REPORT

Fletcher Residential Ltd

Three Kings Renewal
Option 15H2 - Geotechnical Assessment

Tonkin & Taylor

ENVIRONMENTAL AND ENGINEERING CONSULTANTS

REPORT

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Report prepared for:

FLETCHER RESIDENTIAL LTD

Report prepared by:

Tonkin & Taylor Ltd

Distribution:

FLETCHER RESIDENTIAL LTD	1 copy
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July 2014

T&T Ref: 25141.003

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1 Introduction

Fletcher Residential Ltd (Fletcher Residential) is seeking to redevelop the former Three Kings Quarry in Three Kings, Auckland for mid to high density residential use.

The redevelopment option 15H2 will primarily consist of land within the current quarry boundaries, but will also include land to the north east of the quarry pit which is currently a commercial / industrial development. All the land sought to be developed is owned by Fletcher Concrete and Infrastructure Ltd.

Tonkin & Taylor has been engaged to assess the geotechnical elements of the site to ensure that it can be safely developed for residential and open space development.

1.1 Proposed plan change

A plan change is being sought to enable the comprehensive redevelopment of the former Fletcher quarry lands at Three Kings. The proposal is to provide for a mix of townhouses, low rise apartment buildings and multilevel cascading apartments with areas of open space.

1.2 Final landform

The Three Kings Quarry currently extends approximately 40m below Mt Eden Road. To create the final landform for development, the base level of Three Kings Quarry will be lifted by filling to create a relatively level surface between 15 and 17m below Mt Eden Road.

The existing quarry pit cut slopes forming the transition from the development surface to surrounding ground level on the eastern and southern boundary will be re-profiled. Elsewhere, the existing remnant cut slopes will remain as part of the development landform.

1.3 Purpose and format of report

This geotechnical assessment report has been prepared to support the private plan change application for re-zoning this land to an appropriate residential zoning.

The report specifically addresses;

- Building types and foundations
- Fill properties for fill in the quarry floor and the management of potential long term settlement effects
- The stability of cut slopes – both re-profiled quarry faces and remnant quarry faces

It assesses how these issues are already managed through the existing fill resource consent, the design of the proposal and within the District Plan and plan change provisions.

1.4 Summary of assessments

Tonkin & Taylor has been involved in this site since 1996 and the principal author of this report since 2000. Our work at this site has included geological and geotechnical investigations and advice for the development of the quarry and the quarry cut slopes, groundwater assessments as part of consenting processes, and option assessments for the filling and re-development of the completed quarry. We provided expert geotechnical evidence as part of the consenting process for the controlled fill consent, and are undertaking ongoing engineering observations and providing advice for managed fill operations.

This report confirms that there are no geotechnical constraints that preclude the construction of the development as depicted by Option 15H2. Where there is potential for geotechnical issues, each is addressed by the current design, existing or proposed plan provisions, and within the design a range of other commonly adopted mitigation measures available to be utilised by Fletcher Residential.

At the time of writing this report, rock was still being excavated from the quarry. Concurrently, the quarry was being operated as a controlled fill site under the existing controlled fill consent conditions. The fill has been placed in accordance the existing engineering requirements of the consent (more detail of these requirements is provided in Section 3.1) and to meet the engineering requirements of an earlier development intention. To meet the requirements of the Option 15H2 development plan, and the timeframes associated with it, some of this material will be re-worked.

2 Building types and foundations

The proposed development includes a combination of townhouses, low rise apartments (three and four levels, with one block at five levels) and multi-level cascading apartments (up to ten levels). Refer to Figure 1.

2.1 Terrace housing

Lightweight terrace houses will be constructed on fill placed over the base of the quarry and on the higher ground currently supporting commercial/industrial buildings adjacent to Mt Eden Road. It is intended that these terrace houses will be supported on shallow strip and pad or raft foundations.

2.2 Low rise apartment buildings

Lightweight low rise apartments will be constructed on fill placed over the base of the quarry and on the higher ground currently supporting commercial/industrial buildings adjacent to Mt Eden Road. The buildings will be supported on shallow strip and pad or raft foundations.

2.3 Multi-level cascading apartment buildings

Multi-level cascading apartments will be constructed around the quarry perimeter, cascading down a re-profiled quarry face. They will be founded on shallow strip and pad foundations constructed within insitu volcanic materials (basalt rock and scoria) around the quarry perimeter. In isolated locations where the apartment footprint extends over filled ground, piles will be constructed so that the apartment is supported by the rock and scoria below the fill.

3 Fill placement and compaction

Fill is being imported to site and placed over the quarry floor to raise the level for the development, and to support the shallow foundations for terrace houses and low rise apartments. The fill will create a relatively flat final surface between 15 and 17m lower than Mt Eden Road.

To create this surface over the varying quarry floor levels the fill will typically be between 5m to 28m deep. The deepest areas of fill occur on the eastern side of the site adjacent to the Mt Eden Road quarry face.

Fill depths of 5 to 10m are routine for residential subdivision development. The fill will be placed in accordance with NZS 4431:1989 and to a standard such that the upper layers provide adequate bearing capacity for the shallow foundations.

Fill depths greater than 10m have been given specific consideration. In areas of such deeper fill, the deeper layers will be placed to a standard to minimise the potential for long term fill settlement to affect building performance. Analyses show that when the deeper fill is controlled and compacted in accordance with the current design, the long term settlements that are expected are within the normal tolerances of terrace houses and low rise apartments.

3.1 Existing Controlled Fill Consent

Winstone Aggregates (a division of Fletcher Construction and Infrastructure Ltd) has a consent from Auckland Council (AC) authorising "the land use, earthworks and discharges associated with the development of a controlled fill at the worked out Three Kings Quarry site" ([2011] NZEnvC 214) (the Consent).

Soon after obtaining the Consent, Winstone Aggregates commenced controlled fill operations at the quarry. The processes and controls necessary to confirm that the engineering consent requirements at the site are being satisfied are well established, with engineering testing and reporting protocols in place.

The criteria set within the engineering controls were based on an earlier development proposal. To meet the timeframe requirements of the Option 15H2 proposal the engineering criteria will be changed. Fill that has already been placed and that does not meet the new requirements will be reworked so that it does meet the requirements. All fill will continue to be placed in accordance with NZ4431:1989.

To date, fill has been placed primarily within the northern half of the site. Other material has been placed ready for future use as fill (again mostly in the northern part of the site). This material forms a stockpile for future use when creating the final development land form of Option 15H2.

Our earlier geotechnical work for the site identified that the specification for fill placement depended on development plans and development timeframes, but irrespective of this, the final upper 5-10m of fill should be engineered to a high standard to provide adequate founding conditions for residential structures. This advice was presented in expert evidence at council and Environment Court hearings and adopted as a condition of the controlled fill consent, which stated that; "The controlled fill in the upper 5 m layer shall be engineered to a compaction and stability standard in accordance with NZS 4431:1989, that enables future residential use of the finished landform no longer than 5 years after cessation of filling" (Condition 9 of the Consent).

For the specific layout and plans associated with Option 15H2 the full depth of fill supporting residential use will be compacted to this standard. This is discussed further in Section 3.3.

The geotechnical evidence also identified that such a high standard would not be necessary to achieve the requirements for open space and parks. This advice was adopted as a condition of the consent which states that the requirements for the upper 5 m layer "... may be reviewed where a proposed Plan Change or review (or any resource consent addressing the use of the site as a whole) indicates that future uses will demand a lesser standard of compaction" (Condition 9 of the Consent).

For Option 15H2 the fill criteria for public space areas have been set to ensure the fill supports the intended land use and to maintain the required landform (primarily to ensure that long term settlement does not disrupt surface drainage features).

3.2 Bearing capacity

For developments similar to that proposed for the Three Kings site, the upper fill layers are normally compacted to a standard equivalent to an un-drained shear strength of 140kPa and in accordance with NZS 4431:1989. Fill compacted to this standard will be sufficient to provide local bearing capacity for the terrace houses and low rise apartments and is a requirement of the existing consent (refer Section above).

While the fill will be compacted to a high standard it will not be sufficient to support the higher loads associated with the multi-level cascading apartments. These will predominantly be supported on high capacity insitu volcanic materials, however there are some instances where a building, or a small portion of the building footprint, extends over filled ground. In these locations, piled foundations will transfer the building loads through the fill to the insitu materials below.

The insitu materials typically comprise scoria and basalt rock. These materials will, subject to suitably detailed design, provide suitable conditions for shallow foundations for all structures, including the multi-level cascading apartments and for piled foundations where these are necessary. The foundations will require specific design.

3.3 Long term fill settlement

During and after fill placement, self-weight settlement can occur as a result of the load that the upper fill layers impose on the lower fill layers. In very deep fills, or where the deeper fill layers are soft, the imposed loads can cause the deeper fill to consolidate (reduce in volume).

This time dependant consolidation of fill typically results in settlement of the ground surface (the fill surface). The consolidation process can, in some materials, be complete within weeks or months of fill placement and would therefore normally be complete before buildings were constructed on the fill. In some materials however, it may take many months to years to complete; in such situations surface settlements may be ongoing when buildings are constructed.

If there is significant variation in fill depth beneath the building footprint, then the ongoing settlement can lead to differential settlement across the structure and structural distortion. If structural distortion is large, damage can result. Zones of significant variation in fill depth are shown on Figure 2.

Guidance on differential settlement tolerances for buildings in general is provided in the NZ building code. Appendix B B1/VM4, clause B1.0.2 states:

“Foundation design should limit the probable maximum differential settlement over a horizontal distance of 6m to no more than 25 mm under serviceability limit state load combinations of NZS 4203:1992 (updated in 2004), unless the structure is specifically designed to prevent damage under a greater settlement.”

This clause effectively sets a guidance limit of approximately 1:240 differential settlements.

3.3.1 Fill standards to control settlement

At Three Kings the fill design has been developed to limit differential settlement to within the tolerances of the buildings.

It is normal practice when developing engineering fills to provide controls through an engineering specification and this is reflected in the requirement of the current consent for the upper 5m of fill (refer to Section 3.1). The specification sets out the standards that must be achieved during

construction of the fill and the testing required to confirm that the specified standard has been achieved or exceeded.

This approach is being followed for all fill placed at Three Kings (not just the upper 5m), although the engineering criteria set by the specification have been updated to reflect the requirement of Option 15H2. All fill supporting residential development will be compacted to an undrained shear strength of 140kPa (or equivalent).

These fill requirements have been checked against research published by the Building Research Establishment of UK, (Skinner and Charles, 2001). This research provides a method for assessing the potential for differential settlement to arise from varying fill depth in backfilled quarries (such as Three Kings Quarry). It provides a basis for assessing the;

- magnitude to which residual settlement should be limited for there to be no significant impact on buildings
- width of a building exclusion zone either side of the wall boundary or the quarry floor topography change.

Skinner and Charles set 1:500 as the acceptable differential settlement tolerance limit for building construction, which is a factor of two flatter than specified in NZS 4203:1992.

Engineering assessments of the fill at Three Kings, using the methods presented, indicate the fill criteria for Option 15H2 are an appropriate control on long term settlement and can be expected to limit differential settlement to within the tolerances of the town houses and low rise apartments (i.e. the criteria will limit differential settlement to flatter than 1:500 for the fill depth and depth variations expected for Option 15H2).

Where the multi-level cascading apartments are constructed over fill, or partially over fill, pile foundations will isolate them from fill settlement so that differential settlements flatter than 1:500 are expected.

3.4 Groundwater

Another potential cause of long term fill settlement arises if groundwater conditions change significantly within the fill. Such a change might arise if the groundwater level, which is currently held below the base of the quarry by pumping, was allowed to rise into the fill (and potentially fall).

As the groundwater rises in the fill, the newly saturated fill might, depending on fill characteristics, soften, with the result being initiation of additional settlement. Fill that would be expected to soften include some specific rock types which are known to “slake” when saturated.

Subsequent to the rise, if the groundwater level falls back through the fill, further settlement may occur.

Option 15H2 mitigates this potential effect through the fill specification which excludes such water susceptible material types from the fill (this approach has been a requirement since the commencement of filling activities), and compacts the material to a standard that limits the potential for fill to take up water as groundwater rises. This approach is commonly adopted in civil engineering to ensure the long term stability of fill materials where groundwater levels may change over time.

4 Quarry faces

The Three Kings Quarry has been excavated approximately 40m below Mt Eden Road since quarrying began. The existing quarry faces that form the quarry pit perimeter are typically

between 45°and 70° (from horizontal) for heights of between 10m and 20m and overall slope angles of between 40° and 50° for slope heights between 35m to approximately 40m.

In the final Option 15H2 landform most of these slopes will remain, but to a much reduced height. Fill placed on the quarry floor and other trimming works will reduce the maximum slope height from approximately 40m to approximately 15 - 20m.

The proposed development utilises the remaining quarry cut faces in two ways. Remnant cut faces form part of the landform in open spaces and re-cut quarry faces provide space for construction of the multi-level cascading apartment buildings around the quarry perimeter. Refer to Figure 3.

To provide for the development these faces must be suitably stable such that they appropriately support the properties that are immediately above the slopes, and adequately protect properties within the development that are immediately below the slopes.

4.1 Remnant quarry faces

It would be normal to assume that cut faces formed for a quarry environment would be too steep for a residential environment. The quarry context usually involves an operational environment that can tolerate and manage a higher level of risk from slope instability than is acceptable in a residential environment.

At Three Kings however, the quarry is already bounded by residential environments. As such the cut slope design at Three Kings Quarry (by T&T in 1996 and re-reviewed in March 2009) has been developed to provide adequate support to adjacent residential property.

The 2009 slope study provided the following general design guidelines:

- Cut batters at 70° for cut slopes not exceeding 20m in height.
- Overall slope angles not to exceed 60° for slope heights not exceeding 45m.

While this guidance provides an upper bound for quarry development, recent measurements indicate that much of the perimeter quarry slopes are much flatter (more stable angles) than this.

The highest slopes are at overall slopes of 50° or less, while inter-bench slopes typically range from as flat as 35° up to 70°. On this basis, the remnant cut slopes are considered satisfactorily stable to support adjacent residential land (land at the top of the slopes), and to protect residential land within the development (below the slopes) from large scale inundation from above.

While the cut slopes achieve overall stability, local stability issues such as small scale slope failures and rock falls have not previously been an issue in the quarry environment as they do not typically impact quarry operations, but could have an impact on property within the development (should they occur). As such, local stability issues have been given specific consideration in Option 15H2 to protect life and property within the development (below the slopes) and is discussed further in Section 4.2.1.

4.2 Re-cut quarry faces

The multi-level cascading apartments will be constructed on cut platforms created by re-trimming the existing quarry faces on the eastern and southern boundaries. These cut faces will typically be 17m high or less.

The findings of the 2009 study were re-confirmed by a 2013 study, which recommended maximum cut slopes of 70° for cut slopes not exceeding 20m for slopes behind the multi-level cascading apartment buildings.

As discussed above, the assessment of overall slope stability does not address the local stability of the cut face. Local cut face stability is discussed in the following section.

4.2.1 Local stability issues

The cut faces contain gravel, cobble or boulder sized fragments of scoria or basalt rock that have the potential to fall from the cut slopes onto people or property at the base of the slopes. This type of slope instability has been addressed at the quarry in the past by measures appropriate to an operational quarry environment. Other measures are now required to support the change in land use to a residential environment.

One indication of the degree of hazard is to inspect the existing slopes. This provides a direct indication of local stability issues for remnant slopes, and an indication of potential issues for slopes that will be re-cut.

The remnant cut slopes display various degrees of localised stability issues – from areas where there are no observed issues (no indication that material of significant size has been dropping out of the face), to locations where it is likely that there has been, and will continue to be, regular cobble to boulder sized dropouts occurring.

In general, on an area basis, most of the remnant slopes exhibit no issues, or limited issues. Refer to Figure 4.

Where there are issues, observations indicate that cobble to boulder sized material has dropped out (fallen or bounced) of slopes that are steeper than 50°, with the most significant areas of rock fall debris observed at the toe of the steepest slopes (70-80° slopes adjacent to the present haul road). This material was observed as accumulation on the benches within 4m of the toe of the cut slopes.

Deposits of smaller diameter (gravel sized) scoria material that have progressively sloughed off the face typically accumulate at the bottom of these slopes developing a localised talus slope extending 2-3m from the toe of the cut slope.

On the flatter vegetated slopes (up to 50 degrees) scoria deposits attributable to localised drop outs were absent from the base of the slopes, suggesting a combination of the slope angle and re-vegetation is retaining scoria blocks on the slopes.

Option 15H2 includes a combination of cut slope management options to addresses the potential for local stability issues to occur on any cut slope.

- The re-cut slopes along the eastern and southern boundary will be behind the multi-level cascading apartment buildings and access to the base of these cuts will be restricted. Between the buildings, access to the cut slope will be restricted by fencing and vegetation. At the time these slopes are cut, detailed engineering inspections will assess the need for localised stabilisation measures to limit the size and volume of material that could drop out of the face. Such measures would include the commonly used methods such as nails and mesh or shotcrete and mesh.
- Access to the base of the northern remnant slopes will be restricted by a combination of vegetation, fences and wetland areas.
- Access to the base of the western remnant slopes will be restricted by vegetation and fences.

During construction detailed engineering inspections will identify any isolated areas within remnant slopes where more regular rock fall might be expected. Suspect material will either be locally removed from the slope, or where this is not possible additional engineering controls (such as nails and mesh or shotcrete and mesh) may be used to support the material on the slope.

5 Private Plan Change

The specific provisions recommended to form part of the private plan change will appropriately deal with the matters raised in this report.

In section H, 1.2, two assessment criteria are included. Criteria (vi) addresses the stability of cut slopes, quarry filling and structure foundation criteria, and (vii) addresses the treatment of remnant quarry faces.

6 Summary and Conclusions

Fletcher Residential Ltd is seeking a plan change to enable the comprehensive development of the former quarry lands at Three Kings. To enable the development, the existing quarry will be partially filled, and other land and slopes about the quarry will be modified.

A geotechnical assessment of the proposal (as identified on Option 15H2) has been prepared to support the plan change application and is based on involvement and engineering assessments for the site undertaken by the author since 2000, and Tonkin & Taylor since 1996.

It is concluded that there are no geotechnical constraints that preclude the construction of the development as depicted on Option 15H2. The potential geotechnical issues that are specific to the site and the proposed layout are addressed in the design to develop safe and stable building platforms and quarry cut slopes to form an appropriate part of a residential landscape.

During final design, specific details of the design will be confirmed, and alternative measures that are available to achieve the same result may be adopted. The Option 15H2 design should be the basis for confirming that the alternative solution provides an equivalent, or better outcome.

7 Applicability

This report has been prepared for the benefit of Fletcher Residential 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.

Tonkin & Taylor LTD

Environmental and Engineering Consultants

Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
.....	.....
Graeme Twose	pp Robert Hillier
Senior Geotechnical Engineer	Geotechnical Group Manager

With assistance from:

Matthew Kent, Geotechnical Engineer

Cameron Lines, Engineering Geologist

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Figures

Three Kings

May 2014

Plan Option 2

FIGURE 1

Three Kings

May 2014

Plan Option 2

LEGEND

Indicative zones of rapid fill depth transition

FIGURE 2

Three Kings

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Plan Option 2

LEGEND

- Remnant cut scopes
- Re-profiled scopes

FIGURE 3

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