASSIFICATION SYMBOL MOISTURE WEATHERING CONDITION STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200 300 400 500 600 700 800 900 1000 1500 2000	COMPRESSION STRENGTH (MPa) 5 10 20 30 40 50 60 70 80 90 100 150 200 250 300 400 500 600 700 800 900 1000 1500 2000	DEFECT SPACING (mm) 50 100 200 500 1000 2000	SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.										
TOPSOIL FILL			Hole dry on completion	• 147/48kPa  • 176/52kPa  • 191/72kPa  • UTP		VS													SILT, non plastic, moist, dark brown (topsoil)
FILL																			SILT, minor clay, non plastic, moist, yellowish brown, light grey and reddish brown, occasionally low plasticity
NORTHLAND ALLOCHTHON																			sandy SILT, non plastic, dry to moist, grey
																			END OF BOREHOLE 1.3m (very hard to auger)



# BOREHOLE LOG

BOREHOLE No: HA341

Hole Location: LOT 341

SHEET 1 OF 1

PROJECT: Stage 2C			LOCATION: Millwater Precinct 2			JOB No: 21854.001		
CO-ORDINATES:			DRILL TYPE: 50mm HA			HOLE STARTED: 29/4/16		
R.L.:			DRILL METHOD: HA			HOLE FINISHED: 29/4/16		
DATUM:			DRILL FLUID:			LOGGED BY: rbe CHECKED:		
GEOLOGICAL			ENGINEERING DESCRIPTION					
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.			FLUID LOSS WATER CORE RECOVERY (%) METHOD CASING TESTS SAMPLES R.L. (m) DEPTH (m)	GRAPHIC LOG CLASSIFICATION SYMBOL MOISTURE CONDITION WEATHERING STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320 330 340 350 360 370 380 390 400 410 420 430 440 450 460 470 480 490 500 510 520 530 540 550 560 570 580 590 600 610 620 630 640 650 660 670 680 690 700 710 720 730 740 750 760 770 780 790 800 810 820 830 840 850 860 870 880 890 900 910 920 930 940 950 960 970 980 990 1000 1010 1020 1030 1040 1050 1060 1070 1080 1090 1100 1110 1120 1130 1140 1150 1160 1170 1180 1190 1200 1210 1220 1230 1240 1250 1260 1270 1280 1290 1300 1310 1320 1330 1340 1350 1360 1370 1380 1390 1400 1410 1420 1430 1440 1450 1460 1470 1480 1490 1500 1510 1520 1530 1540 1550 1560 1570 1580 1590 1600 1610 1620 1630 1640 1650 1660 1670 1680 1690 1700 1710 1720 1730 1740 1750 1760 1770 1780 1790 1800 1810 1820 1830 1840 1850 1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100 2110 2120 2130 2140 2150 2160 2170 2180 2190 2200 2210 2220 2230 2240 2250 2260 2270 2280 2290 2300 2310 2320 2330 2340 2350 2360 2370 2380 2390 2400 2410 2420 2430 2440 2450 2460 2470 2480 2490 2500 2510 2520 2530 2540 2550 2560 2570 2580 2590 2600 2610 2620 2630 2640 2650 2660 2670 2680 2690 2700 2710 2720 2730 2740 2750 2760 2770 2780 2790 2800 2810 2820 2830 2840 2850 2860 2870 2880 2890 2900 2910 2920 2930 2940 2950 2960 2970 2980 2990 3000 3010 3020 3030 3040 3050 3060 3070 3080 3090 3100 3110 3120 3130 3140 3150 3160 3170 3180 3190 3200 3210 3220 3230 3240 3250 3260 3270 3280 3290 3300 3310 3320 3330 3340 3350 3360 3370 3380 3390 3400 3410 3420 3430 3440 3450 3460 3470 3480 3490 3500 3510 3520 3530 3540 3550 3560 3570 3580 3590 3600 3610 3620 3630 3640 3650 3660 3670 3680 3690 3700 3710 3720 3730 3740 3750 3760 3770 3780 3790 3800 3810 3820 3830 3840 3850 3860 3870 3880 3890 3900 3910 3920 3930 3940 3950 3960 3970 3980 3990 4000 4010 4020 4030 4040 4050 4060 4070 4080 4090 4100 4110 4120 4130 4140 4150 4160 4170 4180 4190 4200 4210 4220 4230 4240 4250 4260 4270 4280 4290 4300 4310 4320 4330 4340 4350 4360 4370 4380 4390 4400 4410 4420 4430 4440 4450 4460 4470 4480 4490 4500 4510 4520 4530 4540 4550 4560 4570 4580 4590 4600 4610 4620 4630 4640 4650 4660 4670 4680 4690 4700 4710 4720 4730 4740 4750 4760 4770 4780 4790 4800 4810 4820 4830 4840 4850 4860 4870 4880 4890 4900 4910 4920 4930 4940 4950 4960 4970 4980 4990 5000 5010 5020 5030 5040 5050 5060 5070 5080 5090 5100 5110 5120 5130 5140 5150 5160 5170 5180 5190 5200 5210 5220 5230 5240 5250 5260 5270 5280 5290 5300 5310 5320 5330 5340 5350 5360 5370 5380 5390 5400 5410 5420 5430 5440 5450 5460 5470 5480 5490 5500 5510 5520 5530 5540 5550 5560 5570 5580 5590 5600 5610 5620 5630 5640 5650 5660 5670 5680 5690 5700 5710 5720 5730 5740 5750 5760 5770 5780 5790 5800 5810 5820 5830 5840 5850 5860 5870 5880 5890 5900 5910 5920 5930 5940 5950 5960 5970 5980 5990 6000 6010 6020 6030 6040 6050 6060 6070 6080 6090 6100 6110 6120 6130 6140 6150 6160 6170 6180 6190 6200 6210 6220 6230 6240 6250 6260 6270 6280 6290 6300 6310 6320 6330 6340 6350 6360 6370 6380 6390 6400 6410 6420 6430 6440 6450 6460 6470 6480 6490 6500 6510 6520 6530 6540 6550 6560 6570 6580 6590 6600 6610 6620 6630 6640 6650 6660 6670 6680 6690 6700 6710 6720 6730 6740 6750 6760 6770 6780 6790 6800 6810 6820 6830 6840 6850 6860 6870 6880 6890 6900 6910 6920 6930 6940 6950 6960 6970 6980 6990 7000 7010 7020 7030 7040 7050 7060 7070 7080 7090 7100 7110 7120 7130 7140 7150 7160 7170 7180 7190 7200 7210 7220 7230 7240 7250 7260 7270 7280 7290 7300 7310 7320 7330 7340 7350 7360 7370 7380 7390 7400 7410 7420 7430 7440 7450 7460 7470 7480 7490 7500 7510 7520 7530 7540 7550 7560 7570 7580 7590 7600 7610 7620 7630 7640 7650 7660 7670 7680 7690 7700 7710 7720 7730 7740 7750 7760 7770 7780 7790 7800 7810 7820 7830 7840 7850 7860 7870 7880 7890 7900 7910 7920 7930 7940 7950 7960 7970 7980 7990 8000 8010 8020 8030 8040 8050 8060 8070 8080 8090 8100 8110 8120 8130 8140 8150 8160 8170 8180 8190 8200 8210 8220 8230 8240 8250 8260 8270 8280 8290 8300 8310 8320 8330 8340 8350 8360 8370 8380 8390 8400 8410 8420 8430 8440 8450 8460 8470 8480 8490 8500 8510 8520 8530 8540 8550 8560 8570 8580 8590 8600 8610 8620 8630 8640 8650 8660 8670 8680 8690 8700 8710 8720 8730 8740 8750 8760 8770 8780 8790 8800 8810 8820 8830 8840 8850 8860 8870 8880 8890 8900 8910 8920 8930 8940 8950 8960 8970 8980 8990 9000 9010 9020 9030 9040 9050 9060 9070 9080 9090 9100 9110 9120 9130 9140 9150 9160 9170 9180 9190 9200 9210 9220 9230 9240 9250 9260 9270 9280 9290 9300 9310 9320 9330 9340 9350 9360 9370 9380 9390 9400 9410 9420 9430 9440 9450 9460 9470 9480 9490 9500 9510 9520 9530 9540 9550 9560 9570 9580 9590 9600 9610 9620 9630 9640 9650 9660 9670 9680 9690 9700 9710 9720 9730 9740 9750 9760 9770 9780 9790 9800 9810 9820 9830 9840 9850 9860 9870 9880 9890 9900 9910 9920 9930 9940 9950 9960 9970 9980 9990 10000 10010 10020 10030 10040 10050 10060 10070 10080 10090 10100 10110 10120 10130 10140 10150 10160 10170 10180 10190 10200 10210 10220 10230 10240 10250 10260 10270 10280 10290 10300 10310 10320 10330 10340 10350 10360 10370 10380 10390 10400 10410 10420 10430 10440 10450 10460 10470 10480 10490 10500 10510 10520 10530 10540 10550 10560 10570 10580 10590 10600 10610 10620 10630 10640 10650 10660 10670 10680 10690 10700 10710 10720 10730 10740 10750 10760 10770 10780 10790 10800 10810 10820 10830 10840 10850 10860 10870 10880 10890 10900 10910 10920 10930 10940 10950 10960 10970 10980 10990 11000 11010 11020 11030 11040 11050 11060 11070 11080 11090 11100 11110 11120 11130 11140 11150 11160 11170 11180 11190 11200 11210 11220 11230 11240 11250 11260 11270 11280 11290 11300 11310 11320 11330 11340 11350 11360 11370 11380 11390 11400 11410 11420 11430 11440 11450 11460 11470 11480 11490 11500 11510 11520 11530 11540 11550 11560 11570 11580 11590 11600 11610 11620 11630 11640 11650 11660 11670 11680 11690 11700 11710 11720 11730 11740 11750 11760 11770 11780 11790 11800 11810 11820 11830 11840 11850 11860 11870 11880 11890 11900 11910 11920 11930 11940 11950 11960 11970 11980 11990 12000 12010 12020 12030 12040 12050 12060 12070 12080 12090 12100 12110 12120 12130 12140 12150 12160 12170 12180 12190 12200 12210 12220 12230 12240 12250 12260 12270 12280 12290 12300 12310 12320 12330 12340 12350 12360 12370 12380 12390 12400 12410 12420 12430 12440 12450 12460 12470 12480 12490 12500 12510 12520 12530 12540 12550 12560 12570 12580 12590 12600 12610 12620 12630 12640 12650 12660 12670 12680 12690 12700 12710 12720 12730 12740 12750 12760 12770 12780 12790 12800 12810 12820 12830 12840 12850 12860 12870 12880 12890 12900 12910 12920 12930 12940 12950 12960 12970 12980 12990 13000 13010 13020 13030 13040 13050 13060 13070 13080 13090 13100 13110 13120 13130 13140 13150 13160 13170 13180 13190 13200 13210 13220 13230 13240 13250 13260 13270 13280 13290 13300 13310 13320 13330 13340 13350 13360 13370 13380 13390 13400 13410 13420 13430 13440 13450 13460 13470 13480 13490 13500 13510 13520 13530 13540 13550 13560 13570 13580 13590 13600 13610 13620 13630 13640 13650 13660 13670 13680 13690 13700 13710 13720 13730 13740 13750 13760 13770 13780 13790 13800 13810 13820 13830 13840 13850 13860 13870 13880 13890 13900 13910 13920 13930 13940 13950 13960 13970 13980 13990 14000 14010 14020 14030 14040 14050 14060 14070 14080 14090 14100 14110 14120 14130 14140 14150 14160 14170 14180 14190 14200 14210 14220 14230 14240 14250 14260 14270 14280 14290 14300 14310 14320 14330 14340 14350 14360 14370 14380 14390 14400 14410 14420 14430 14440 14450 14460 14470 14480 14490 14500 14510 14520 14530 14540 14550 14560 14570 14580 14590 14600 14610 14620 14630 14640 14650 14660 14670 14680 14690 14700 14710 14720 14730 14740 14750 14760 14770 14780 14790 14800 14810 14820 14830 14840 14850 14860 14870 14880 14890 14900 14910 14920 14930 14940 14950 14960 14970 14980 14990 15000 15010 15020 15030 15040 15050 15060 15070 15080 15090 15100 15110 15120 15130 15140 15150 15160 15170 15180 15190 15200 15210 15220 15230 15240 15250 15260 15270 15280 15290 15300 15310 15320 15330 15340 15350 15360 15370 15380 15390 15400 15410 15420 15430 15440 15450 15460 15470 15480 15490 15500 15510 15520 15530 15540 15550 15560 15570 15580 15590 15600 15610 15620 15630 15640 15650 15660 15670 15680 15690 15700 15710 15720 15730 15740 15750 15760 15770 15780 15790 15800 15810 15820 15830 15840 15850 15860 15870 15880 15890 15900 15910 15920 15930 15940 15950 15960 15970 15980 15990 16000 16010 16020 16030 16040 16050 16060 16070 16080 16090 16100 16110 16120 16130 16140 16150 16160 16170 16180 16190 16200 16210 16220 16230 16240 16250 16260 16270 16280 16290 16300 16310 16320 16330 16340 16350 16360 16370 16380 16390 16400 16410 16420 16430 16440 16450 16460 16470 16480 16490 16500 16510 16520 16530 16540 16550 16560 16570 16580 16590 16600 16610 16620 16630 16640 16650 16660 16670 16680 16690 16700 16710 16720 16730 16740 16750 16760 16770 16780 16790 16800 16810 16820 16830 16840 16850 16860 16870 16880 16890 16900 16910 16920 16930 16940 16950 16960 16970 16980 16990 17000 17010 17020 17030 17040 17050 17060 17070 17080 17090 17100 17110 17120 17130 17140 17150 17160 17170 17180 17190 17200 17210 17220 17230 17240 17250 17260 17270 17280 17290 17300 17310 17320 17330 17340 17350 17360 17370 17380 17390 17400 17410 17420 17430 17440 17450 17460 17470 17480 17490 17500 17510 17520 17530 17540 17550 17560 17570 17580 17590 17600 17610 17620 17630 17640 17650 17660 17670 17680 17690 17700 17710 17720 17730 17740 17750 17760 17770 17780 17790 17800 17810 17820 17830 17840 17850 17860 17870 17880 17890 17900 17910 17920 17930 17940 17950 17960 17970 17980 17990 18000 18010 18020 18030 18040 18050 18060 18070 18080 18090 18100 18110 18120 18130 18140 18150 18160 18170 18180 18190 18200 18210 18220 18230 			

# BOREHOLE LOG

BOREHOLE No: HA352  
Hole Location: LOT 352  
SHEET 1 OF 1

PROJECT: Stage 2C				LOCATION: Millwater Precinct 2				JOB No: 21854.001													
CO-ORDINATES:				DRILL TYPE: 50mm HA				HOLE STARTED: 29/4/16													
R.L.:				DRILL METHOD: HA				HOLE FINISHED: 29/4/16													
DATUM:				DRILL FLUID:				DRILLED BY: geotechnics		CHECKED:											
GEOLOGICAL				ENGINEERING DESCRIPTION																	
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.				FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE WEATHERING CONDITION	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSION STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION  Soil type, minor components, plasticity or particle size, colour.  ROCK DESCRIPTION  Substance: Rock type, particle size, colour, minor components.  Defects: Type, inclination, thickness, roughness, filling.	
TOPSOIL FILL																VSI					SILT, clayey, low plasticity, moist, dark brown (topsoil)
FILL																					SILT, minor clay, non plastic, occasionally low plasticity, moist, grey and yellowish brown
									• 132/74kPa												
									• >202kPa			0.5				H					0.5-
									• UTP												1.0-
									• >202kPa												
									• >202kPa			1.5									1.5-
									• 94/40kPa							St					
									• UTP			2.0				H					2.0-
WEATHERED NORTHLAND ALLOCHTHON									• UTP					ML							SILT, non plastic, moist, grey and dark grey
									• UTP			2.5									2.5-
									• UTP					MS							fine sandy SILT, non plastic, moist, grey
									• UTP					ML							SILT, non plastic, moist to dry, grey
									• UTP			3.0									3.0-
																					END OF BOREHOLE 3.05m (very hard to auger)

T+T DATATEMPLATE.GDT rbe



# BOREHOLE LOG

BOREHOLE No: HA382  
Hole Location: LOT 382  
SHEET 1 OF 1

PROJECT: Stage 2C		LOCATION: Millwater Precinct 2		JOB No: 21854.001														
CO-ORDINATES:		DRILL TYPE: 50mm HA		HOLE STARTED: 29/4/16														
R.L.:		DRILL METHOD: HA		HOLE FINISHED: 29/4/16														
DATUM:		DRILL FLUID:		LOGGED BY: rbe CHECKED:														
GEOLOGICAL		ENGINEERING DESCRIPTION																
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION	WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour.  ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
TOPSOIL FILL														H				SILT, non plastic, moist, brown (topsoil)
FILL						• UTP			0.5									SILT, minor clay, non plastic, moist, grey and yellowish brown
						• >202kPa												
						• 202/77kPa			1.0									
						• UTP												
						• >202kPa			1.5									SILT, some clay, non plastic, moist, yellowish orange brown and light greyish white, grey inclusions from 1.55m
RESIDUAL SOILS						• 192/121kPa					ML			VSt				SILT, non plastic, moist, yellowish brown mottled light greyish white
						• 110/52kPa			2.0		MC							clayey SILT, low to medium plasticity, moist, yellowish brown with minor light greyish white mottles
						• 88/45kPa			2.5					St				
						• 90/38kPa												
						• 84/35kPa			3.0									-low plasticity, yellowish brown mottled light greyish white
																		END OF BOREHOLE 3.2m (target depth)

T+T DATATEMPLATE.GDT rbe





\$15-11338
\$15-1165
\$15-1166
\$15-1178
\$16 001/01
\$16 001/02
\$16 002/03
\$16 002/04
\$16 002/05
\$16 003/01
\$16 003/02
\$16 003/03
\$16 005/01
\$16 005/02
\$16 006/02
\$16 008/03
\$16 012/1
\$16 012/2
\$16 012/3
\$16 012/4
\$16 012/7
\$16 013/3
\$16 013/4
\$16 014/1
\$16 014/2
\$16 015/7
\$16 015/8
\$16 016/3
\$16 016/4
\$16 016/5
\$16 017/1
\$16 017/2
\$16 017/3
\$16 017/4

Unit Name	Unit Number	Unit Type	Unit Description	Unit Status	Unit Location	Unit Area	Unit Volume	Unit Weight	Unit Density	Unit Temperature	Unit Pressure	Unit Flow	Unit Velocity	Unit Acceleration	Unit Displacement	Unit Rotation	Unit Vibration	Unit Noise	Unit Emission	Unit Pollution	Unit Hazard	Unit Risk	Unit Impact	Unit Mitigation	Unit Monitoring	Unit Maintenance	Unit Repair	Unit Replacement	Unit Upgrade	Unit Decommission	Unit Salvage	Unit Recycling	Unit Disposal	Unit Final
S16 0182	26559816.245	NTW	Behind Shear Key	NTW	27/01/2016	49.300	6006675.775																											
S16 0183	6508677.579	NTW	Behind Shear Key	NTW	27/01/2016	49.034	6508677.579																											
S16 0184	6508675.077	NTW	Behind Shear Key	NTW	27/01/2016	48.993	6508675.077																											
S16 0201	6508681.120	NTW	Behind Shear Key	NTW	28/01/2016	49.212	6508681.120																											
S16 0202	6508687.598	NTW	Behind Shear Key	NTW	28/01/2016	49.282	6508687.598																											
S16 02014	6508682.681	TAJ	Silt pond	TAJ	28/01/2016	48.804	6508682.681																											
S16 02015	6508680.627	TAJ	Silt pond	TAJ	28/01/2016	50.029	6508680.627																											
S16 0221	6508685.163	NTW	Behind Shear Key	NTW	28/01/2016	49.212	6508685.163																											
S16 02022	6508684.854	TAJ	Behind shear key	TAJ	30/01/2016	51.047	6508684.854																											
S16 0241	6508674.087	TAJ	shear key	TAJ	21/02/2016	37.015	6508674.087																											
S16 0253	6508682.819	TAJ	shear key	TAJ	31/02/2016	36.895	6508682.819																											
S16 0286	6508678.446	TAJ	shear key	TAJ	4/02/2016	37.723	6508678.446																											
S16 02810	6508684.321	TAJ	Wall 803	TAJ	4/02/2016	43.555	6508684.321																											
S16 02811	6508677.418	TAJ	Wall 804	TAJ	4/02/2016	43.576	6508677.418																											
S16 0281	6508677.593	TAJ	shear key	TAJ	9/02/2016	41.007	6508677.593																											
S16 0282	6508673.149	TAJ	shear key	TAJ	9/02/2016	35.505	6508673.149																											
S16 0281	6508686.289	TAJ	Shear Key	TAJ	10/02/2016	38.988	6508686.289																											
S16 0284	6508680.180	TAJ	silt pond	TAJ	10/02/2016	24.795	6508680.180																											
S16 0281	6508644.767	TAJ	Undercut	TAJ	11/02/2016	40.343	6508644.767																											
S16 0282	6508649.577	TAJ	Undercut	TAJ	11/02/2016	44.089	6508649.577																											
S16 0283	6508675.525	TAJ	Shear Key	TAJ	11/02/2016	41.325	6508675.525																											
S16 0284	6508685.709	TAJ	RE Wall	TAJ	11/02/2016	45.461	6508685.709																											
S16 0285	6508646.331	TAJ	Re Wall	TAJ	11/02/2016	45.588	6508646.331																											
S16 0286	6508682.689	TAJ	Shear Key	TAJ	11/02/2016	41.161	6508682.689																											
S16 0287	6508672.302	TAJ	Shear Key	TAJ	11/02/2016	41.284	6508672.302																											
S16 0284	6508678.880	TAJ	Shear Key	TAJ	12/02/2016	42.123	6508678.880																											
S16 0305	6508683.725	TAJ	Shear Key	TAJ	12/02/2016	41.084	6508683.725																											
S16 0306	6508646.863	TAJ	RE Wall	TAJ	12/02/2016	46.443	6508646.863																											
S16 0307	6508646.146	TAJ	RE Wall	TAJ	12/02/2016	46.580	6508646.146																											
S16 0321	6508627.693	TAJ	RE Wall	TAJ	15/02/2016	48.066	6508627.693																											
S16 0322	6508679.386	TAJ	Undercut	TAJ	15/02/2016	57.805	6508679.386																											
S16 0326	6508655.223	TAJ	RE wall	TAJ	15/02/2016	47.658	6508655.223																											

1.88	1.56	20.0	2.7	10.3	89	101	75	81	Y
1.92	1.46	32.2	2.7	0.0					
1.92	1.46	32.2	2.7	0.0					
2.00	1.71	16.4	2.7	8.4	196	186	196	196	
2.00	1.73	16.4	2.7	8.3					
1.97	1.69	22.9	2.7	4.4	196	186	196	196	
1.98	1.59	22.9	2.7	4.5					
2.03	1.52	25.1	2.7	0.0	154	186	196	182	
2.04	1.63	25.1	2.7	0.0					
1.92	1.80	20.6	2.7	8.0	196	196	196	196	
1.93	1.80	20.6	2.7	7.8					
1.99	1.74	14.3	2.7	10.8	205	205	205	205	Y
1.98	1.73	14.3	2.7	11.1					
1.94	1.54	26.2	2.7	2.6	205	205	205	205	
1.94	1.54	26.2	2.7	2.7					
1.94	1.56	24.3	2.7	4.5	196	196	196	196	
1.94	1.58	24.3	2.7	4.4					
2.02	1.53	31.4	2.7	0.0	196	196	196	196	
2.02	1.54	31.4	2.7	0.0					
2.00	1.87	18.6	2.7	5.3	205	157	139	163	
1.99	1.86	18.6	2.7	5.7					
1.99	1.53	23.2	2.7	7.8	192	205	183	183	
1.88	1.53	23.2	2.7	8.0					
2.00	1.81	24.2	2.7	1.8	205	205	205	205	
1.98	1.60	24.2	2.7	1.8					
1.78	1.27	41.3	2.7	0.8	205	193	159	142	
1.79	1.26	41.3	2.7	1.1					
1.85	1.52	22.0	2.7	10.2	205	205	205	205	Y
1.80	1.52	22.0	2.7	10.3					
2.02	1.63	23.9	2.7	0.8	205	205	205	205	
2.02	1.63	23.9	2.7	0.7					
2.07	1.81	14.3	2.7	6.8	205	205	205	205	
2.06	1.80	14.3	2.7	7.4					
1.96	1.45	28.3	2.7	3.2	205	205	205	205	
1.86	1.45	28.3	2.7	5.3					
1.87	1.50	24.5	2.7	7.8	192	205	205	171	183
1.87	1.59	24.5	2.7	7.5					
1.91	1.54	24.3	2.7	5.6	205	205	205	205	
1.91	1.54	24.3	2.7	5.6					
1.93	1.38	33.7	2.7	3.4	137	133	144	152	142
1.92	1.36	33.7	2.7	3.8					
1.72	1.24	38.7	2.7	6.2	140	137	133	150	140
1.73	1.25	38.7	2.7	5.5					
1.79	1.35	35.0	2.7	-1.5	205	171	150	147	188
1.81	1.31	38.0	2.7	1.8					
1.99	1.65	20.3	2.7	5.2	205	205	205	205	
2.03	1.72	17.7	2.7	3.8	205	205	205	205	
2.03	1.72	17.7	2.7	5.8					
1.84	1.48	30.1	2.7	0.6	190	150	150	150	
1.84	1.41	30.1	2.7	5.2					
1.91	1.52	25.7	2.7	4.9	150	152	150	151	
1.91	1.52	25.7	2.7	4.8					
1.96	1.45	35.0	2.7	-4.1	205	205	205	205	
1.95	1.45	35.0	2.7	-4.1					
1.82	1.39	31.2	2.7	5.2	205	205	205	205	
1.91	1.39	31.2	2.7	6.7					
1.94	1.75	10.7	2.7	16.3	205	205	205	205	
1.94	1.75	10.7	2.7	16.4					
1.89	1.48	28.2	2.7	3.5	205	205	205	205	
1.89	1.47	28.2	2.7	3.9					
1.92	1.53	25.3	2.7	4.4	205	205	205	205	
1.91	1.53	25.3	2.7	4.8					
1.82	1.43	27.6	2.7	7.8	205	205	205	205	
1.80	1.41	27.6	2.7	9.1					
2.05	1.78	15.2	2.7	7.1	205	205	205	205	
2.03	1.76	15.2	2.7	7.9					

S16 0327
S16 0354
S16 0365
S16 0386
S16 0387
S16 0403
S16 0406
S16 0411
S16 0474
S16 0475
S16 0476
S16 0481
S16 0482
S16 0487
S16 0488

26559834.025	6508681.461	47.686	RE Wall	TAJ	15022016
26559820.329	6508686.004	49.060	Re wall	TAJ	22022016
26559811.009	6508681.941	48.138	Re wall	TAJ	22022016
26559947.549	6508670.529	42.578	Above Shear Key	TAJ	24022016
26559967.908	6508682.310	42.700	Above Shear Key	TAJ	24022016
26559977.855	6508687.841	44.022	Above Shear Key	TAJ	25022016
26559947.717	6508684.324	44.324	Above Shear Key	TAJ	25022016
26559945.872	6508710.467	45.023	above shear key	TAJ	28022016
26559889.639	6508681.182	45.117	Re Wall	TAJ	10032016
2655931.48	6508682.33	44.979	Re Wall	TAJ	10032016
26559976.169	6508690.36	44.995	Re Wall	TAJ	10032016
26559954.445	6508688.21	47.036	Re Wall	TAJ	14032016
26559955.997	6508686.53	46.933	Re Wall	TAJ	14032016
26559909.668	6508687.47	47.393	Re wall	TAJ	14032016
26559916.04	6508687.54	47.498	Re wall	TAJ	14032016

2.01	1.68	18.4	2.7	5.2	205	205	205	205	205	P
2.01	1.84	19.4	2.7	5.2	205	205	205	205	205	P
1.95	1.55	25.8	2.7	2.7	205	205	205	205	205	P
1.84	1.55	25.8	2.7	2.9	205	205	205	205	205	P
2.02	1.68	19.9	2.7	4.2	205	205	205	205	205	P
2.02	1.88	19.9	2.7	4.0	205	205	205	205	205	P
1.90	1.53	24.4	2.7	6.1	205	205	205	205	205	P
1.90	1.53	24.4	2.7	6.0	205	205	205	205	205	P
2.01	1.60	25.4	2.7	0.8	205	205	205	205	205	P
1.99	1.88	25.4	2.7	1.1	205	205	205	205	205	P
2.03	1.66	21.9	2.7	2.1	205	205	205	205	205	P
2.03	1.66	21.9	2.7	2.0	205	205	205	205	205	P
1.95	1.62	20.5	2.7	7.0	205	205	205	205	205	P
1.85	1.81	20.5	2.7	7.1	205	205	205	205	205	P
2.03	1.74	16.9	2.7	6.2	205	205	205	205	205	P
2.04	1.74	16.9	2.7	6.1	205	205	205	205	205	P
2.03	1.72	17.9	2.7	8.4	205	205	205	205	205	P
2.02	1.72	17.9	2.7	8.7	205	205	205	205	205	P
2.03	1.70	19.0	2.7	4.8	205	205	205	205	205	P
2.03	1.71	19.0	2.7	4.3	205	205	205	205	205	P
2.05	1.72	19.6	2.7	2.3	205	205	205	205	205	P
2.06	1.73	18.5	2.7	2.3	205	205	205	205	205	P
1.99	1.92	22.1	2.7	4.2	196	196	196	196	196	P
1.99	1.82	22.1	2.7	4.1	196	196	196	196	196	P
1.93	1.57	23.2	2.7	5.5	196	196	196	196	196	P
1.95	1.68	23.2	2.7	4.8	196	196	196	196	196	P
1.99	1.84	21.3	2.7	4.9	196	196	196	196	196	P
2.00	1.64	21.3	2.7	4.1	196	196	196	196	196	P
2.03	1.76	15.8	2.7	7.2	196	196	196	196	196	P
2.02	1.74	15.8	2.7	7.9	196	196	196	196	196	P

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