SHRIMPTON & LIPINSKI

THE LAKES DEVELOPMENT
STAGES 2A - 2F INCLUSIVE
PYES PA, TAURANGA

Report on Earthworks and
Recommendations for Development

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CONTENTS

Appendices

1.0 Introduction

This report collates and summarises geotechnical reports prepared by S&L Consultants Ltd for Grasshopper Farms Ltd as the site development earthworks were completed for Stages 2A, 2B, 2C, 2D, 2E and 2F of The Lakes residential subdivision development at Pyes Pa.

The locations of each of these stages are shown on subdivision scheme plan 124825-2-RC04 prepared by Harrison Grierson. A copy of this plan is included in Appendix 1 of this report. This plan indicates the following proposed residential developments.

Stage 2A	Lots 400, 406 and 411 on which medium density residential development will require resubdivision into smaller lots or designated building areas.
Stages 2B, 2C, 2E and 2F	Lots 412, 448, 476 and 499 respectively on which medium density residential development will also require resubdivsion into smaller lots or designated building areas.
Stage 2D	Lots 449 to 470 inclusive and Lot 3 (part Lot 471) on which single dwelling development on each lot will occur. These lots are also shown on appended plan 124825-LT01 by Harrison Grierson.

Approval for the Lakes Development was initially granted jointly by the Tauranga City Council and Western Bay of Plenty District Council on 24 May 2004 based on subdivision plan 16916 dated 20 April 2004 prepared by S&L Consultants Ltd.

A variation was approved by the Tauranga City Council on 18 September 2007 for the proposed development on the area known as Stage 2 at The Lakes. The basis of the Stage 2 development was subdivision scheme plan 124825-2-RC04 prepared by Harrison Grierson.

Access to the Stages 2A, 2B, 2C, 2D, 2E and 2F areas is by Lakes Boulevard from the subdivision entrance at Takitimu Drive. Internal access is also available from the Stage 1 area at Landing Drive and will be, at a later time, from the extension of Kennedy Road to Lakes Boulevard.

Stages 2A, 2B, 2E and 2F are located on the lower lying areas. Parts of these stages are within the former flood plain of the Kopurererua stream which flows past the Lakes development to the west.

The ground rises to the east and stages 2C and 2D are located on this rising ground.

This composite report has been prepared for the Section 224 Certificate application for DP400022 and describes the earthworks undertaken in the formation of Stages 2A to 2F of the subdivision and summarises the suitability of the prepared ground in cut and fill for future urban housing development. The report states the relevant standards adopted for the placement of filling to support residential buildings and recommendations for developing future building sites.

During the report references are made to two as built drawings prepared for each stage. The first drawing is a reference plan which shows the positions of compaction tests undertaken during the earthworks, pre and post construction borehole positions and post construction

settlement control markers. The second of the two drawings shows the depths of the filling that was placed and depths of cut that were made.

The following drawings are referred to in this composite report:

Stage No:	Reference Plan:	Cut/Fill Plan:
2A	AB2	
2B, 2C	AB3	AB4
2D	AB5	AB6
2E, 2F	AB7	AB8

These drawings are contained in Appendix 1.

2.0 Original Landform and Geology

The landform prior to the commencement of the subdivision construction comprised:

- Elevated areas along the eastern side as a central plateau described locally as the Te Ranga Tablelands. These areas have been variously used for farming and horticultural cropping. The existing Pyes Pa residential area further to the east has been established on similar level areas of the same elevation.
- Lower lying areas mainly along and adjacent to the Kopurererua Stream to the west and extending eastwards.
- Transitional slopes of varying steepness between the lower lying areas and the elevated central plateau. Re entrant erosion gullies were present on some of these slopes but most were uniform in slope gradient, albeit steep in some locations.

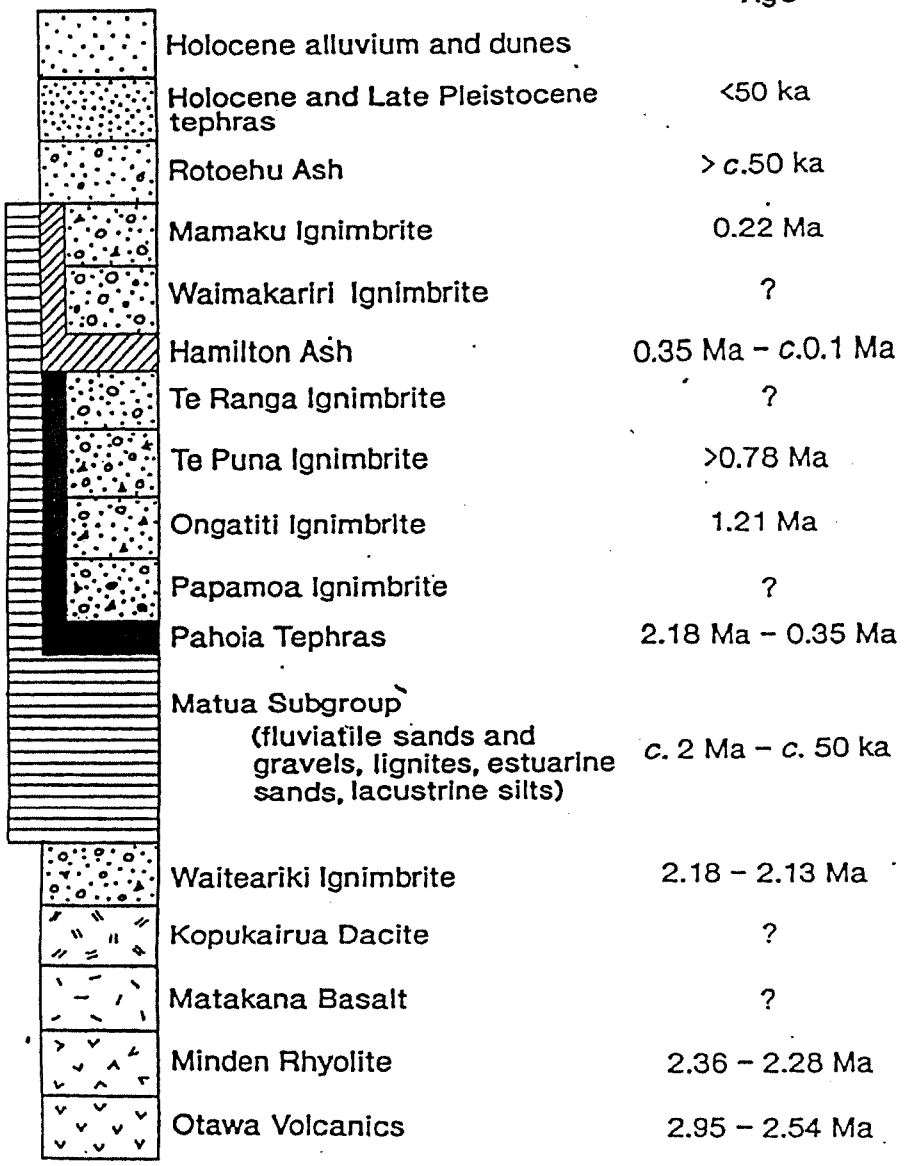
The geological setting for the development area can be derived from the publication:
Occasional Report 22 – Department of Earth Sciences University of Waikato
"Geology of the Tauranga Area" by Briggs et al – 1996

The geology within the Stages 2A to 2F area can be described as:

(i) On the steep sided hills to the east and south east.

- Taupo volcanic zone tephras comprising Rotoehu ash (light grey sand) overlaid by brown or yellow post Rotoehu ash being coarse grained silts, sandy silts and sands. These are collectively referred to as "younger ashes" and overlay.
- "Older" ash derivative strongly weathered clay textured tephra beds and palaesols (Hamilton ash) overlaying.
- Older terrestrial and estuarine sediments deposits of the Matua subgroup of the Tauranga formation. These may comprise a wide variety of lithologies.
- Te Ranga ignimbrite being white-grey pumiceous sands and coarse silts.

A summary of this stratigraphy is shown on the diagram on page 5.



TAURANGA RELIC SLIP VERIFICATION STUDY
Figure 2: Generalised stratigraphy of the Tauranga area

Adapted from Oliver 1997 and Briggs et al 1996

DESCRIPTION OF ASH SEQUENCE MATERIALS AND MATUA SUBGROUP

YOUNGER ASH

The Post-Rotoehu Ash Tephras consist of a number of ashfall tephra deposits, most of which are sourced from the Taupo Volcanic Zone. The thickness of the individual tephra layers varies from 0.1 to 3m.

ROTOEHU ASH

The Rotoehu Ash is a distinctive sequence of shower-bedded tephras derived from the Taupo Volcanic Zone. Individual beds within the 0.3 to 2.4m thick sequence vary from 0.5 to 20 cms in thickness and are typically white to greyish yellow and fine to coarse sandy texture.

HAMILTON ASH

The Hamilton Ash Formation consists of strongly weathered clay-textured tephra beds and palaeosols. It consists of up to eight units. The sequence ranges in thickness from <0.5m to about 6m in areas of ponding.

TAURANGA GROUP

The Pahoia Tephras comprise all the tephras older than the Hamilton Ash Formation and are intercalated with fluvial and other sediments of the Matua Subgroup. They are a sequence of clay-rich rhyolitic tephras which consist of a wide range of grain sizes and structures, including clay, silts, silty sands and pebbles.
The presence of an intermediate aquifer layer gives rise to seepage and erosion problems in outcrop.

MATUA SUBGROUP

The Matua Subgroup includes a wide range of lithologies from fluvial pumiceous and rhyolitic silts, sands and gravels, lacustrine to estuarine muds, lignites and peats intercalated with airfall tephras and thin distal ignimbrites. The sediments display a number of sedimentary structures such as cross-bedding, planar stratified and massive units, and post-depositional slump and water escape structures. Most of these sediments were derived from reworked ignmibrites, lava domes and flows, and tephras from the Tauranga region and the TVZ.

(ii) At the lower areas to the west below the transition slopes and adjacent to the Kopurererua Stream:
- Alluvial silts, sands and gravels transported by the stream.
- Organic peat at the existing ground surfaces or overlaid by alluvial soils at depth.
- Eroded sections of the more elevated Taupo volcanic zone tephra that have been reduced to the levels of the stream plain or rise above these levels as mounds or ridges that extend in to the stream plain area.

3.0 Presubdivision Investigations

Prior to obtaining subdivision approval on 24 May 2004 a comprehensive geotechnical assessment was undertaken by S&L Consultants Ltd. The subsequent report that accompanied the consent application was titled "Pyes Pa West Urbanisation Development, Geotechnical Assessment Report, reference 16944" and was dated October 2003.

Fifty two machine drilled boreholes and twenty six excavated pits were used to identify the subsoils that are present on the development area. Relevant test positions for each stage were:

Stage No.	Reference Plan.	Machine Bores:	Test Pits:
2A	AB2	9, 10, 12	
2B, 2C	AB3	16, 19, 20, 30, 31, 32, 48	
2D	AB5	47, 48	24, 25
2E, 2F	AB7	16, 20, 49, 50	24

Each of these boreholes showed the presence on the lower areas of Stage 2 to be:

- Peat (organic silt) ranging from depths of zero (borehole 32) to 4.5m (borehole 19). Relevant depths of peat present on each stage were:
  Stage 2A – 2m.
  Stages 2B, 2C – 0.6m (borehole 16) to 1.7m (borehole 31).
  Stage 2D – 2.4m (borehole 48).
  Stages 2E, 2F – 0m (borehole 49) to 1.2m (boreholes 20 and 50).

- Grey sandy silts and sands underlying the surface peat. These inorganic soils were found to be of varying densities and strengths with uncorrected SPT N values in the range of 1 to 6. The investigation borehole depths ranged from 6m to 18.5m. No further organic soils were encountered in that depth apart from the surface cover of peat.

Machine drilled borehole 52, located on higher ground within the Stage 1B area showed the ash stratigraphy that may be present in the slope profiles to the north of Stage 2A and to the east of Stages 2C and 2D. Subsequent test drilling in the Stage 1B area and as discussed in S&L Consultants Ltd report dated 21 December 2006 identified in more detail the presence of the Te Ranga ignimbrite as the base constituents of the higher ground. Machine drilled borehole 47 was located on the Grant plateau adjacent to Kennedy Road (future stages 2J and 2L) and showed the subsoils present within the slope profiles down to the Stage 2D area.

The presubdivision investigations concluded that:

- The soils to be obtained in areas of cut on the higher ground would be suitable for placement as filling to support future houses although some conditioning may be required so that placement would be near optimum moisture contents.
- Areas of higher ground away from the areas of peat and not to be disturbed by construction earthworks would be suitable for the support of future houses in accordance with NZS3604.
- As the volcanic ash stratigraphy varies in type and relative strength foundation bearing conditions may vary across building sites formed in areas of cut.
- Similar variations in soil type may be encountered in road subgrades and insitu testing would be required to determine pavement depths applicable to the subgrade conditions present.
- The peat soils can be removed to depths governed by the capability of the earthmoving machinery on the site and the cost effectiveness of removing the peat and undertaking its replacement with filling obtained from elsewhere within the subdivision development area.

4.0 Scope of Subdivision Earthworks

The general earthworks undertaken in Stages 2A to 2F inclusive were:

(a) The removal of the surface peats and the replacement of the peat with filling obtained from borrow areas within The Lakes development. Prior to placement of the filling over the stripped areas extensive subsoil drainage systems were constructed. The positions of these drains and their outfalls are shown on the reference plans in this report for each stage. The drains mainly originated at the bases of shallow gullies that extended southwards into the peat areas from the steep hillsides to the north and south to south east. The points of seepage that are serviced by the drains were identified when removal of the peat commenced.
(b) The minor trimming at the base of the hill to the north of Stage 2A to establish flatter areas at the rear of lots 406 and 411.
(c) The minor trimming at the base of the hill in the subdivision borrow pit to the north of Stage 2C. As a result of this trimming minor depths of filling were placed at the northern end of Stage 2C to ease slopes into the stage as shown on 18264-AB4.
(d) The reduction of a ridgeline that ran through Stage 2D from the east and extended into Stage 2F.
(e) The trimming of the steep slopes to flatter gradients on the rising ground to the south east of Stage 2D up to the Grant Plateau within future Stage 2L and up to the rural residential development of Freeburn Park beyond the eastern boundary of The Lakes development.
(f) The formation of earthfilled bunds at the rear of Lots 406 and 411 in Stage 2A, to the north east of Stage 2C and at the rear of Lots 460 and 462 to 464 in Stage 2D. The purposes of these bunds are described in the individual sections of this report that relate to these stages.

The depths of cut and filling shown on drawings 18264-AB2, AB3, AB5 and AB7 were derived from surveyed contours of the finished surface taken on completion of the earthworks compared with topographical surveys undertaken by S&L Consultants Ltd and

Grasshopper Farms Ltd prior to the subdivision construction and also after the removal of the unsuitable surface soils and prior to the placement of the replacement filling.

The earthworks for the Stage 2A area were undertaken by RPL Services Ltd during the 2005-2006 earthworks season. Hick Bros Earthmoving undertook the remainder of the earthworks during the 2006-2007 and 2007-2008 earthworks seasons.

The earthworks were undertaken in compliance with consent 62387 issued by Environment Bay of Plenty.

5.0 Earthworks Standards

The performance specification required of the Contractors for the earthworks was based on the guidelines contained in NZS 4431:1989 "Code of Practice for Earthfill for Residential Development". Compliance with the compaction requirements listed below satisfies the standards listed in Section 7 of the NZS 4431.

Air voids percentage (as defined in NZS 4402: Part 1:1980)

- Average value less than 10% (any 10 tests)
- Maximum single value 12%

Undrained shear strength (measured by in situ vane)

- average value not less than 150kPa (any 10 tests)
- Minimum single value 100kPa

Where the filling placed was clearly pumiceous sand obtained from borrow pits in the Te Ranga ignimbrite Scala penetrometer tests were specified with blow counts of 4 or more per 100mm of penetration being required.

The calculation of air voids percentages was dependant on the determination of the solid densities of the soils used in the filling. These soils mainly comprised mixed silts, clayey silts, sandy silts and sands depending on the depths below the original ground surfaces that the cuts were made for obtaining fill materials. For cohesive silt/clay soil mixtures a value of solid density of 2.65t/m^3 was used in the calculation of air voids. Where the sample taken for laboratory determination of insitu water content comprised pumiceous sands and was indicative of the soils in which the nuclear densometer test was undertaken a lower value of 2.56t/m^3 was used in the calculations.

The earthworks were supervised by site project engineers employed by Grasshopper Farms Ltd and observed by engineering staff from S&L Consultants Ltd during specific site inspections.

Compaction and strength control testing was undertaken by IANZ accredited Opus International Consultants Ltd both on site and in their Tauranga laboratory.

The following numbers of complying compaction tests were undertaken:

Stage No.	No. Tests
2A	63
2B, 2C	61
2D	77
2E, 2F	57

The test results are listed in Appendix 3.

6.0 Recommendations for Development of Stage 2A

6.1 Subdivision Construction Filling

Supervised structural filling, as shown on drawing 18264-AB2 was placed on Stage 2A in accordance with the methods and standards quoted in NZS 4431 under the management of S & L Consultants Ltd. Compaction testing on site confirmed that a high and uniform degree of compaction has been achieved suitable for the support of buildings. Compaction test results are summarised in Appendix 3.

For all of the lots which are located in the areas of filling the ultimate ground bearing capacity in the limit state may be taken at 300kPa and this capacity meets the definition of "good ground" as defined in NZS3604.

A statement in support of the suitability of the filled areas for the erection of future buildings in terms of NZS 3604 is contained in Appendix 2 of this report.

Within areas of structural filling on which buildings may be erected, however, the possibility of variation of soil type and strength may exist away from observation or compaction tests locations. The normal inspection of foundation conditions during construction of buildings by competent tradesmen as described in NZS 3604 and by building inspectors would still be undertaken. If for any reason areas of low soil strength are found professional geotechnical advice should then be sought.

6.2 Areas of Cut or Undisturbed Ground

All areas within Stage 2A were earthworked initially in cut to remove peat and other soft ground and then were subsequently filled. No areas of the original topography apart from the hill to the north were left unmodified by the subdivision earthworks.

6.3 Land Stability

Steep but uniform slopes rise beyond the rear boundaries of lots 406 and 411. These slopes are up to 29m in height and stand at 30 to 35 degrees. The original gorse and other weed cover and some large trees had been removed from the slope faces and geomorphic features could then be seen. The slopes have now been planted for revegetation with native species, mainly flaxes.

The only apparent evidence of past instability that has occurred is present as erosion on the old quarry face at the north western corner of Lot 411 to a lesser degree and above the reserve accessway between lots 406 and 411.

Soil exposures seen on the slope faces under the grass cover and in the old quarry face are of the Matua subgroup as described in Section 2.0 of this report being cream coloured sandy silts and also of the dense pumiceous sands of the Te Ranga ignimbrite.

The ability of the slopes to stand at relatively steep angles is due to be angular pumiceous soil particles present on the matrix of the Te Ranga ignimbrite. The largely shallow and superficial erosion scarps have occurred where the ash cover has moved off the underlying ignimbrite. Any future slope movement is therefore likely to be in a similar mode where the ash (Matua subgroup) cover could be mobilised. To reduce the risk of such erosion occurring the slope surfaces have been stabilised by the replanting of native vegetation plants including flaxes and coprosma taiko. Future erosion, if any, would only be mobilised by rainfall arriving at and running down the slope faces to the bases of the slopes. There are no upslope catchments from where surface water runoff may originate. The development at the crest of the hill as a reserve and lookout has created an overland flow path down the access steps on the northern side of the hill.

To protect future development on lots 406 and 411 from surface water runoff down the slope faces and also any transported soil from future surface erosion an earthfill bund has been erected along the rear boundaries of lots 406 and 411. The bund has been shaped to divert surface water into an overland flow path within the access to the future reserve from Landing Quay between lots 406 and 411. Sufficient room and storage has also been created between the base of the slope and the bund to capture and hold any future transported soil from erosion on the upper slopes and allow the accumulated soil to be removed by earthmoving equipment that would gain access from Landing Quay, either up the western cul de sac or up the reserve accessway between lots 406 and 411 or from Lakes Boulevard.

No bunds have been erected at the rear of lot 400 and the north eastern end of Lot 411 because natural ridges extend towards those lots. Surface water would shed to the lower ground and pass behind the bunds.

The long term security of lots 406 and 411 will depend on the maintenance of the earthfill bunds in their present form and with a dense grass cover. No excavations should be made into the bunds from any of the future lots that would reduce their mass or height. Furthermore any accumulated material in the reserve behind the bunds should be removed immediately after deposition. Regular inspections will be required to identify the presence of such accumulated material and to also ensure that the stormwater runoff routes remain in place. A consent notice that would refer to this recommendation is to be placed on the Certificates of Title for lots 406 and 411 and should be carried forward to lots adjacent to the bunds in any further subdivision.

With these controls in place it is unlikely that Lots 406 and 411 would be subject to the effects of natural hazards such as erosion, falling debris or slippage as defined in section 71 of the Building Act 2004.

7.0 Recommendations for Development on Stages 2B, 2C

The Stage 2B area is located on the western side of Lakes Boulevard on the lower lying areas within the flood plain of the Kopurererua Stream which flows past the subdivision to the west.

The Stage 2C area is located on slightly rising ground to the east of Lakes Boulevard. This area is also bounded to the north by rising ground which eventually steepens to the ridgeline that extends south westwards from the end of Rexford Heights which was constructed in the Stage 1B development at the Lakes.

7.1 Subdivision Construction Filling

Supervised structural filling as shown on drawings 18264-AB3 and AB4 in Appendix 1 was placed in accordance with the methods and standards quoted in NZS 4431 under the management of S & L Consultants Ltd. Compaction testing on site confirmed that a high and uniform degree of compaction has been achieved suitable for the support of buildings.

After placement of the filling in Stages 2B and 2C settlement markers 6, 6A and 32 were installed at locations shown on 18264-AB3 immediately to the south of these stages as ongoing topsoiling and grassing operations may have damaged or disturbed the markers if they were placed in the centres of the stage areas.

The levels on these markers have been surveyed at regular intervals including during the construction of the roading and services periods for both stages. The results of these surveys to the date of this report are within Appendix 3 and show that no significant settlements have recently taken place. Settlement marker 6 was located in the filling that overlaid some underlying peat. The marker was relocated to position 6A on the structural filling and no further significant settlements were recorded.

Future ground settlement is expected to be within the limits stated in Appendix B of compliance documents B1/VM4 for the New Zealand Building Code prepared by the Department of Building and Housing.

The future development of Stage 2C would include the construction of the subdivision roading which would be set below the levels of adjacent lots. It is likely that some additional filling will be placed on areas for future building. This filling would be placed to the standards listed in Section 5.0 of this report and tested for compliance with the specification.

For all of the lots which will be located in the areas of filling the ultimate ground bearing capacity in the limit state may be taken at 300kPa and this

capacity meets the definition of "good ground" as defined in NZS3604. Future buildings may therefore be detailed in accordance with NZS3604.

A statement in support of the suitability of the filled areas for subdivision is contained in Appendix 2 of this report.

Within areas of structural filling on which buildings may be erected, however, the possibility of variation of soil type and strength may exist away from observation or compaction tests locations. The normal inspection of foundation conditions during construction of buildings by competent tradesmen as described in NZS 3604 and by building inspectors would still be undertaken. If for any reason areas of low soil strength are found professional geotechnical advice should then be sought.

7.2 Areas of Cut or Undisturbed Ground

Areas of cut exist on stages 2B and 2C are shown on 18264-AB3. These occur where the former ridgeline that ran from north east to south west into Stage 2C was reduced for the use of the cut material in the subdivision filling on stages 2B and 2C and elsewhere on the subdivision.

The insitu soils in the areas of cut are considered suitable to support buildings on shallow surface foundations. This opinion is based on observations of the soil types present at the finished ground levels after the completion of the earthworks and before the placement of surface topsoil. It is recommended that, after the urban development proposals for Stages 2B and 2C are known in the areas of cut shown in 18264-AB3 additional tests are undertaken at a frequency determined by the investigating engineer to confirm future building foundation conditions. The subsequent reporting should contain recommendations for the ongoing development of each new lot including, if applicable, modifications to standard foundations detailed in NZS3604 to suit any areas of low ground bearing capacity.

7.3 Land Stability

Two land stability issues are relevant to Stages 2B and 2C namely:

- The stability of the replacement filling for the peat that was present and was removed in Stages 2B and 2C.
- The stability of the sloping ground that rises to the north east and east of Stage 2C.

7.3.1 Stability of Replacement Filling

The extent of the structural filling shown on 18264-AB3 along the south western and north western margins of Stage 2B and the eastern margin of Stage 2C was determined by the practical limits to which the surface peat soils could be removed. The extent of the filling shown on this drawing was determined by survey as being at the base of the excavation. For stability purposes during construction the excavations were battered into the remaining peat before the controlled backfilling took place. Additional filling was placed over the peat beyond the replacement filling areas to raise ground levels.

A building restriction line is applicable to limit future buildings to be located on the structural filling where reliable ground will be present to support conventional buildings with surface foundations. Beyond the restriction lines filling will be present which may not be suitable to support buildings and future ground settlement is possible where this filling has been placed over organic soils which were not removed during the subdivision earthworks.

To confirm that the building restriction line identified from site surveys during the earthworks is in the correct position, additional boreholes were machine drilled along the building restriction line in February 2008. The test positions are shown on 18264-AB3 and summary logs are in Appendix 4. Each borehole showed the depth of filling that is present and also the absence of any former peat soils indicating that the correctly filled ground extends beyond the building restriction lines.

The building restriction lines are shown on 18264-AB3 and the survey plan DP400022.

7.3.2 Stability of Steep Ground Adjacent to Stage 2C

Steep but uniform slopes rise to the north east and east of Stage 2C.

The rising ground to the north east has been recontoured in cut at the end of the borrow area for filling during the subdivision earthworks to date. The soils exposed in the cut faces which have been formed at 1 vertical : 2 horizontal (26 degrees) comprise Te Ranga ignimbrite (dense grey pumice sands). These slopes are considered to be sufficiently stable at these formation angles to permit buildings to be erected in the Stage 2C area at the base of the slopes without any future risk.

Steeper slopes exist to the east beyond the reserve area at the southern side of the Stage 2C area. These slopes are up to 40m high and stand at 30 to 35 degrees. The original gorse and other weed cover has been removed and the geomorphic features can be seen. The slopes have now been planted for revegetation with native species. There is evidence of some superficial erosion having occurred on the slope faces in the past.

The ability of the slopes to stand at relatively steep angles is due to the angular pumiceous soil particles present in the matrix of the Te Ranga ignimbrite that is present in the sloping ground and can be seen in cut faces further to the north. Any future instability is therefore likely to be in a similar mode to that existing whereby the surface ash derivative soils may be mobilised. The replanting with native species will, in time, reduce the risk of such erosion from occurring.

Should such erosion occur any runout will be directed into the reserve to the east of Stage 2C. To assist with this direction the low ridgeline that exists along the southern boundary of Stage 2C and running in a

north to south direction has been extended for a further 30m by placing additional filling at the southern end of the ridge during the earthworks season of 2007-2008.

8.0 Recommendations for Development on Stage 2D

8.1 Scope of Development Earthworks

The Stage 2D area is located on the eastern side of Lakes Boulevard and is served by the loop road of Bathurst Crescent. Twenty one individual lots are contained in Stage 2D. The relative lot positions are shown on Harrison Grierson drawing 124825-LT01 and 18264-AB5 in Appendix 1. Dimensions of these lots are shown on DP400022.

The original topography within Stage 2D comprised:

- A ridgeline which entered from higher ground to the north east and ran through Lots 453 to 461 inclusive and into the Stage 2E area to the west.
- Lower lying ground to the north west within Lots 449 to 452 which formed part of the flood plain of the Kopurerua stream which was also present in adjoining Stages 2B and 2F.
- Lower lying ground to the south west within Lots 462 to 470 and Lot 3 (part Lot 471). Behind these lots to the south east the ground rose steeply to the Grant Plateau adjacent to Kennedy Road.

Prior to construction in the Stage 2D area substantial earthworks were undertaken to:

(a) Reduce the Grant Plateau levels by up to 10m to provide near flat building areas in the future Stages 2J, 2K, 2L and 2M development areas and to obtain filling for the development of Stages 2B, 2C, 2E and 2F where replacement of the peat soils was undertaken with this filling. The haul routes from the Grant Plateau were down a gully which existed within future Stage 2G to the south west of Stage 2D and up an original farm track which started at the rear of Lots 459 and 460 within Stage 2D and rose to the Grant Plateau at a position above Lots 466 and 467. This haul track has now been reshaped to be part of the pedestrian and cycleway system that traverses the slopes between Stages 2D and upper future Stage 2L.

(b) Establish a route for the realignment of the natural gas pipeline behind Lots 456, 459, 460, 462 to 470 and Lot 3 (part Lot 471). Initial earthworks were undertaken mostly in cut as the pipeline easement 6m wide was created as a near level berm on the sloping ground. Where groundwater was encountered in the cut faces subsoil damage was installed some of which was located in a trench below the gas pipeline invert. These drains are shown running parallel to the rear boundaries of Lots 462 to 467 on drawing 18264-AB5.

(c) Reduce the original steep slope face angles present on the rising ground above Stage 2D and up to the Grant Plateau (Stage 2L). This required the easing back of the original slopes to be not steeper than 1 on 2 (26 degrees) with an intermediate maintenance berm at midslope. This berm will be utilised as part of the walkway system. To regularise the final slope faces on old erosion scarp was infilled behind Lots 466 to 468 to the standards listed in Section 5.0 of this report. Extensive subsoil drainage was installed after this fill area had been stripped in preparation for the filling. The subsoil drainage system was also extended vertically at perched seepage levels as the filling was raised. The extent of the subsoil drainage system is shown on drawing 18264-AB5. The scope of the earthworks undertaken on the steep slopes to the south east of Stage 2D was derived from the stability analysis described in Section 8.3 of this report. The lower limits of resulting slopes were defined by the gas main easement that runs to the rear of Lots 460 and 462 to 471.

In the areas of filling shown on 18264-AB6 on Lots 449 to 452 and 462 to 470 as well as the subgrade to the loop road of Bathurst Crescent the underlying peat was first removed down to the underlying inorganic soils. Subsoil drains were constructed where required following an inspection of the excavated levels and the identification of points of incoming seepage. Structural filling was then undertaken to the standards listed in Section 5.0.

8.2 Subdivision Construction Filling

Supervised structural filling as shown on drawings 18264-AB5 and AB6 was placed in accordance with the methods and standards quoted in NZS4431 under the management of S&L Consultants Ltd. Compaction testing on site confirmed that a high and uniform degree of compaction has been achieved suitable for the support of buildings.

After placement of the filling in Stage 2D settlement markers were installed at locations shown on 18264-AB5. Five markers numbered 9, 11, 12, 42 and 47 were present in or adjacent to the Stage 2D areas. The levels on these markers have been surveyed at regular intervals and the surveys were continued during the construction of the roading and services. The results of these surveys to the date of this report are within Appendix 3.

The degrees of settlement have fluctuated over the monitoring period with variations up or down probably due to the expected accuracy of the survey.

The trends during the monitoring period indicate that any future settlement will be within tolerable limits for future buildings constructed on surface foundations.

For all of the lots which will be located in the areas of fill the ultimate ground bearing capacity in the limit state may be taken at 300kPa and this capacity meets the definition of "good ground" as defined in NZS3604. Future buildings may therefore be detailed in accordance with NZS3604.

Within areas of structural filling on which buildings may be erected, however, the possibility of variation of soil type and strength may exist away from observation or compaction test locations. The normal inspection of foundation conditions during construction of buildings by competent tradesmen as described in NZS3604 and by building inspectors would still be undertaken. If for any reason areas of low soil strength are found professional geotechnical advice should then be sought.

8.3 Areas of Cut

Areas of cut existing on Stage 2D are shown on 18264-AB6. These areas occur where the former ridgeline that ran from the east into Stage 2D was reduced for the use of cut material in the subdivision filling.

The depths of cut ranged from zero at the north western boundary of Lot 453, the north eastern boundary of Lots 453 to 455 in the western boundaries of Lots 457 and 458 to 4m within Lots 454 to 455.

In the areas of cut shallow post construction boreholes were put down to identify the type and continuity of the soils likely to be present at building foundation levels. These test positions are shown as Boreholes 453A and B, 454, 455A and B and 456 to 461 inclusive. The numbers refer to the lots on which they were located on 18464-AB5 and summary logs of the soils found in the boreholes are in Appendix 4.
These boreholes showed that the soil types present on Lots 454 to 460 comprised surface topsoil overlaying brown or grey pumiceous sands. On Lot 461 ash derivative brown sandy silts overlaid light brown clayey silts.

Tests using a shear vane in the cohesive soils on Lot 461 and a Scala penetrometer on the other lots where sand based soils are present showed sufficient shear strengths or densities in the soils likely to be present at future foundation levels at all test positions except at position 453B. At this location the Scala penetrometer blow counts were low in the order of 1 to 2 per 100mm.

The recorded shear strengths are shown on the borelog for Lot 461. The recorded Scala penetrometer blow counts per 100mm of penetration are tabulated on the results sheet with the summary borehole logs in Appendix 4.

On all lots, except on part of Lot 453, "good ground" in terms of NZS3604:1999 is present, as indicated by the test results and therefore future buildings may be supported on shallow surface foundations.

On Lot 453, borehole 453B located at the rear of the lot, as shown on 18264-AB5, indicated that loose sands are present and that the ground bearing capacity at the position of that borehole for the detailing of foundations may have to be reduced by up to 50% of that specified in NZS3604. It is recommended that when building details are being prepared for Lot 453 additional subsoil tests are undertaken to identify the soil types and strengths on the actual building area. The supervising engineer would then advise appropriate ground bearing capacities based on these tests or any ground

improvement works required so that surface foundations can be detailed in accordance with NZS3604. Borehole 453A near the front of the lot indicated that good ground is present.

8.4 Stability of Sloping Ground Above Lots 460, 462 to 470 inclusive and Lot 3

To assess the finished profiles that were formed on the steep sloping ground that rose above Lots 460 and 462 to 470 up to the Stage 2L area to the south east investigation boreholes were put down under the supervision of S&L Consultants Ltd by Perry Drilling Ltd during April 2007. These boreholes supplemented the original subsurface data that was available from machine borehole MB47 drilled in September 2003 that was located above Lot 470.

The summary log for MB47 is contained in Appendix 5. The soils that made up the slopes above Stage 2D and as described in MB47 down to a depth of about 9.5m were removed in the subdivision earthworks in the Grant Plateau area in the 2006-2007 earthworks season and prior to the earthworks to form the finished slopes above the Stage 2D area, that took place in November – December 2007. This initial borehole showed that below a depth of 9.0m the subsoils comprised medium to coarse grained pumiceous sand being Te Ranga ignimbrite. The borehole indicated that the ignimbrite extended to and beyond the depth of the borehole of 27m. Standard penetration tests (SPT) in the rock showed that densities increased with depth.

The boreholes put down in April 2007 were located at the crests of the original slopes at the Grant Plateau and at intermediate lifts on the slope faces on the haul tracks for the bulk earthmoving equipment. From this borehole data and the existing slope geometry it was deduced, by analysis, that the sloping ground between the Grant Plateau and the proposed residential areas in Stages 2D, 2G and 2L had to be reduced in slope to not more than 26 degrees (1 on 2) to provide acceptable factors of safety against slope failure. In plotting these slope angles and for providing for an intermediate berm for slope maintenance and also as an extension of the cycle and walkway through the subdivision it was found that the surface ash soils would be mostly removed by the recontouring earthworks leaving the Te Ranga ignimbrite to be mostly exposed on the cut faces.

8.4.1 Stability Analysis

For the sloping ground above the Stage 2D area the stability of four cross sections were analysed. These cross sections are numbered 8 to 11 inclusive and are shown in position on 18264-AB5.

Each of these cross sections have differing profiles and constituents. The finished sloping ground at each of the cross sections was formed in the following manner.

Cross Section 8 (above Lot 469)

- Constructed mostly in cut with the maximum cut depth being 8.0m at the intermediate berm.
- Minor structural filling at the toe of the slopes up to 2.0m deep.
- Finished slope angles at 24 degrees.

Cross Section 9 (above Lot 467)

- Comprised mostly of structural filling below the lower berm where an old erosion gully was infilled. The maximum depth of filling was of the order of 6.0m placed on benches cut into the original hillslope as the filling was placed. Subsoil drainage was placed in the initial undercut platform at the base of the slope.
- Minor cuts on the upper slopes to depths of up to 2.5m.
- Finished slope angles at 24 to 25 degrees.

Cross Section 10 (above Lot 464)

- Constructed entirely in cut with the maximum cut depth being 10m at the intermediate berm.
- Finished slope angles of 26 to 27 degrees above and below the intermediate berm.

Cross Section 11 (above Lots 460, 462 and 463)

- Minor structural filling placed at the base of the slope to regularise the finished slope angles to 26 degrees up to the cycleway berm.
- Minor trimming in exposed ignimbrite from the cycleway berm up to an old farm track near the subdivision boundary to develop a slope angle of 26 degrees.
- The removal of existing bush cover and the trimming of old ignimbrite exposures above the farm track and up to the property boundary leaving the original slope angles of 30 to 45 degrees intact.

The borehole data and also inspections of the exposed soils and rock derivatives on the finished slope faces was used to determine effective strength parameters that were used in the stability analyses for each cross section.

Each slope profile was analysed in the fully drained (ambient) state and also when soil porewater pressures were raised by the assignment of a pore pressure ratio Ru.

The soil strength parameters adopted were:

Soil Type	Effective Cohesion kPa	Effective Friction Angle Degrees	Density kN/m³	Maximum Ru
Structural filling (sandy)	3	32	16	0.15
Surface sandy silt	2	32	14	0.15
Silt (Matua subgroup)	2	30	14	0.15
Ignimbrite	2	40	14	0.15

The value of effective angle of internal friction of 40 degrees for the Te Ranga ignimbrite was derived from SPT values in the investigation boreholes and the back analysis of original slopes which stood at angles of up to 45 degrees where the ignimbrite was present in the slope faces.

Analyses were undertaken using the program X-Slope where the input was the slope geometry established by survey (as plotted on 18264-AB5) and the soil strength parameters listed above.

Computed factors of safety were:

Cross Section	Lower Slope		Upper Slope		Total Slope	
	Fully Drained	Raised Ru	Fully Drained	Raised Ru	Fully Drained	Raised Ru
8	1.54	1.30	1.74	1.50	1.61	1.30
9	1.55	1.37	1.87	1.49	>1.5	>1.5
10	1.51	1.34	1.62	1.34	2.10	1.74
11	1.78	1.38	1.5	1.0	>1.5	>1.5

The analyses show that, for slope profiles 8, 9 and 10, stability factors of safety are in excess of the conventionally acceptable factors of safety of:

1.5 For ambient or fully drained slopes which is the expected condition for the slopes as formed.

1.2 For transient conditions whereby porewater pressures may be raised for a short period of time and dissipation occurring after the storm even which raised the porewater levels.

For cross section 11 factors of safety were computed for the upper slopes which are less than these values. The possibility exists that some superficial failure may occur on the steeper slopes above the old farm track (refer to 18264-A5 for the location of this track above lots 460 and 462). To provide additional protection to Lots 460, 462 and 463 mitigation measures were undertaken on the gas line easement below the slopes and partly within Lots 460, 462 and 463 as described in Section 8.4.2.

8.4.2 Control of Slope Erosion, Lots 460, 462, 463

To protect future development on Lots 460, 462 and 463 from surface water runoff down the slope faces and also any transported soil from possible upslope erosion the following diversion works are in place.

- The old farm track has been left intact and access has been created for small equipment to maintain this track (these slopes are within the proposed reserve to be vested in Council at a later time). This track will therefore capture surface runoff and any eroded soil from the steeper slopes above if the limiting conditions assumed in the numerical analyses do occur.

- The lower pedestrian/cycleway formation has been formed to divert stormwater runoff and any further transported eroded soils that may overtop the upper old farm track, in a northerly direction.

- An earthfilled bund has been constructed within the gas line easement and partly within the rear of lots 460, 462 and 463. Sufficient room and storage has been created between the base of the slope and the bund to capture and hold any future transported soil that may not be arrested by the upper level pedestrian/cycleway and old farm track. Sufficient access is available along the gas main easement to allow the any accumulated soil to be removed by earthmoving equipment that would gain access from the pedestrian/cycleway. The long term security of Lots 460, 462 and 463 will depend on the maintenance of the earthfill bunds in their present form and with a dense grass cover. No excavations should be made into the bunds that would reduce their mass or heights. Furthermore any accumulated material behind the bunds should be removed immediately after disposition.

  Regular inspection will be required to identify the presence of such accumulated material in the gas easement and reserve area above the easement and to ensure that the stormwater runoff routes remain in place. A consent notice that would refer to this recommendation is to be placed on the certificates of title for Lots 460, 462 and 463.

  With these controls it is unlikely that Lots 460, 462 and 463 would be subject to the effects natural hazards such as erosion, falling debris or slippage as defined in Section 71 of the Building Act 2004.

9.0 Recommendations for Development on Stages 2E, 2F

9.1 Subdivision Construction Filling

Supervised structural filling as shown on drawings 18264-AB7 and AB8 was placed in accordance with the methods and standards quoted in NZS 4431 under the management of S & L Consultants Ltd. Compaction testing on site confirmed that a high and uniform degree of compaction has been achieved suitable for the support of buildings.

After placement of the filling in Stages 2E and 2F seven settlement markers numbered 8, 9, 10, 11, 47, 48 and 49 were installed at locations shown on 18264-AB7 in or adjacent to the Stage 2E, Stage 2F areas. The levels on these markers were surveyed at regular intervals. The results of these surveys to the date of this report over the previous period of up to 180 days are within Appendix 3.

The degrees of settlement have fluctuated over the monitoring period with variations up or down probably due to the accuracies of the surveys. Recorded monthly settlements up to the preparation of this report were in the range of 1 to 3mm. The trends during the monitoring period indicate that any

future settlement will be within tolerable limits for future buildings constructed on surface foundations. These limits are stated in Appendix B of compliance document B1/VM4 for the New Zealand Building Code prepared by the Department of Building and Housing.

The future development of both stages would include the construction of the subdivision roading which would be set below the levels of adjacent lots. The same high degree of compaction of the filling occurred in the areas for future roads, as for the likely building areas. A stable road subgrade would therefore be present. It is recommended that the road pavements be detailed for a subgrade CBR of 7.

For all of the lots which will be located in the areas of fill the ultimate ground bearing capacity in the limit state may be taken at 300kPa and this capacity meets the definition of "good ground" as defined in NZS3604. Future buildings may therefore be detailed in accordance with NZS3604.

A statement in support of the suitability of the filled areas for subdivision is contained in Appendix 2 of this report.

Within areas of structural filling on which buildings may be erected, however, the possibility of variation of soil type and strength may exist away from observation or compaction tests locations. The normal inspection of foundation conditions during construction of buildings by competent tradesmen as described in NZS 3604 and by building inspectors would still be undertaken. If for any reason areas of low soil strength are found professional geotechnical advice should then be sought.

9.2 Areas of Cut

Areas of cut exist on Stage 2E as shown on 18264-AB8. These areas occur where the former ridgeline that ran from the east into Stage 2E was reduced for the use of the cut material in the subdivision filling.

In the areas of cut shallow post construction boreholes were put down to identify the type and continuity of the soils likely to be present at building foundation levels. These test positions are shown as BH721 to 723, 729 and 730 on 18264-AB7.

These boreholes showed that the soil types varied depending on the depths of cut that had taken place. At borehole positions 721 and 729 where cuts of up to 1.0m took place orange-brown ash derivative sandy and clayey silts are present. At borehole positions 722, 723 and 730 where cuts of 2 to 3m occurred brown grey pumiceous sands are present.

Tests using a shear vane or Scala penetrometer as appropriate showed sufficient shear strengths or densities in the soils likely to be present at future foundation levels so that buildings may be supported on shallow surface foundations detailed in accordance with NZS3604. Summary logs of the soils found in the post construction boreholes and the results of insitu testing are contained in Appendix 4 of this report.

9.3 Stability of Replacement Filling

The extent of the structural filling shown on 18264-AB8 along the northern, southern and western margins of Stage 2F was determined by the practical limits to which the surface peat soils could be removed. The extent of the filling shown was determined by survey as being at the base of the excavation. For stability purposes during construction the excavations were battered into the remaining peat before the controlled backfilling took place. Additional filling was placed over the peat beyond the replacement filling areas to raise ground levels.

A building restriction line is applicable to limit future buildings to be located on the structural filling where reliable ground will be present to support conventional buildings with surface foundations. Beyond the restriction lines filling will be present which may not be suitable to support buildings and ground settlement may occur where this filling has been placed over organic soils which were not removed during the subdivision earthworks.

To confirm that the building restriction line identified from the survey during the earthworks is in the correct position additional boreholes were machine drilled along the building restriction line in February 2008. The test positions are shown on 18264-AB7 and summary logs are in Appendix 4. Each borehole showed the depth the filling that is present and also the absence of any former peat indicating that the correctly filled ground extends beyond the building restriction lines.

The building restriction lines are shown on 18264-AB8 and the survey plan DP400022.

10.0 Professional Opinion

A statement in the format of Council's Code of Practice for Development (Form G2) that the lots shown on Harrison Grierson drawing 124825-LT01, DP 400022 and appended drawings 18264-AB1 to AB8 inclusive for Stages 2A to 2F of The Lakes are suitable for residential development is contained in Appendix 2. This development would include building on individual lots still to be defined by survey and the construction of roads and the installation of services.

A "lot summary report" in the format of Council from G2A is also in Appendix 2.

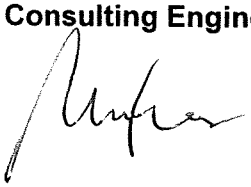
11.0 Applicability

Recommendations contained in this document are based on data from pre and post subdivision boreholes, observations of soil exposures during earthworks, and the results of tests in filling placed. Inferences about the nature and continuity of subsoils away from these locations are made but cannot be guaranteed.

In all circumstances, if variations in the subsoils occur which differ from those described or are assumed to exist the site should be inspected by an engineer suitably qualified to make an informed judgement and provide advice on appropriate improvement measures.

This report has been prepared specifically for the proposed subdivision development in Stages 2A to 2F of the Lakes Development as shown on DP 400022 and no responsibility is accepted by S & L Consultants Ltd for the use of any part of this report for other development sites without their written approval.

S & L Consultants Ltd
Consulting Engineers, Surveyors, Planners



M W Hughes CPEng
Geotechnical Engineer

17 March 2008

Appendix One

Drawings

Subdivision Scheme Plan by Harrison Grierson
Stage 2D – Lots For 224 Certificate by Harrison Grierson
Reference Plans

- 18264-AB1 - Stage 2A
- 18264-AB2 - Stage 2A
- 18264-AB3 - Stages 2B, 2C
- 18264-AB4 - Stages 2B,2C
- 18264-AB5 - Stage 2D
- 18264-AB6 - Stage 2D
- 18264-AB7 - Stages 2E, 2F
- 18267-AB8 - Stages 2E, 2F