REPORT

MARIST HOLDINGS (GREENMEADOWS) LTD, MISSION TRUST

Extension to Western Hills Subdivision
Geotechnical Report

Report prepared for:

MARIST HOLDINGS LTD

Report prepared by:

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1 Introduction

Tonkin & Taylor Limited (T&T) have carried out a supplementary geotechnical investigation at Puketitiri Road, Greenmeadows, in support of an extension to a proposed residential subdivision (Western Hills Residential Development) for Marist Holdings (Greenmeadows) Limited, Mission Trust.

Dezign Works HB Limited (DW) have prepared drawings GMT01 E100, E101, XS and XS1 for the proposed additional bulk earthworks, showing a substantial volume of cut from a knob above the Puketitiri Road cutting, with corresponding fill volumes in a shallow valley to the west of the knob and a steeper valley to the south.

This report is based on visual inspection, preliminary engineering geological mapping and aerial photograph interpretation of landscape features. A 20 tonne hydraulic excavator was used to excavate a series of test pits to characterise the subsurface conditions across the site.

On the basis of our observations and geological appraisal we consider that the proposed earthworks are feasible and that a suitable building platform will be available on each lot provided the recommended earthworks practices are followed.

2 Previous report

T&T have previously reported on the geotechnical aspects of the original Western Hills Residential Development, and the reader is referred to Report 21027, issued in February 2004. That report raised minor concerns about the presence of surficial loess and tephra but concluded that sound earthworks construction practices would permit building development generally in accordance with NZS 3604:1999.

3 Proposed development

The Western Hills Residential Development will involve subdivision of the north eastern corner of the 295 hectare Lot 1 DP 27138 to create over 200 lots. In the extension to the scheme being reported on here, it is proposed to undertake bulk earthworks with cuts of up to about 8 m maximum height from the crest of the eastern knob, and fills of up to 14 m height both between ridges and at the head of 2 valleys.

4 Investigations

Field investigations have consisted of reconnaissance engineering geological mapping of available rock outcrops and the recent road cutting in Puketitiri Road, interpretation of vertical aerial photographs, and a series of twelve test pits (TP1 to TP12) spread over both the proposed cut and fill areas. The general locations of the test pits relative to the Puketitiri road cutting are shown on Figure 1 and in greater detail on the site plan, Figure 3, in Appendix A. The test pit logs are presented in Appendix B. The pits were taken to a maximum depth of up to 2.5 m and all terminated in hard ground inferred to be the upper surface of the locally well known highly competent Roys Hill siltstone.

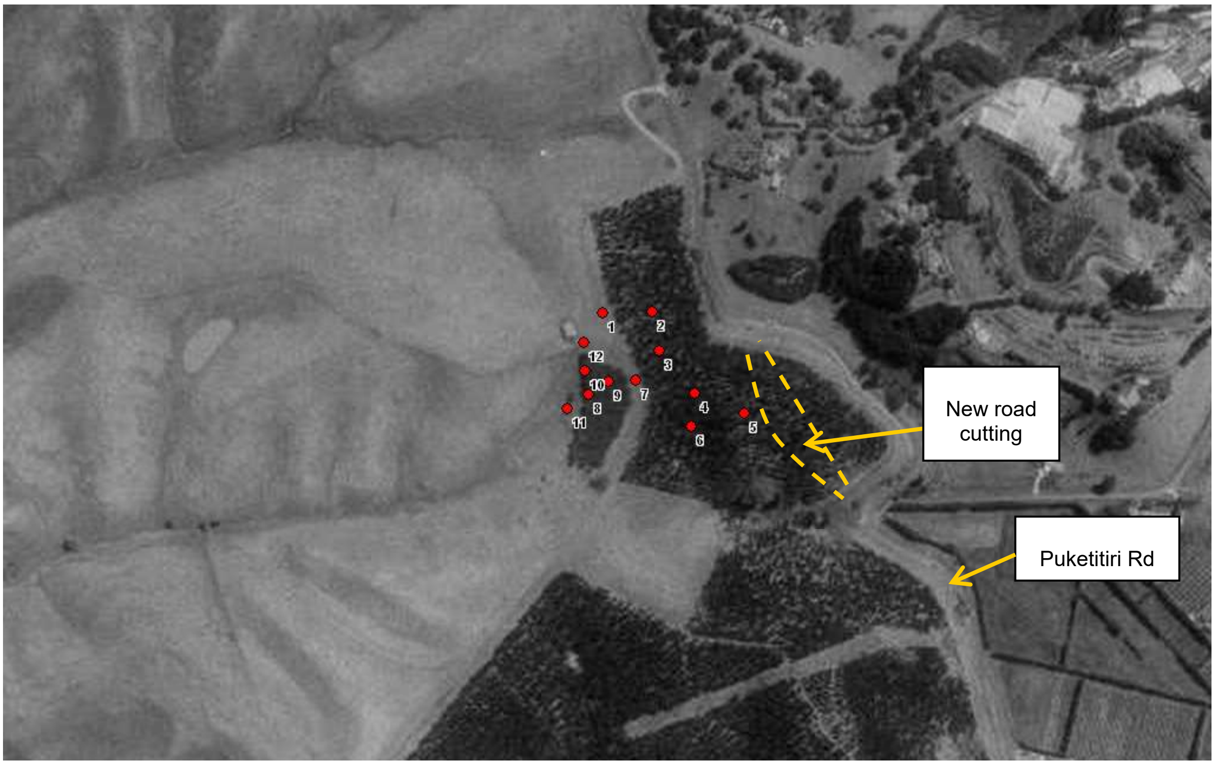

Figure 1: Locations of test pits

Bag samples of the proposed bulk fill material were taken for laboratory consolidated undrained triaxial testing to determine effective stress strength parameters to facilitate stability analyses, particularly under seismic shaking.

5 Site description

5.1 Surface features

The proposed extension to the Western Hills Residential Development is located west of the recently constructed approximately 25 m high cutting in Puketitiri Road as shown on Figure 2. The cut area is situated on a knob of higher ground, planted in pine trees, with views over Lagoon Farm to the suburbs of Napier. The proposed fill area lies at the head of a westerly trending shallow valley. This valley contains a small stock water dam at its head, and forms the headwaters of a small unnamed stream draining west into the Tutaekuri River near Springfield Road. The land in this area is mostly pastoral and has been farmed for the last 100 years or so. A small stand of eucalypt trees is growing on the valley slope east of the dam. The westerly trending valley has side slopes of 10° to 15° degrees extending up to the crests of broad ridges on either side of the main valley.

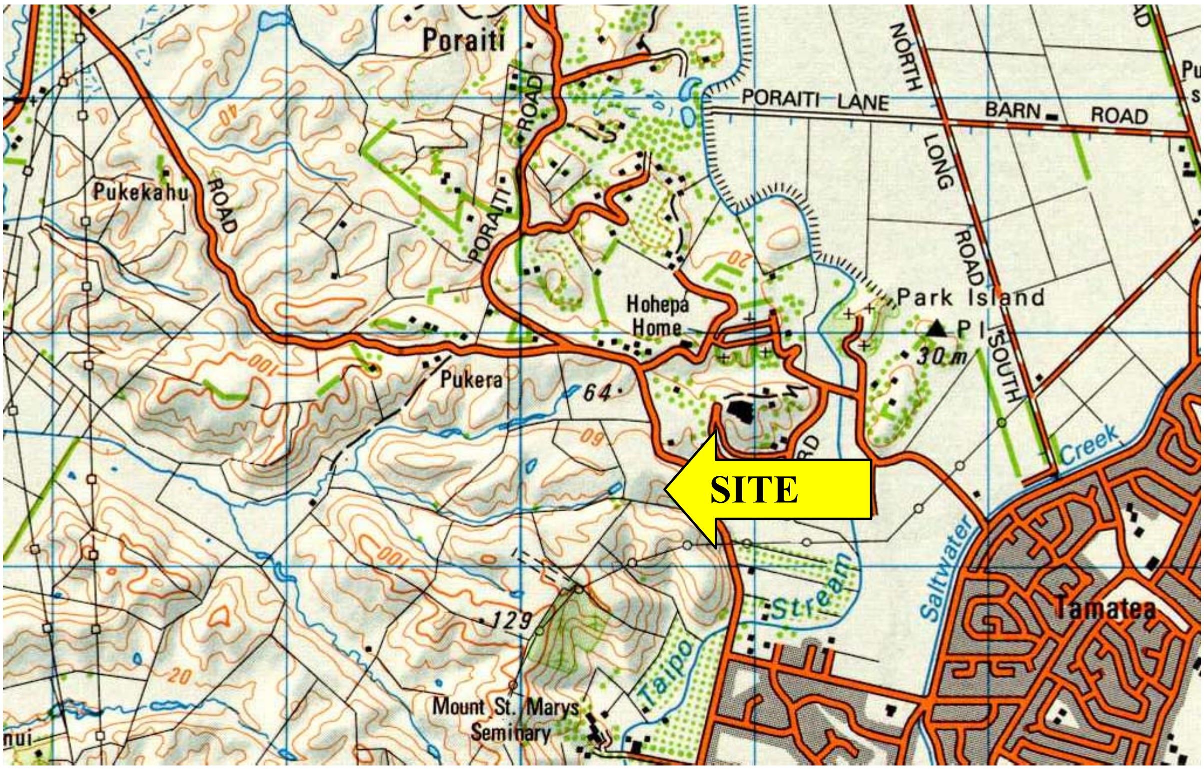

Figure 2: Location Plan

5.2 Geological setting

NZ Geological "Maps N134 and N135, Napier and Hastings – Kidnappers", J.T. Kingma, indicates that the subject property is underlain by sub-horizontal to gently east-dipping beds of Nukumaruan-aged, brown, weak siltstone of the Roys Hill Formation, overlying greyish white, slightly gravelly limestone and coquina shelly limestone at depth. The limestone and coquina are well exposed in batters in the recently constructed road cutting in Puketitiri Road to the east of the subject property but were not observed on the subject site in the relatively shallow test pits. Recent wind blown loess and volcanic tephra mantle the topography which has formed on the base rocks.

5.3 Seismicity

The Western Hills area lies close to the axis of the active Napier Fault (1931) rupture in an area where shallow crustal faults and the subduction zone between the descending Pacific Plate and Australian Plate are capable of producing a wide range of earthquake shaking intensities.

Peak ground acceleration expected at 10% probability in 50 years is shown as 0.40 g on Figure 5a in "Probabilistic Seismic Hazard Assessment of New Zealand: New Active Fault Data, Seismicity Data, Attenuation Relationships and Methods" prepared by IGNS for the Earthquake Commission Research Foundation in May, 2000.

This data uses all geological data and historical earthquake records to define locations of earthquake sources across and beneath the country, and the likely magnitudes, tectonic type or mechanism, and frequencies of earthquake that may be produced by each source.

6 Results of investigations

6.1 Ground conditions

The test pit excavations have shown that generally the site is underlain by between 150 and 450 mm of black silty topsoil overlying a sequence of up to 1.5 m of loose greyish-white pumiceous fine sand (volcanic tephra) interbedded with damp brown silt (loess). This sequence is underlain (at typically less than 1 m depth) by slightly weathered siltstone (inferred to be the "Roys Siltstone") of relatively high strength (estimated unconfined compressive strength exceeding 5 MPa). This material was very difficult to excavate with a 20 tonne excavator fitted with a rock bucket, and refusal occurred at relatively shallow depths. We expect that ripping will be necessary to allow bulk earthworks by motor scrapers.

In TPs 7 and 11, Roys Siltstone was found at the greatest depths of 1.8 m and 2.4 m respectively, with the overlying materials being a variable strength mixture of tephra, loess and colluvium.

Groundwater was not encountered in any of the pits.

6.2 Laboratory testing

Bulk samples of proposed cut to fill material were taken from two of the test pits and compacted in a triaxial cell to a bulk density similar to that expected to be achieved during earthworks (approximately 2.00 t/m^3). The compacted material was subjected to consolidated undrained triaxial testing (with pore pressure measurement) in the Geotechnics Laboratory in Auckland, to obtain a better understanding of the likely seismic performance of the proposed fills and confirm required setback distances from steeper slopes. The detailed results are presented in Appendix C and indicate effective stress parameters $Ø' = 40°$ $c' = 23$ kPa for the 50 to 200 kPa range of consolidation pressures.

6.3 Stability

6.3.1 Visual assessment

Based on our walkover observations and study of vertical aerial photography, we have not identified any areas of slope instability on the subject property. Minor tunnel gully erosion (confined to the recent loess cover) is present on the site but was not observed in the subdivision extension area. However, the potential for such shallow instability is present and careful site inspections are necessary.

6.3.2 Numerical assessment

Typical cross-sections through the highest fill platforms (Sections F and G on DW's Sheet G103) are shown as Sections A and B in Appendix A. We have carried out computerised stability analyses assuming effective stress parameters based on both the normally adopted strength parameters and the measured laboratory triaxial strength parmeters suitably adjusted for future relaxation and softening. Analyses were carried out for both static stability and seismic stability, initially assuming a basic peak ground acceleration (PGA)of 0.4g (475 year return period PGA which has a 10% probability of occurrence in 50 years). In addition, we assessed the effect of amplification of the basic ground shaking by a 15 m high embankment, which can be expected to produce peak embankment crest accelerations of up to about 0.8g (for a 0.4g basic PGA). Factors of Safety for the critical failure surface for various conditions are presented in Table 1 below.

Table 1: Critical Factors of Safety

Effective stress parameters	Average seismic ground acceleration	Section A	Section B
c´ = 10 kPa φ´ = 34°	Static (zero ground acceleration)	1.83	1.86
	0.4g 0.6g	0.91 0.70	0.89 0.68
c´ = 15 kPa φ´ = 38°*	0.6g 0.8g	0.87 0.70	

* Allows for relaxation and softening from measured triaxial parameters.

It can be seen that the minimum Factor of Safety under design static conditions exceeds the normally accepted minimum of 1.5 but that the minimum Factors of Safety under ground accelerations exceeding 0.4g are less than one for all critical surfaces. We have, however, assessed the likely surface displacement a 0.8g crest acceleration at the outer edge of the fill platform (using the higher strength parameters) and have determined it is less than 60 mm. Most of the critical failure surfaces are relatively shallow-seated and it would be possible to install shallow piled building foundations to extend below the critical surfaces if required. However, we would generally recommend a setback of 8 m from the outer edge of fill platforms without specific design to ensure foundations are landward of the likely slope deformation zone during seismic shaking. Alternatively, foundations may be constructed within 8 m of the outer edge of fill platforms with specific foundation design allowing for the expected seismic displacement. In addition, we recommend a maximum fill batter of 2.5(H) :1 (V) for ease of construction and also to enhance stability.

7 Engineering considerations

7.1 Earthworks

Recommendations and opinions contained in this report are based upon data from test pits, surface exposures and laboratory testing. Inferences about the nature and continuity of subsoils away from these points are made but cannot be guaranteed.

Because of the concerns regarding shallow instability, it is recommended that the fill platforms be constructed by benching into the siltstone as shown on Section A, i.e. beneath any loess or tephra that may be present. To ensure satisfactory stability, the fill will need to be carefully placed in layers less than 300 mm loose thickness and compacted with suitable equipment to achieve:

- Minimum shear: strength 200 kPa
- Maximum air voids: 8%

Laboratory testing should be carried out to determine a suitable earthworks Specification and confirm that the above parameters are readily achieveable. It is, however, expected that the cut material will make good fill and should compact well at existing water content (or slightly wetter) with a heavy sheepsfoot roller. Compaction tests will confirm the optimum water content for compaction. Subsoil drainage will need to be installed beneath the fill platforms to ensure all pre-existing drainage areas and seeps are intercepted and conveyed to a suitable discharge point.

To avoid localised instability, fill batters should not exceed 2.5(H):1(V).

Because of the relatively high fill heights (up to 15 m), it is likely that some self – weight induced consolidation of the fill will occur following earthworks. It is therefore recommended that immediately after earthworks, a network of survey level points be established in the deepest fill areas and regularly monitored to determine settlement rates and when it is appropriate for building to commence. Building while settlement rates are high could cause significant damage to houses.

Excavations up to 3 m high may be made in the siltstone at batters up to 1(H):1(V) although materials above the siltstone should be battered no steeper than 2(H):1(V). Higher excavations than this should receive specific design.

Cut platforms should be excavated to the siltstone to achieve a suitable foundation to the satisfaction of the Engineer.

The above requirements will necessitate a significant component of site observation and testing during the earthworks phase. Accordingly, we recommend that all excavations be inspected by a suitably qualified person to confirm the assumptions made.

7.2 Foundations

Recommendations for foundations are made assuming that the above earthworks recommendations have been followed. In addition to the recommended 10 m setback from breaks in slope (without specific design), all building foundations should be founded within either weathered or recompacted siltstone (fill platforms) at a minimum of 1.0 m depth beneath adjacent finished ground level to ensure they are beneath the zone that may be affected by seasonal water content changes (shrink/swell). At this depth, a safe (FoS = 3.0 on geotechnical ultimate) bearing capacity of 150 kPa (225 kPa (Ultimate

Limit State)) is available. Accordingly, house foundations may be constructed in accordance with NZS 3604:1999 "Timber Frame Buildings" or alternatively specific foundation design may be made.

7.3 Roading and services

The proposed access road alignment is expected to be generally either in cut ground or close to existing ground level. Where possible cuts in the loess-derived soils should be kept flatter than 2H:1V and grassed to minimise the effects of erosion.

Where accessways are in sidling cuts, we recommend that a zone of filter compatible drainage material be installed at the base of the cut to control the potential for internal erosion from the permeable loess and volcanic ash deposits where the cut depth is less than the thickness of these materials. Similarly, all service pipes (e.g. power, stormwater, Telecom etc.) should be backfilled with sand at selected locations to minimise the potential for conduit scour and piping problems in the loess-derived soils. Also, pipe bedding should be able to drain at pipe outfalls, to prevent groundwater build-up.

The road subgrade should be excavated into the Roys Siltstone where a CBR of 15 is available for pavement design, subject to site confirmation that the "softened" surface is of adequate strength.

7.4 Stormwater disposal

We understand that all stormwater runoff from the proposed development will be channelled to the western valley to discharge via the existing watercourse to the Tutaekuri River.

7.5 Household sewage

All sewage from the proposed Western Hills Residential Development will be piped into the Napier City sewerage system.

8 Conclusions and rcommendations

The investigations have established that the site is suitable for the proposed extension to the Western Hills Residential Development in accordance with the following summary:

- Specific recommendations for benching into the competent Roys Siltstone (typically shallower than 1 m depth) and for fill placement have been made for the earthworks platforms. The recommended maximum fill batter is 2.5(H):1(V). Because fill heights are relatively great (up to 14 m), there is potential for consolidation of the fill and we recommend establishment and regular monitoring of a network of survey level points to determine when building construction can safely commence.
- An 8 m setback from the outer edge of fill platforms is recommended without specific foundation design and all building foundations should be founded a minimum of 1.0 m beneath adjacent finished ground level and be founded within either weathered or recompacted siltstone (fill platforms). A safe (FoS = 3.0 on geotechnical ultimate) bearing capacity of 150 kPa (225 kPa ULS) is available and building may proceed in accordance with NZS 3604:1999 or incorporating specific design
- Stormwater runoff from the proposed development will be conveyed to the western valley and discharged to the unnamed stream that flows into the Tutaekiri River.
- Excavations up to 3 m high at batters up to 1(H):1(V) are acceptable in the siltstone although overlying materials should not be battered steeper than 2(H):1(V). Higher and/or steeper excavations require specific design. Cuts within the surficial loess or tephra which do not reach siltstone require a filter compatible drain at the base of the cut to minimise possible internal erosion. Similarly, services trenches should be backfilled with sand or approved filter material at regular intervals.

9 Applicability

This report has been prepared for the benefit of Marist Holdings (Greenmeadows) Ltd Mission Trust 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.

TONKIN & TAYLOR LTD

Environmental and Engineering Consultants

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Appendix A: Site plan, Figure 3. Cross Section A and stability analyses

Appendix B: Test pit logs

Appendix C: Laboratory triaxial test results