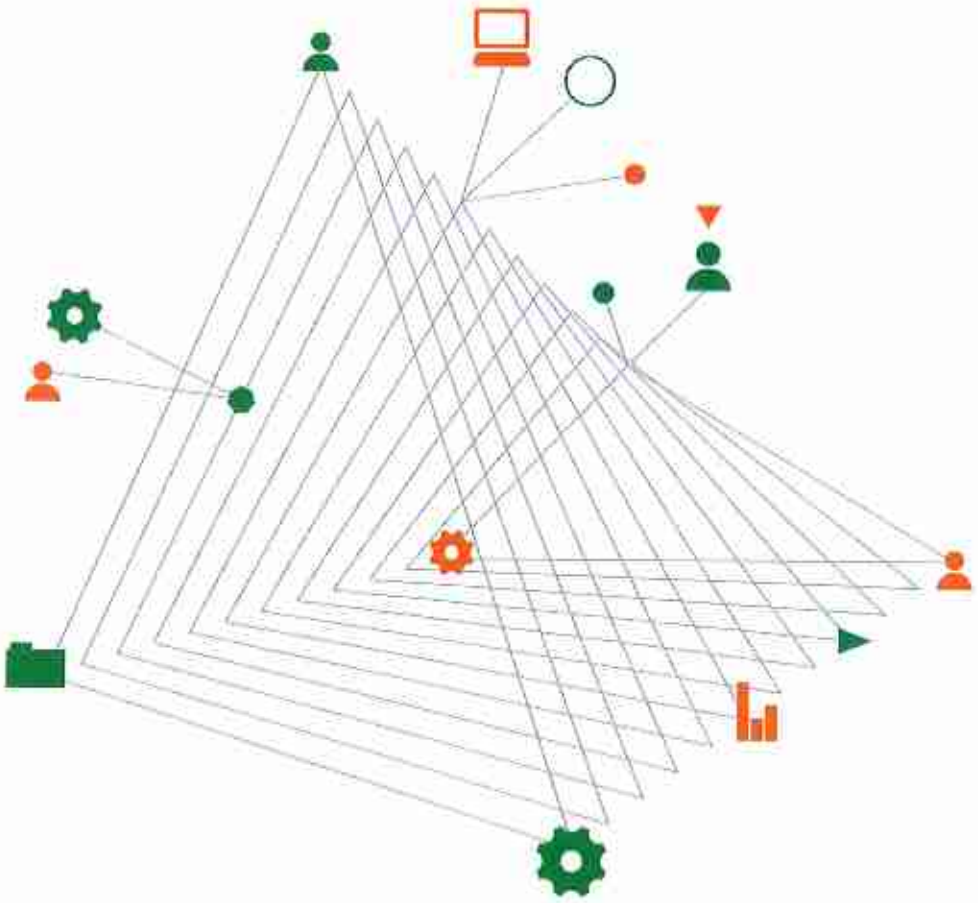
The Lakes (2012) Limited

The Lakes Subdivision - Stage 3A & 3B

Geotechnical Completion Report

24 April 2015



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The Lakes Subdivision - Stage 3A & 3B

Prepared for
The Lakes (2012) Limited

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For and on behalf of Coffey

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Appendices

1. Introduction and Scope

This Geotechnical Completion Report (GCR) has been prepared by Coffey Geotechnics (NZ) Ltd (Coffey) for the Lakes (2012) Limited following completion of earthworks for Stages 3A and 3B of the Lakes subdivision and in general accordance with the conditions of Council resource consent number RC21332. These stages are collectively known as Stage 3AB.

This report contains the results of site investigations and relevant control test data, together with as-built plans derived from Harrison Grierson Consultants Ltd (HGCL) topographical data. It describes bulk earthworks completed during the 2007-2008 and 2013-2014 earthworks seasons. Minor works completed during construction of the civil infrastructure during the 2014 – 2015 earthworks season are also discussed.

The extent of earthworks supervised by Coffey is shown on the appended plans (Figures 1 to 7, Appendix A). A Statement of Professional Opinion (Form G2) and Summary of Technical Data (Form G3) for the works described herein are also appended.

1.1. Excluded Lots

As shown on Figure 1, Lots 104, 105 and 106 have been excluded from this GCR. These lots were subject to filling during the latter part of the 2014-2015 work season and settlement monitoring for this area is ongoing.

1.2. Pedestrian Walkway

As well as overseeing the bulk and minor earthworks within Stage 3AB, Coffey has also provided geotechnical inputs for a pedestrian walkway connecting Stage 3A and Stage 2S of the Lakes development. Coffey's inputs comprised the specific design of the timber pole retaining wall and geotechnical advice for the construction of a 30m high staircase.

A separate letter summarising Coffey's observations during construction of these features is included in Appendix G of this report.

2. Description of Subdivision

Stages 3AB of the Lakes subdivision are located near the intersection of Takitimu Drive (SH36) and Pyes Pa Road in Pyes Pa, Tauranga. The site location and original ground contours are shown on Figure 1.

Before work began, the majority of the site consisted of an elevated, flat or gently rolling north-south oriented plateau at approximately RL 60m (Moturiki Datum, 1953). An approximately 15m deep gully cut into this plateau from the south-west. To the west, the topography slopes steeply to very steeply towards previous stages of the Lakes development (Stage 2QRST) and SH36.

Earthworks have been completed in two stages. In 2007 and 2008, excavation was undertaken on the plateau and western slope to form a more level development area and reduce slope angles. Excavated material was placed as engineered fill within the central gully. Cut and fill contours and the finished ground surface for this work period are shown on Figures 2 and 3 respectively.

During the 2013-2014 work season minor cuts and fills were completed on the plateau and over the original gully to create the finished ground surface. A large, 13m deep cut was also completed on the western slope to form a 1V:2.5H batter, referred to as the Western Batter in this and previous reports.

Approximately 10m of fill was placed at the southern end of the Western Batter. Cut/fill contours and the finished ground surface for this season are shown on Figures 4 and 5.

Finally, minor cuts and fills and were completed during civil infrastructure construction in 2014-2015. Up to approximately 2m of fill was placed at the base of the Western Batter to re-grade the finished lots in this area (Lots 1 to 7). Filling was also placed on Lots 29, 30, 62 to 64 and 145 – 146 as shown on Figure 6. Final finished ground contours for the site are shown on Figure 7.

The Western Batter and the natural slope to the north of the batter are to be vested as reserve land with the Tauranga City Council.

3. Related Reports

The following documents were prepared prior to or during the design and development of Stages 3AB.

1. *'Pyes Pa West Urbanisation Development, Tauranga – Geotechnical Assessment Report'*, report prepared by S&L Consultants Ltd (Ref: 16944, dated October 2003).
2. *'Detailed Site Investigation for the Lakes Subdivision Stage 3, Takitimu Drive, Tauranga'*, report prepared by Coffey Environments (Ref: ENNZAUCK51132AA, dated 21 March 2013).
3. *'Geotechnical Investigation Report for the Lakes Subdivision – Stage 3 (Phase 1) at Pyes Pa, Tauranga'*, report prepared by Coffey (Ref: GENZTAUC13086AF-AA, dated 29 April 2013).
4. *'Earthworks Inspections & Tomo Backfilling'*, memo prepared by Coffey (Ref: GENZTAUC13086AF, dated 18 December 2013).
5. *'Summary of Works Report, The Lakes, Stage 3, Tauranga'* report prepared by Coffey Environments (Ref: ENNZAUCK51132AB, dated 7 April 2014).
6. *'The Lakes Subdivision Stage 3 Zone 1 Earthworks Completion Report'*, report prepared by Coffey (Ref: GENZTAUC13086AF-AE, dated 15 August 2014).

Key conclusions of the main documents are summarised below.

3.1. Geotechnical Assessments

The original geotechnical assessment for the Lakes subdivision was completed by S&L Consultants Ltd and contained an overview of geotechnical conditions for the entire Lakes project. The report concluded that the site was generally suitable for subdivision and residential development, subject to appropriate design and construction. With regard to the Stage 3 area, S&L determined that the slopes to the west and south-west of the site had been affected by previous instability. The report recommended that future buildings be set back from the crest of these slopes or that the slope profiles should be modified by earthworks to improve their stability.

The subsequent geotechnical investigation report by Coffey in April 2013 summarised additional and more detailed investigations that were completed to specifically assess the Stage 3 area. These investigations generally confirmed the S&L conclusion that the site was adequate for subdivision. In addition to the western and south-western slopes, Coffey concluded that the slope to the east of Stage 3 had also been affected by past instability. Coffey recommended that buildings adjacent to this slope within Stage 3 also be set back from the crest.

3.2. Contaminated Soils Reports

Due to the presence of farm buildings and facilities on the original site, Coffey was also engaged to complete an environmental assessment of the proposed development area. The results of this assessment were described in the Coffey Environments report of March 2013 (Section 3, reference 2). This report identified isolated areas of possibly contaminated soil at the sites of a (suspected) pre-existing sheep dip, an above-ground fuel storage tank and a diary effluent pond.

Further investigation at the suspected sheep dip site did not find any evidence of significant soil contamination in this area. Soils beneath the fuel storage tank and the effluent pond were sub-excavated during the early stage of earthworks in 2013 and were buried beneath road areas within the development area as required by the Environmental Management Plan. This work was supervised and certified by Coffey Environments in the Summary Works Report of April 2014 (Section 3, reference 5).

3.3. Earthworks Completion Report

The August 2014 Earthworks Completion Report concluded that the bulk earthworks undertaken in 2007-2008 and 2013-2014 were generally completed in accordance with the relevant standards and guidelines including NZS 4431 (Code of Practice for Earth Fill for Residential Development) and the Tauranga City Council Infrastructure Development Code (TCC IDC). The report did however identify several areas that needed to be re-visited in this GCR. These were:

1. Some of the soils encountered at the base of the Western Batter are potentially prone to earthquake induced liquefaction and required specific investigation and analyses to assess the possible risk to the development;
2. The very steep natural slope to the north of the Western Batter was assessed as having relatively low factors of safety under elevated groundwater (storm) conditions and under earthquake loading. A preliminary Building Restriction Line was placed on these lots to reduce the risk posed to dwellings above this slope. This BRL was to be confirmed in this GCR;
3. Excavation for the Western Batter also exposed highly erodible pumice sands at the finished ground surface. The Earthworks Completion Report recommended that this area be covered with a thick layer of topsoil and that stormwater in the vicinity was collected and piped to the subdivision's reticulated network.

Works undertaken to resolve these issues are described in this GCR.

4. Investigations Completed

Geotechnical investigations have been undertaken on this and adjacent sites during each stage of the subdivision's design and construction. The investigations used for this report are listed below. Logs of each investigation are included in Appendix C.

- Five machine boreholes drilled to depths of up to 20m near the Western Batter in 2007 (S&L Consultants, MB34 to MB38 on Figure 1);
- Seven test pits excavated in 2012 within or near the subject stages to maximum depths of up to 5m to assess shallow ground conditions before the 2013-2014 work season (Coffey, TP01 –TP05 and TP09 – TP10 on Figure 3);

- Two Cone Penetration Tests (CPTs) drilled in 2013 to 20m depth to assess ground conditions beneath the 2007-2008 filling to the south of the Western Batter (Coffey, CPT01 & CPT02 on Figure 3);
- Four additional CPTs and two machine boreholes completed in 2014 on lots below the Western Batter to assess the potential liquefaction risk in this area (Coffey, CPT-3A-01 to CPT-3A-04 and MH3A-01 & MH3A-02 on Figure 5).

On completion of the bulk and minor earthworks, Coffey drilled a total of 136 hand-auger boreholes to a target depth of 2m on every lot underlain by natural (cut) soils and approximately every second lot underlain by engineered fill. The location of each borehole is shown on Figure 7. Although not shown on the plan, the boreholes are numbered according to the relevant stage and lot number. For example, the borehole on Lot 63 in Stage 3A is referred to as HA3A-063. Logs of these boreholes are included in Appendix D.

5. Overview of Geological Conditions

The majority of the subject area is located on an elevated, gently sloping plateau. Below the topsoil layer, the pre-development soil profile across this plateau comprised approximately 10m to 15m of volcanic ashes including the Hamilton Ash and Rotoehu Ash. This ash sequence is common throughout the Tauranga area. At this location the volcanic ashes overlie weakly cemented pumice sands of the Te Ranga Ignimbrite.

Excavations in 2007-2008 and 2013-2014 reduced the thickness of the volcanic ashes across most of the plateau by up to 5m to 10m. In the area of the Western Batter, excavation up to 7m depth in 2007-2008 and a further 13m in 2013-2014 penetrated through the surficial ash sequence to expose pumice sands of the Te Ranga Ignimbrite. Near the toe of the batter the excavation also exposed variable alluvial sands, silts and clays of the Matua Subgroup.

6. Earthworks Operations

6.1. Plant

Earthworks during the 2007-2008 season were completed by Bob Hicks Earthmovers Ltd. The contractor for the 2013-2014 season was JMC Civil Construction Ltd. As previously mentioned, minor earthworks were also completed by Higgins Contractors (Higgins Group Holdings Ltd) during the civil infrastructure construction phase.

The main items of plant used during each of the bulk earthworks phase comprised Terex motor-scrapers and bulldozer towed 'scoops', hydraulic excavators, bulldozers and sheeps-foot rollers.

6.2. Construction Programme

6.2.1. 2007 – 2008 Earthworks Season

Earthworks in 2007 and 2008 summer included excavations of up to 6m deep on the main plateau and up to 13m deep at the western edge of the site in the area of the Western Batter (see Figure 2). Excavated material was used for filling of up to 13m deep within the central gully and for construction of the SH36 road embankment. The gully filling was supervised by Coffey. Nuclear Density Meter (NDM) tests were also completed by Coffey as work progressed.

As shown on Figure 2, subsoil drains were installed beneath the filling where shallow groundwater or seepages were encountered.

6.2.2. 2013 – 2014 Earthworks Season

In 2010, work on the Lakes subdivision site ceased under the original developer (Grasshopper Farms Ltd) and records from this time are incomplete. Work on the subdivision recommenced in 2012 under The Lakes (2012) Ltd, with earthworks in the subject area beginning in late 2013.

Earthworks consisting of up to 13m of cut and 7m of engineered filling were completed within Stages 3AB to form the majority of the current ground surface. These works were supervised by Coffey, with fill quality testing being carried out by Geotechnics Ltd. Contours of cuts and fills for this season and the resulting ground surface are shown on Figures 4 and 5 respectively.

Other works completed during this earthworks phase included the excavation and infilling of two sub-surface erosion features ('tomos') that were identified on site in late 2013. The tomo features were undercut by JMC and backfilled with compacted earthfill under Coffey supervision. The extent of the tomo excavation and back filling is shown on Figure 4.

Several pre-existing farm buildings and facilities were removed from site at this time. This included the sub-excavation and disposal of contaminated soils from areas around the buildings in accordance with the 2014 Summary of Works Report.

At the end of the 2013-2014 season, the majority of the Western Batter was covered with an approximately 300mm thick layer of track-rolled topsoil to reduce the risk of erosion of the underlying sandy soils. The lower portion of the batter was not topsoiled during the 2013-2014 earthworks season due to the presence of a number of groundwater springs on the batter face. These springs occurred where perched groundwater tables within the Matua Subgroup soils day-lighted at the ground surface.

6.2.3. 2014-2015 Earthworks Season

During late 2014 and early 2015, minor earthworks completed by Higgins during civil infrastructure construction included the placement of up to 2m of fill in Lots 1 to 7 and up to 1.4m of fill in Lots 29, 30, 145 and 146. A previously formed road alignment within Lots 62 to 64 was also backfilled after the scheme plan was changed during the work season. The minor earthworks completed at this time are shown on Figure 6.

The filling was supervised and tested by Coffey as work progressed. Settlement markers were installed within Lot 1 and Lot 30 to monitor consolidation as a result of the fill placement. The locations of the settlement markers are shown on Figure 6 and monitoring results are discussed in Section 8.4 below.

A series of four 'fans' of inclined bored drains were installed at the toe of the Western Batter to intersect the perched water tables discussed in the previous section. These drains were designed by Coffey and are shown on Figure 6. They were primarily intended to reduce the risk of slope instability at the toe of the batter due to elevated or perched groundwater levels within the slope.

Outflow from the bored drains is directed to a 1.5m deep subsoil drain that was installed along the back boundary of Lots 1 to 8. A 1m wide, 'rip-rap' lined swale drain was also constructed along the rear boundaries of these lots to collect surface runoff from the batter. Towards the end of the 2014-2014 earthworks season this swale was extended along the boundaries of Lots 9 and 10, although this section of drain has only been formed with compacted topsoil and is not lined with 'rip-rap'.

The bored drains and subsoil drain greatly reduced the amount of water seeping from the Western Batter face. However, shallow groundwater levels and localised springs were encountered within Lots 5 and 7 during final earthworks on these sites. 'Novaflo' subsoil drains and gravel drainage blankets were therefore installed at the locations shown on Figure 6.

Installation of the bored drains, the subsoil drains and surface swale was overseen and inspected by Coffey. Once the drainage had been installed, the remaining areas of the Western Batter were covered with a 300mm thick layer of topsoil. Several shallow erosion gullies that had formed in the topsoil placed in 2013-2014 were also sub-excavated and reinstated at this time.

7. Quality Control

7.1. Site Preparation Observations

Prior to filling within the central gully in 2007-2008, gully cleaning, topsoil stripping and partial removal of soft or unsuitable soils was periodically observed by Coffey. Subsoil drains were installed where wet ground was encountered.

During 2013-2014, Coffey undertook regular observations of fill areas to ensure topsoil, vegetation or unsuitable materials had been removed before filling. The areas filled by Higgins in 2014-2015 were also observed and approved by Coffey before the fill was placed.

7.2. Fill Control

During 2007-2008, in-situ density, strength and water content tests were carried out on the filling by Coffey. The locations of all tests are shown on Figure 2.

In the 2013-2014 earthworks season, Nuclear Density Meter (NDM), laboratory moisture content and shear vane tests were carried out by Geotechnics Ltd. The locations of NDM tests completed in 2013 and 2014 are shown on Figure 4. Summary tables of the test results are included in Appendix E.

The minor areas of filling completed during 2015 were tested by Coffey using a field shear vane and Scala penetrometer where appropriate.

7.2.1. Compaction Control Criteria

The original compaction control criteria for this project were specified for quality assurance purposes predominantly using the minimum allowable shear strength and maximum allowable air voids method as defined below:

- Air voids percentage (as defined in NZS 4402:1986 and as measured by NDM, targeting an average value less than 10% over any 10 consecutive tests and maximum single value no greater than 12%.
- Undrained shear strength (measured by hand held shear vane calibrated using NZGS 2001 method, targeting an average value greater than 150kPa and minimum single value no less than 140kPa. The average value was to be determined over any ten consecutive tests in any one fill area.

7.2.2. Test Results

Summary tables showing the results of the laboratory fill tests for the two stages of bulk earthworks are included in Appendix E and the locations of the tests are shown on Figures 2 and 4. The majority of tests met or exceeded the compaction control criteria given above. Failed tests are shown in red on the relevant figures.

Three tests during the 2007-2008 season did not meet the required values. Test 403 was deemed to be a marginal failure based on a slightly high percentage air voids value. Given that other tests in this area passed, it is considered this result is an outlier and likely represents an isolated pocket of insufficiently compacted or slightly dry of optimum fill at approximately 3m below finished ground level. Tests 826 and 827 also failed due to high percentage air voids values. These tests are adjacent to Lots 104 to 106 which are not included in this report. The filling in this area will be re-assessed when the GCR for these lots is completed.

Results provided by Geotechnics Ltd indicate one test failed during the 2013-2014 season due to low undrained shear strength measurements (FT65 on Lot 20). Testing completed by Coffey on adjacent lots at the end of works however indicate that this failed test is likely due to a localised pocket of insufficiently compacted fill. Boreholes on nearby Lots 110 and112 indicate that some fill materials used in this area contained a high percentage of sand which would also explain the low shear strength results.

7.2.3. 2014-2015 Season

The filling placed by Higgins during 2014-2015 was inspected and tested by Coffey. Hand-auger boreholes were also completed in each lot on which fill was placed at the end of the work season (logs included in Appendix D). These tests indicated the fill material was adequately compacted and met the required fill standards.

8. Engineering Evaluation and Recommendations

8.1. Fill Quality

Based on the appended earth fill quality control test data and reliance on the diligence of the bulk earthworks contractor at times when engineering staff were not present on site, results indicate that the compaction control criteria were generally met during the bulk earthworks periods in 2007-2008 and 2013- 2014. The filling placed during 2015 also generally met the required fill standards.

8.2. Topsoil

All lots within Stage 3AB were covered by a layer of topsoil upon earthworks completion. This layer is nominally 100mm to 300mm thick. Subsequent testing by Coffey however indicated that the depth of topsoil on some lots may exceed 300mm. It is therefore important that future owners or builders confirm the depth of topsoil when preparing site development plans and cost schedules.

In addition to the topsoiling within the lots, a 300mm thick layer of topsoil was placed over the Western Batter. Localised scouring occurred within this layer in 2014 during a heavy rainfall event. The scouring was isolated to an area that had been recently grassed and where the vegetation was not well established. The scoured topsoil was excavated and reinstated in early 2015 and the Western Batter was grassed and planted. No further erosion or scouring has been observed since this work was completed.

It is considered that the thick layer of topsoil and planting on the Western Batter is sufficient to reduce the risk of future erosion or scouring of the sandy soils that underlie this part of the site. As with other large batters and natural slopes around Tauranga however, the potential for future scouring cannot be entirely ruled out particularly during heavy rainfall events. It is therefore important that this slope is inspected by Council periodically and that maintenance is carried out where required. These inspections will be particularly important while the planting and vegetation become established.

8.3. Drainage

The inclined bored drains, subsoil drain and surface swale drain at the toe of the Western Batter were observed by Coffey during construction. It is considered that these drains have been installed in accordance with Coffey's design and instructions. The location of these drains is shown on Figure 6. A construction detail of the drains is included as shown on Figure 8.

The bored drains have been 'flushed' after installation to remove any sediment or loose soil that may have accumulated after drilling. At the time of writing the drains appear to be clean with no significant sediment visible in the drains or collection sumps.

The bored drains should be inspected periodically by Council to ensure that they do not become blocked by sediment over time. Maintenance (i.e. flushing) may be required if sediment accumulates, although typically the buildup of sediment within drains of this type reduces after installation as the soil around the drains stabilises.

The presence of the surface and subsoil drains near the rear boundary of Lots 1 to 8 will need to be considered when planning excavations in this area. Any excavations or retaining walls within 1.5m of this boundary will need to be specifically designed.

As mentioned in Section 6.2.3, the surface swale drain has also been extended behind Lots 9 and 10, although this section of drain was not lined with 'rip-rap'. HGCL advised that the catchment area above lots 11 to 13 was sufficiently small that a specifically installed drain was not required above these lots. This notwithstanding, the collection and disposal of stormwater from the part of the batter above Lots 9 to 13 will need to be considered when they are developed.

Additional recommendations regarding general stormwater collection and disposal as they affect slope stability are given in Section 8.6.1.

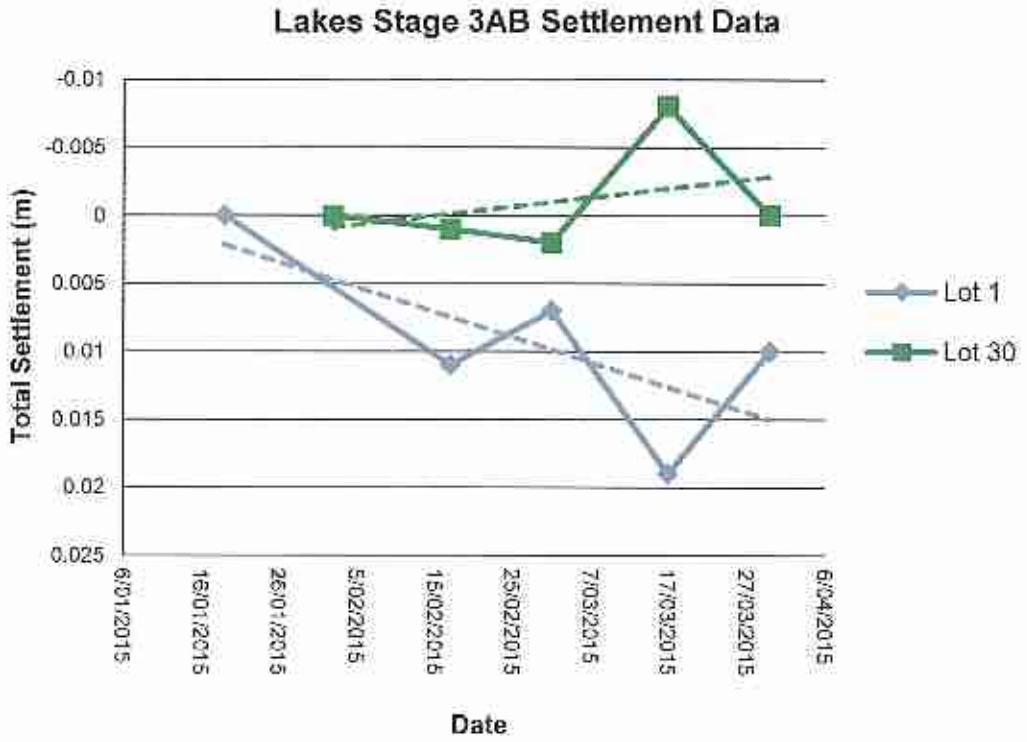
8.4. Static Settlement

Static settlements due to the placement of fill in the central gully during the 2007-2008 and 2013-2014 earthworks seasons were not monitored. However, ongoing monitoring of filling in a gully approximately 200m south of Stage 3AB and underlain by similar geology indicates that primary consolidation settlements at this site typically take between 4 and 6 months to reach effective completion. Based on this trend, it is considered that primary settlements due to filling within the central gully are effectively complete at the time of writing.

It is possible that long term secondary or 'creep' settlement may still be occurring within the central gully. For the majority of lots in this area, any creep settlement that does occur would be relatively uniform and should not adversely affect the proposed development. Around the perimeter of the gully however there is potential for minor differential creep settlement on lots which are partially underlain by fill and partially by natural ground (i.e. Lots 16, 24, 26, 27, 73, 74, 97 to 103 and 145 to 147).

The magnitude of differential settlement expected should be within the performance capabilities of shallow foundations designed in accordance with NZS 3604 and as recommended in the New Zealand Building Code[1] (e.g. less than 25mm differential settlement per 6m horizontal length). However, to provide additional protection, Coffey recommends the dwellings on these sites be supported by 'pod-raft' type foundations or specifically designed strip footings.

As noted in Section 6.2.3, settlement markers were installed by Higgins on Lot 1 and Lot 30 during the civil works season in 2014 – 2015 and after approximately 2.0m and 1.4m of fill was placed on these sites respectively. The marker locations are shown on Figure 6. Plots of the data from these points provided by HGCL are graphed below. It is noted that the settlement data appear to be affected by significant fluctuation and the survey methodology used can cause such fluctuation. Future monitoring of the settlement marker on Lot 1 will be completed by HGCL using a more accurate levelling instrument to reduce these errors.



The data suggest that Lot 1 has settled approximately 10mm to 20mm at the time of writing (allowing for survey tolerances) and that settlement is likely to be continuing at this location. It is therefore recommended that construction on Lot 1 and Lot 2 should not proceed until further monitoring and analyses by a TCC Category 1 geotechnical professional confirm that settlement has reached an acceptable level for the proposed development.

The sites to the south of Lot 2 received approximately 0.2m to 0.4m of filling during 2015 and finished ground levels in this area are below the original, pre-earthworks levels. The potential for adverse effects to development on these lots due to fill induced settlement is therefore relatively low. It is

[1] Ministry of Business, Innovation and Employment, '*Acceptable Solutions and Verification Methods B1/VM4*', 2014.

considered that development on these sites may proceed, subject to the specific foundation design recommendations given in Section 8.4 and 8.6.

The data for Lot 30 indicates that limited settlement has occurred at this location since the settlement marker was installed towards the end of the 2015 earthworks season (within survey tolerances). It is therefore considered that Lot 30 and the adjacent lots which received minor filling in 2015 are adequate for residential development subject to the other recommendations in this report.

8.5. Liquefaction

Excavations at the toe of the Western Batter encountered alluvial soils of the Matua Subgroup beneath Lots 1 to 8 (inclusive). These soils are highly variable and inter-bedded with materials ranging from weathered pumiceous gravels to stiff clays. The groundwater table was measured at approximately 5m depth below finished ground level beneath Lot 1, increasing to approximately 11m depth below Lot 8. Several higher level springs and seepage points were also encountered during work on these sites, indicating smaller 'perched' groundwater tables are also present at shallower depth.

Analyses of data from CPT-3A-01 to -04 and samples from machine boreholes MH3A-01 and -02 indicate that some soils beneath Lots 1 to 8 may be subject to liquefaction during a large or Ultimate Limit State (ULS) earthquake. Analysis results are included in Appendix F. The depth to the potentially liquefiable soils is relatively large due to the 5 to 11m depth of groundwater at this location. However, it is considered that these sites have a moderate risk of both vertical settlement and lateral spreading as a result of liquefaction in a ULS event.

It is therefore recommended that dwellings on these sites be supported on pod-raft type foundations (e.g. 'rib-raft') that have been specifically designed to safely accommodate up to 100mm of differential vertical settlement and up to 500mm of lateral stretching beneath the building platform during a ULS event.

The calculations indicate these soils are unlikely to be affected by significant liquefaction in a smaller Serviceability Limit State (SLS) earthquake. It is therefore considered that the design of foundations on these sites should not need to specifically consider liquefaction induced ground deformation for the SLS design case.

The potential for adverse effects due to liquefaction reduces to the south of Lot 8 as a result of the increasing depth to groundwater. Foundations on Lot 9 and above therefore do not need to be specifically designed to accommodate the effects of liquefaction.

8.6. Slope Stability

8.6.1. Building Restriction Lines

Lots 1 to 13 and Lots 115 to 124 are located adjacent to the 35m high Western Batter, which has been formed at a gradient of 1V:2.5H. To the north, this batter merges with a very steep natural slope that extends below Lots 50, 51 and 125 to 131 (see Figure 7).

The natural slope shows visible evidence of recent and historic instability. Stability analyses described in the April 2013 Coffey Geotechnical Investigation Report also indicate that this slope has a relatively low factor of safety (FoS) against slope movement, particularly under elevated groundwater or extreme storm conditions. To reduce the risk to dwellings above this slope, a Building Restriction Line (BRL) has been placed on the affected lots as shown on Figure 7.

Calculations and experience with similar soil conditions in the Tauranga area indicate that the re-graded 1V:2.5H Western Batter is sufficiently stable for residential development in accordance with

the TCC IDC and New Zealand Building Code. Sites above and below this batter are therefore considered to have a low risk of adverse effects due to slope movement. This notwithstanding, there is always potential for shallow erosion or scouring of steep slopes during extreme rain events. The BRL has therefore been extended through the lots above the Western Batter to reduce the risk of adverse effects due to erosion or scouring along the slope crest.

Development beyond (west of) the BRL line will require specific input and design by a Category 1 geo-professional. It should be understood however that a BRL does not automatically preclude development within the restricted area. In general, it is often relatively cost effective to extend a building up to 2m beyond a BRL, either by supporting the overhanging foundations on specifically designed perimeter piles or by 'cantilevering' the foundations over the restriction line. Development more than 2m beyond the BRL may require more extensive, specifically designed slope improvement and/or protection measures.

The recommended BRL identifies the extent of ground which is appropriate for the construction of dwellings and other buildings without specific foundation design or slope improvement measures. To further reduce the risk of slope movement, stormwater from impervious areas within the affected lots needs be collected and piped to the reticulated network and the sites graded so that stormwater flows away from the slope crest wherever possible. Stormwater should not be disposed via ground soakage on these lots.

As with other similar areas around Tauranga, there is still a possibility for erosion, scouring or localised slumping beyond the BRL and along the slope crest and that this could be exacerbated through poor stormwater management and control.

8.6.2. Earthquake Induced Slope Movement

As noted in Section 8.4, soils beneath the Western Batter may be affected by partial liquefaction during a large or ULS earthquake. This liquefaction would reduce the strength of affected soils and may adversely affect the stability of the lower part of the batter.

It is considered that the lots above the Western Batter are set far enough above and back from the crest and toe of the slope that the potential for adverse effects to these lots as a result of slope movement is relatively minor. The recommended BRL on these lots has also been positioned to account for seismic slope stability risks.

For lots below the batter (i.e. Lots 1 to 10 inclusive), it is possible that movement may occur on the slope during a ULS or approximately 1 in 500 year earthquake. While this movement should not pose a significant safety risk to occupants of these lots, the slope should be inspected for signs of damage following any significant earthquake.

8.7. Foundation Design & Bearing Capacity

The large majority of lots within Stages 3AB are considered adequate for standard foundations. Some restrictions will however apply to individual lots due to the underlying ground conditions. Foundation design recommendations for the new lots are outlined below.

8.7.1. Lots 1 to 8

Due to the presence of potentially liquefiable soils beneath these lots, it is recommended that dwellings on Lots 1 to 8 (inclusive) should be supported on pod-raft type foundations that have been specifically designed to safely accommodate up to 100mm of vertical differential settlement and up to 500mm of horizontal ground stretching beneath the building platform. As discussed in Section 8.4, it is considered that the designer of these foundations should not need to consider the effects of

liquefaction under SLS conditions. Foundations on these sites should be designed for a geotechnical ultimate bearing capacity of 300kPa in accordance with NZS 3604.

It is noted that Lots 1 and 2 are currently subject to on-going settlement monitoring. As stated in Section 8.3, development should not proceed on these lots until this settlement has been reviewed and approved by a Category 1 geotechnical professional.

As shown on Figure 6, subsoil drains have been installed within Lot 3 and Lot 5. The presence of these drains should not adversely affect the foundation design for these sites, but should be considered by the foundation design engineer.

8.7.2. Lots 12 and 37

Boreholes drilled within Lot 12 and Lot 37 indicate these sites are underlain by loose sandy soils at shallow depth which do not meet the minimum requirement for standard foundations set out in NZS 3604. The foundations for dwellings on these lots will therefore need to be specifically designed for a geotechnical ultimate bearing capacity of 180kPa at an assumed foundation depth of 300mm below finished ground level.

8.7.3. Lots 16, 24, 26, 27, 73, 74, 97 to 103 and 145 to 147

As discussed in Section 8.4, there is potential for minor differential creep settlement under these lots. Foundations on these sites should therefore consist of 'pod-raft' type foundations or specifically designed strip footings. Foundations should be designed for a geotechnical ultimate bearing capacity of 300kPa.

8.7.4. Remaining Lots

The remaining lots within Stages 3AB are underlain by either engineered fill or natural soils that meet or exceed the conditions for 'good ground' as defined by NZS 3604. Dwellings on these sites may therefore be supported on standard shallow foundations designed for a geotechnical ultimate bearing capacity of 300kPa.

8.7.5. Strength Reduction Factor

As required by Section B1/VM4 of the New Zealand Building Code Handbook, a strength reduction factor of 0.50 or 0.80 should be applied to all recommended geotechnical ultimate soil capacities in conjunction with their use in factored design load cases for static and earthquake overload conditions respectively.

8.7.6. Variable Subsoils

It should be understood that due to the volcanic nature of the natural soils on this site, it is possible that local soil conditions may vary from those discussed above. It is therefore important that any potentially soft or unsuitable soils encountered in the foundation excavations are brought to the attention of a geotechnical professional.

8.8. Stormwater and Wastewater

All stormwater from roofs and impervious areas within the new lots should be collected and piped to the reticulated stormwater system. Additional recommendations are given in Sections 8.3 and 8.6 regarding lots above and below the Western Batter and adjacent slope. Disposal of stormwater to soakage is not recommended on any new lot within this subdivision.

Similarly, all wastewater from new dwellings should also be piped to the Council sewer system.

9. Summary of Conclusions & Recommendations

Based on the earth fill quality control test data and observations discussed above, it is considered that the earthworks and drainage features described in this report have been completed in general accordance with the necessary standards and guidelines. Additional conclusions and recommendations regarding the development are listed below:

Lots 1 & 2

- Due to ongoing settlement monitoring, construction on these lots should not proceed until the settlement data has been reviewed by a Category 1 Geotechnical Professional and it is considered that settlement has reached an acceptable level for the proposed development.
- Some soils beneath these sites may also be affected by liquefaction in a large or ULS earthquake. Dwellings on these lots should therefore be specifically designed in accordance with the recommendations given in Section 8.4.
- Excavations near the rear boundary of these sites will need to consider the close proximity of the subsoil and swale drain at the foot of the Western Batter. Any excavations or retaining walls within 1.5m of the rear boundary will therefore need to be specifically designed.

Lots 3 to 8 (inclusive)

- As with Lots 1 and 2, these sites are underlain by potentially liquefiable soils under large or ULS earthquake conditions. Foundations for these lots should therefore be specifically designed in accordance with the recommendations given in Section 8.4. Provided these recommendations are followed, the risk of adverse effects due to future settlement on these sites is considered to be acceptably low and there is no geotechnical reason to delay construction on these sites.
- Excavations near the rear boundary of these sites will need to consider the close proximity of the subsoil and swale drain at the foot of the Western Batter. Any excavations or retaining walls within 1.5m of the rear boundary will therefore need to be specifically designed.

Lots 9 to 13

- Dwellings on these lots may be supported on standard foundations designed in accordance with NZS 3604.
- The proposed development on these sites will however need to consider and allow for the collection and disposal of stormwater from the adjacent Western Batter.

Lots 12 & 37

- These sites are underlain by natural sandy soils that do not meet the minimum requirements of 'good ground' as set out in NZS 3604. Foundations for these lots should therefore be specifically designed for a geotechnical ultimate bearing capacity of 180kPa at an embedment depth of 300mm.

Lots 16, 24, 26, 27, 73, 74, 97 to 103 and 145 to 147

- Due to the potential for long term differential settlement on these lots, dwellings on these sites should be supported by either of 'pod-raft' type foundations or specifically designed strip footings. Foundations may be designed for a geotechnical ultimate bearing capacity of 300kPa.

Lots 50, 51 & 115 to 131 (inclusive)

- These lots are located above a significant slope and are subject to a Building Restriction Line (BRL) as discussed in this report. Development including construction or filling beyond (west of) the BRL shown on Figure 7 will require specific geotechnical input from a Category 1 geo-professional. Additional recommendations regarding development on these lots are given in Section 8.5.1.
- Provided the recommendations regarding the BRL are followed, these sites are considered suitable for standard foundations designed in accordance with NZS 3604.

Remaining Lots

- The remaining lots within Stage 3AB are considered adequate for standard foundations designed in accordance with NZS 3604.

General Recommendations

- Stage 3AB either includes or is adjacent to significant natural and engineered slopes. As discussed in Section 8.5 these slopes may be affected by ground movement in the event of a large or ULS earthquake. While this movement should not pose a significant safety risk to residents of the development the affected slopes should be inspected by a Category 1 geotechnical professional following a large earthquake event.
- Much of the developed area is underlain by volcanically derived soils which can be highly variable. It is important that any potentially unsuitable soils or soil conditions encountered during construction which differ from those described in this report are brought to the attention of a geotechnical professional.
- The finished lots within Stage 3AB have been covered with topsoil to a typical depth of 100mm to 300mm. However, it is possible that the depth of topsoil may exceed 300mm on some lots. Topsoil depths should therefore be confirmed before final plans or cost schedules are prepared for these sites.

10. Limitations

This report has been prepared solely for the use of the client, The Lakes (2012) Limited, their professional advisers and the relevant Territorial Authorities in relation to the specific project described herein. No liability is accepted in respect of its use for any other purpose or by any other person or entity. All future owners of this property should seek professional geotechnical advice to satisfy themselves as to its ongoing suitability for their intended use.

The opinions, recommendations and comments given in this report result from the application of normal methods of site investigation. As the post construction factual evidence has been obtained solely from laboratory testing, boreholes, CPTs and test pits, which by their nature only provide information about a relatively small volume of subsoils, there may be special conditions pertaining to this site which have not been disclosed by the investigation and which have not been taken into account in the report.

For and on behalf of Coffey

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Important information about your **Coffey** Report

As a client of Coffey you should know that site subsurface conditions cause more construction problems than any other factor. These notes have been prepared by Coffey to help you interpret and understand the limitations of your report.

Your report is based on project specific criteria

Your report has been developed on the basis of your unique project specific requirements as understood by Coffey and applies only to the site investigated. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the client. Your report should not be used if there are any changes to the project without first asking Coffey to assess how factors that changed subsequent to the date of the report affect the report's recommendations. Coffey cannot accept responsibility for problems that may occur due to changed factors if they are not consulted.

Subsurface conditions can change

Subsurface conditions are created by natural processes and the activity of man. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Because a report is based on conditions which existed at the time of subsurface exploration, decisions should not be based on a report whose adequacy may have been affected by time. Consult Coffey to be advised how time may have impacted on the project.

Interpretation of factual data

Site assessment identifies actual subsurface conditions only at those points where samples are taken and when they are taken. Data derived from literature and external data source review, sampling and subsequent laboratory testing are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact on the proposed development and recommended actions. Actual conditions may differ from those inferred to exist, because no professional, no matter how qualified, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions. For this reason, owners should retain the services of Coffey through the development stage, to identify variances, conduct additional tests if required, and recommend solutions to problems encountered on site.

Your report will only give preliminary recommendations

Your report is based on the assumption that the site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption cannot be substantiated until project implementation has commenced and therefore your report recommendations can only be regarded as preliminary. Only Coffey, who prepared the report, is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report there is a risk that the report will be misinterpreted and Coffey cannot be held responsible for such misinterpretation.

Your report is prepared for specific purposes and persons

To avoid misuse of the information contained in your report it is recommended that you confer with Coffey before passing your report on to another party who may not be familiar with the background and the purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

Important information about your **Coffey** Report

Interpretation by other design professionals

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, retain Coffey to work with other project design professionals who are affected by the report. Have Coffey explain the report implications to design professionals affected by them and then review plans and specifications produced to see how they incorporate the report findings.

Data should not be separated from the report*

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way.

Logs, figures, drawings, etc. are customarily included in our reports and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples. These logs etc. should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

Geoenvironmental concerns are not at issue

Your report is not likely to relate any findings, conclusions, or recommendations about the potential for hazardous materials existing at the site unless specifically required to do so by the client. Specialist equipment, techniques, and personnel are used to perform a geoenvironmental assessment.
Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated or create an environmental hazard, you are advised to contact Coffey for information relating to geoenvironmental issues.

Rely on Coffey for additional assistance

Coffey is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction. It is common that not all approaches will be necessarily dealt with in your site assessment report due to concepts proposed at that time. As the project progresses through design towards construction, speak with Coffey to develop alternative approaches to problems that may be of genuine benefit both in time and cost.

Responsibility

Reporting relies on interpretation of factual information based on judgement and opinion and has a level of uncertainty attached to it, which is far less exact than the design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Coffey to other parties but are included to identify where Coffey's responsibilities begin and end. Their use is intended to help all parties involved to recognise their individual responsibilities. Read all documents from Coffey closely and do not hesitate to ask any questions you may have.

* For further information on this aspect reference should be made to "Guidelines for the Provision of Geotechnical Information in Construction Contracts" published by the Institution of Engineers Australia, National headquarters, Canberra, 1987.