5 November 15

Shotover Country Limited

C/o Clarke Fortune Macdonald and Associates Ltd

Po Box 553

Queenstown

50295 SHOTOVER COUNTRY SHA GEOTECH

REVIEW OF LIQUEFACTION POTENTIAL FOR SHOTOVER COUNTRY SPECIAL HOUSING AREA.

Dear Simon

1. INTRODUCTION

RDAgritech were commissioned by Shotover Country Limited, in a Confirmation email from Simon Barr on the 3 November 2015,

RDAgritech's scope of work was to undertake a Desktop review of the geotechnical conditions present on the proposed Special Housing Area (SHA) site with the aim to provide commentary on any liquifaction Hazard for the site.

The content is to respond to a request for further information from the Otago Regional Council in a letter dated 27th October 2015. This is highlighted below and forms the basis of the scope for this review.

> As noted above, there is potential for the area to be affected by seismic hazards. Development of a raised terrace raises questions about the proposed infill design to prevent effects such as lateral spreading through mobilisation of the underlying terrace embankment toward the river. The Shotover River basin (including the delta) where the development is proposed, is shown to be on ground or soils that are 'possibly susceptible' to liquefaction (Opus, 2005). Tonkin and Taylor (2012) completed a liquefaction assessment for the true right bank of the Shotover River and mapped it as having a 'probably low' liquefaction risk, mapping was not undertaken on the true left bank. No demonstrable remediation of this risk has been noted for the proposed SHA.

The following information was provided to us:

- Plans for the proposed SHA subdivision
- Previous geotechnical reports
    - Geoconsulting Ltd – Shotover Country Structure Plan and Geotechnical Assessment, February 2010
    - Royden Thomson – Review of Liquifaction issues February 2011

I am also the Geoprofessional testing and certifying engineer for the bulk fill placement, currently underway in the Activity Area 1f of the Shotover Country Subdivision. I have been involved in sighting and testing the natural soil subgrades for this neighbouring stages' construction.

2. LIQUIFACTION TRIGGERS

For liquifaction to occur there are a number of conditions that need to be present for it to trigger.

- Fine grained soils (silts/sands)
- Saturated soils (typically due to groundwater levels)
- Unconsolidated, soft to loose soils
- Sufficient cyclic shear straining (ground shaking from seismic activity)

The amount and susceptibilty of the insitu soils to liquefaction is dependant on the variations that are experienced with the parameters above.

The following elements will control the amount of settlement or ground surface displacement that could occur.

- Depths of the respective soil profiles
- Grading of the respective soils
- Bedding and layering of the respective soil profiles.
- Depth of non saturated soils over the saturated soils (depth to groundwater)
- Overburden pressures due to the above point
- The number and length of cyclic shaking associated with the Pga from the seismic event.

3. REVIEW OF THE SUPPLIED INFORMATION

Design drawings: The subdivision design drawings show a very large fill importation operation with a nominal 2.5m of fill to be placed across the entire site.

If liquefaction was a potential hazard then one of the most likely solutions for mitigating its effects on the proposed SHA would be for a thick gravel raft such as the proposed.

Geoconsulting report: This report doesn't contain any deep geotechnical investigations such as boreholes, CPT's or HDCP's, however it does identify:

- groundwater levels greater than 1.4 m below existing ground for the SHA area with a borrow pit static level of 1.2m
- Sandy gravels in TP1 to TP4 in the area of the SHA to a depth of 1.4 m below existing ground with a minor loess silt capping, no evidence of flood/silty lake deposits in the SHA area. (These seemed to be confined to the southern lower terraces T6 which are not part of the SHA proposal)
- Younger Quaternary Deposits comprising Alluvial Gravels, Loess, Lake sediments, swamp deposits, peat and aggradation Glacial Gravels.
- Seismic ground shaking for the area is a hazard
- For the SHA area the aggradation gravels and Alluvial gravels appear to be the dominate geological sequence present, with a capping layer of Loess.
- The author concludes that the SHA area is unlikly to be affected by liquifaction.

Royden Thomson report: This report was produced to provide a review and commentary on the Geoconsulting report specifically to address the liquifaction Potentail for the site. This report idendtified:

- Some 18,000 years ago the depositional environment for the site was largely a deltaic sediment depositional zone within the Wakatipu proto Lake that had a level of around 355 msl, the higher energy depositional environment would have mobilised the finer fractions such as silt and transported them downstream towards the original lake outlet at kingston to the south.
- There is an expected increase in grain size with a coarsing upwards profile
- Stratified (layered) alluvial Sediments would be present under the site, and with a deltaic environment this would be partially Kaotic with interfingered deposits.
- The deposition and infilling of the Frankton and Lake Hayes basin area resulted in sediment levels around the 355 to 360 msl level at the current site area. These are the levels around the Glenda drive terraces and upper terraces of Lake Hayes estate and the Glenpanel area. This would have resulted in nearly 40 to 45m of alluvial and deltaic gravel sediments overlying the present site, this would have provided considerable consolidation pressures to the underlying sediments.
- This concludes that the underlying soils of the SHA have been consolidated to a moderate to high degree.
- During and post deposition, several large siesmic events have occurred in the region with a nominal return period of 1000 years likely to have produced sufficent Pga and cyclic motions to instigate consolidation of any unconsolidated sediments.
- From around 7,500 to 5,000 years ago a rapid degredation of the Kawarau and Shotover river bed removed the built up deposits and transported these along the respective drainage channels. The stepped terraces of the Ladies Mile Lake Hayes and Shotover Country areas clearly shows a stop start process of downcutting into the sediments to create the present landform.

- The report concludes the sediments of the SHA area are older than the more elevated terraces, have undergone consolidation and been through several seismic events to further consolidate the sediments. Are predominatly gravel with cobbles with the possibility of minor silt rich and sand units of unknown thickness but limited lateral extent.
- His reporting also provides two deep water well logs of the stalker and Jones properties. These were constructed to the northeast of the SHA on the upper elevated terraces. These confirm a coarsing sequence towards the SHA area with less silty sands and gravels to more sandy gravels. They were in the order of 65m deep with groundwater encountered at a nominal 50m below Ground level. This would also confirm a relative flat groundwater profile for the area that is at similar levels to the shotover and kawarau river bed levels.
- His report concurs that the flat groundwater regime of the SHA area is present and the depth to groundwater increases towards the northwest (upstream)
- He acknowledges the presence of a thin sand layer in TP5 within the SHA zone however qualifies that further investigation for its extents could be utilised if of concern.
- He concludes the SHA area is not likely to Liquify.

4. ASSESSMENT

Further to the above we spoken with Paul Faulkner the author of the Tonkin & Taylor Ltd report on liquifaction hazards for the Wakatipu basin, mentioned in the RFI Letter paragraph above. Paul confirmed they had no information on the true left and assigned the area as uncategorised. This according to the Investigation and reporting requirements for QLDC Guidelines for Liquefaction investigations elevates it to the same requirements for LIC1 (nil to low). The minimum investigation requirement therefor is for good ground determination in accordance with NZS3604, this involves shallow investigations only.

According to the QLDC Hazard registry and mapping of the area the SHA is not within the Opus zones for potential susceptibilty or susceptible and they also do not indicate any mapping or hazard for the site for Liquifaction. The susceptible zone is present in the active shotover river channels from bank to bank but not beyond these. And therefor not present within the SHA. From the mapping the SHA would be estimated to be a nominal 60 to 100m away from the mapped susceptibility zone.

It must be noted that the reporting and conclusions from Royden Thomson would apply across the channel and to the True right hand side and therefor concur with the Tonkin and Taylor Assessment. Hence conversly the LIC1 (p) category for the True Right can apply for the True Left as well as they all part of the same depositional environment.

The localised and shallow channels and sediments within the active Shotover river channel may be unconsolidated gravels sands and minor lenses of silt, be saturated, and possibly consolidate under seismic cycling, however their depth and lateral extents are confined and any settlement induced would be considered minor.

The concern for Lateral spreading of the terraces towards the lower river profiles is also not founded as the presence of saturated, unconsolidated moderate to deep fine soils (silts/silty sands) is not present in this zone based on the exposures present and information provided.

The recent QLDC Land Developmentand subdivision code that has been ratified by council requires that under section 1.8.1.1 (c) “A Geoprofessionals report on the suitability of the land for subdivision or development if required by the council” is to be supplied for review and acceptance as part of the resource consent process for the subdivision. It would be at this stage that the geoprofessional would have conducted the necessary investigations to satisfy the liquifaction likely hood and remedial measures likely if present.

Therefore if category LIC1(p) is adopted for the site and given the lack of specific deep information for the SHA area I would recommend a nominal 1 to 2 boreholes with SPT testing of sufficent depth to confirm the liquifaction risk is indeed not present. It is unlikely CPT or HDCP testing will be able to penetrate the gravels present. Some additional test pitting may be required to determine the extents of any soft surficial soils as per Royden’s reporting however this would also be determined by the Geoprofessional for the site.

This information could also then be used to update the hazard maps for processing guidence for the SHA and surrounding and future property owners of the immedate area.

The proposed fill extents would also be expected to be a suitable mitigation and remediation measure if in the unlikely event liquifaction is found to be a possibility of affecting the SHA area. However this would be detailed by the Geoprofessional for the site in the reporting to be provided as part of the main resource consent application to QLDC.

5. APPLICABILITY

Findings presented as part of this letter are for the sole use of Shotover Country Limited and their advisors in accordance with the specific scope and the purposes outlined above. While other parties may find this reporting useful, the findings are not intended for use by other parties and may not contain sufficient information for the purposes of other parties or other uses.

Our professional services are performed using a degree of care and skill normally exercised, under similar circumstances, by reputable consultants practicing in this field at this time. No other warranty, expressed or implied, is made as to the professional advice presented in this report.

Yours Sincerely

David Rider
BSc (Geol)

Senior Engineering Geologist/Geoprofessional

50295 Shotover Country SHA Liqu Assess

☑ Issued, date sent 05/11/2015

☑ Typed by: DWR

☑ Reviewed by: LM

Attached: Previous reporting and SHA plan and sections

GEOCONSULTING Ltd

SHOTOVER COUNTRY

STRUCTURE PLAN AND GEOTECHNICAL ASSESSMENT

REPORT PREPARED FOR: CLARK FORTUNE MACDONALD & ASSOCIATES

09 February 2010

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INTRODUCTION

This report has been prepared for the Ladies Mile Partnership (LMP) as part of a technical information requirement for a proposed private plan change request to the Queenstown Lakes District Council. The proposed study area encompasses approximately 130 hectares lying between the Ladies Mile section of SH 6 to the north and the Kawarau River to the south with the lower Shotover River to the west. The scope of this report is to assess the existing landform, soil types, natural hazards (if any) and to provide a summary of the geotechnical suitability of the site for development.

The following work was undertaken to accomplish the above scope of work:

- Desk studies comprising aerial photo interpretation of stereo photo pairs dated 1956, review of the Council hazard register, review of the GrowOtago website and review of a previous report on the lower terraces of this block
- Field work involving a site walkover and excavation of 10 hand-dug pits.

SITE DESCRIPTION

The site is located within the predominantly rural Ladies Mile area of Queenstown and is bounded by the Shotover River to the west and the terrace edges to the east. Further to the east, the recent Lake Hayes Estate and Walnut Grove subdivisions are separated from the area of interest by a higher-standing terrace remnant. The proposed study area boundaries are shown in red on the annotated aerial photo (Figure 1).

Current access is off SH6 via Stalker Road. This road leads down onto the next terrace on which the upper part of the site is located. Several formed roads and farm tracks feed off Stalker Road to give access to the lower terraces. Old School Road leads to the northwestern corner of the structure plan boundary with access to this off Spence and Lower Shotover Roads.

LANDFORMS

The site comprises several river terrace platforms successively cut down by meanders of the Shotover River over the past few thousand years. Six distinct river terraces that decrease successively in elevation from the northeast to the southwest have been identified with several degraded intermediary terraces also visible. For the purpose of this report, each of the main terraces has been labelled from T1 (the highest in elevation) to T6 (the lowest in elevation) as shown on Figure 2.

The terrace slopes rising above each terrace have been labelled with the identifier for the terrace below and the suffix S. Slope heights range from 15 to 20 m for T1s down to 1 to 2 m for T6s; the general trend is for the terrace slope heights to reduce towards the southwest. Slope angles typically

range from 30° to 40° and sometimes up to 50° indicating oversteep slopes not in equilibrium with the geomorphic processes shaping the landforms.

The river terraces grade very gently towards the river with only 1 to 2 m of fall across the surface. Localised humps and depressions representing palaeochannels are more pronounced on the lower terraces but become less distinguished with height. The difference in relief is typically as a result of the lower terraces being younger geologically and therefore having less soil profile formed to "fill in these hollows". Recent farming activities including cultivation, sowing of crops, irrigation and grazing on the upper terraces, has levelled out the platforms further. The lower terraces (T4, T5 & T6) have been subjected to less intensive farming hence the more pronounced palaeochannel visibility, as evidenced on the aerial photo in Figure 1.

No active watercourses were observed on T1 to T5 however several old channels were noted. Some of these would be ancient stream beds that are now cut off from their source of water whilst others only activate in times of persistent or heavy rain fall. Many of these features lead to incised gullies in the terrace slopes with debris fans extending out into the terrace flats.

T6, the lowest terrace adjacent to the Shotover River, has had man-made ponds and ditches excavated into it that are flowing actively as a result of groundwater inflow. A small channel about 1 to 2 m across has been cut across T6 to divert water from the northwest corner and discharge to the Kawarau River. This feature is visible on the aerial photo in Figure 1 as the linear structure in the south corner of the study area.

There are nine larger debris fans present across the study area as shown on Figure 2. The fans extend from incised gullies out on to the terrace platform from a few meters to tens of metres. They are likely to have formed during periods of prolonged or heavy rainfall when ephemeral streams were active. The farming history of the site is not known but it is suspected that flood irrigation practices may also have been partly responsible for their emplacement. The largest debris fan, labelled D1 on Figure 2, has been modified by roading earthworks to create the existing access of Stalker Road. Other debris fans, particularly the larger ones, have been utilized to provide access to the terraces below by recent roading and earlier farm tracks.

The site is bounded to the south by a hill of schist bedrock that comprises the only observed outcrop in the area. Bedrock was not encountered in the course of the subsurface investigations but is estimated to range between a few meters to 10's of meters deep depending on terrace elevation.

SITE INVESTIGATIONS

A site walkover and 10 hand dug pits were conducted as part of this scope to supplement the existing soil information from the previous Geoconsulting Ltd investigations, which comprised 9 test pits to depths of 2.2 m in January 2006 for the purpose of aggregate supply. Locations of the test pits and hand pits are shown on Figure 2.

To complement the site walkover a stereoscopic review of 1959 aerial photos (Queenstown to Lumsden series 2824/11 and 2824/12) was conducted to identify any previous instability within the study area.

The hand pit and test pit logs are summarized in the following table.

Pit No.	Depth (m)	Description	Name
HP1	0.0	Grass roots, ORGANIC Silt minor sand, dark brown, dry, stiff	Topsoil
	0.15	Silty fine SAND, brown, dense	Loess
	0.4	Becoming medium dense to dense	
	0.6	Sandy GRAVEL, fine to medium gravels fine to coarse sand, brown, dense	Alluvium
	0.7	End of pit, difficult to excavate further, no groundwater encountered	
HP2	0.0	Grass roots, ORGANIC Silt minor sand dark brown, moist, stiff	Topsoil
	0.05	Sandy SILT, blue/grey, firm to very loose, micaceous, wet	Alluvium (Flood Deposit)
	0.15	Sandy SILT ORGANIC, dark brown, wet, firm with extensive roots and mild pungent odour	Buried Topsoil
	0.35	Sandy SILT, blue/grey, firm to very loose, micaceous, wet	Alluvium (Flood Deposit)
	0.45	SAND coarse, some silt blue/grey saturated loose to medium dense. Wet	Alluvium (sands)
	0.60	Groundwater encountered	
	0.70	End of pit, becoming gravelly	
HP3	0.0	Grass roots with blue/grey SILT, wet	Alluvium (Flood Deposit)
	0.20	PEAT/roots, no soil mass, saturated	Peat
	0.40	Silt, blue grey with extensive roots and organics, firm, soils oxidize to brown in minutes when exposed to air, saturated	Alluvium (Flood Deposit)
	0.5	End of pit, groundwater infilling hole	
HP4	0.0	Grass roots, ORGANIC Silt minor sand dark brown, moist, stiff	Topsoil

Pit No.	Depth (m)	Description	Name
	0.2	SILT some sand, minor fine gravels, moist light brown, stiff to loose.	Alluvium (silts)
	0.35	GRAVEL medium to coarse some sand and silt, brown, dense dry	Alluvium (gravels)
	0.40	End of pit, difficult to excavate further, no groundwater encountered	
HP5	0.0	Grass roots, ORGANIC Silt minor sand, dark brown, dry, stiff	Topsoil
	0.1	SILT sandy, brown, very stiff to dense, dry	Loess
	0.4	GRAVEL sandy, fine to medium, brown, medium dense to dense, dry	Alluvium (gravels)
	0.6	SAND coarse, some fine gravels, brown, loose, dry	Alluvium (sands)
	0.7	End of pit, no groundwater encountered	
HP6	0.0	Grass roots, SILT dark brown, dry, stiff	Topsoil
	0.05	SILT minor sand, brown, dense, dry	Loess
	0.4	GRAVEL coarse, sandy, brown dense, dry	Alluvium (gravels)
	0.45	End of pit, difficult to excavate further, no groundwater encountered	
HP7	0.0	Grass roots, SILT, dark brown, dry, stiff	Topsoil
	0.05	SILT sandy fine to medium, brown, very stiff to dense, dry	Loess
	0.70	SILT, fine gravelly, brown, dense dry	Alluvium
	0.75	End of pit, difficult to excavate further, no groundwater encountered	
HP8	0.0	Grass roots, SILT, dark brown, dry, stiff	Topsoil
	0.08	SILT fine sandy, brown, very stiff to dense, dry	Loess
	0.90	GRAVEL silty, medium to fine gravels, brown,	Alluvium

Pit No.	Depth (m)	Description	Name
		dense dry	(gravels)
	0.90	End of pit, difficult to excavate further, no groundwater encountered	
HP9	0.0	Grass roots, SILT, dark brown, dry, stiff	Topsoil
	0.08	SILT fine sandy, brown, very stiff to dense, dry	Loess
	0.90	Becoming slighrly moist	
	1.00	GRAVEL silty, medium to fine gravels, brown, dense dry	Alluvium (gravels)
	1.00	End of pit, difficult to excavate further, no groundwater encountered	
HP10	0.0	Grass roots, SILT dark brown, dry, stiff	Topsoil
	0.1	SILT fine sandy, brown, very stiff to dense, dry	Loess
	0.95	GRAVEL silty, medium to fine gravels, brown, dense dry	Alluvium (gravels)
	1.00	End of pit, difficult to excavate further, no groundwater encountered	
Test pits from March 2006 Geoconsulting Ltd report			
TP1	0.0	Topsoil/ Loess	Loess
	0.4	Sandy Gravels	Alluvium
	1.5	End of pit	
TP2	0.0	Topsoil/ Loess	Loess
	0.4	Sandy Gravels	Alluvium
	1.25	End of pit	
TP3	0.0	Topsoil / Loess	Loess
	0.15	Sandy Gravels	Alluviumm
	1.5	End of pit	

Pit No.	Depth (m)	Description	Name
TP4	0.0	Topsoil/ Loess	Loess
	0.36	Sandy Gravels	Alluvium
	1.4	End of pit, wet near base	
TP5	0.0	Topsoil/ Loess	Loess
	0.3	Sandy Gravels with sand beds 0.3m to 0.6m thick	Alluvium
	1.4	End of pit, groundwater at 1.4m	
TP6	0.0	Topsoil/ Loess	Loess
	0.45	Sandy Gravels	Alluvium
	1.4	End of pit	
TP7	0.0	Topsoil/ Loess	Loess
	0.3	Sandy Gravels	Alluvium
	1.1	End of pit, groundwater at 0.8m	
TP8	0.0	Topsoil/ Loess	Loess
	0.4	Sandy Gravels	Alluvium
	2.1	End of pit, groundwater at 2.1m	
TP9	0.0	Topsoil/ Loess	Loess
	0.4	Sandy Gravels	Alluvium
	2.2	End of pit	

GEOLOGY

The geology of the block is mapped by the 1:250,000 Geological Map of New Zealand (QMAP), published by GNS Science as Younger Quaternary deposits comprised of alluvial gravels, loess, lake silts, swamp deposits, peat and aggradation gravels (glacial).

The typical soil profile encountered in the hand pits displayed a sequence of: topsoil, loess and alluvium in order of depth. This sequence is consistent with the mapped geology (QMAP).

Although not encountered during the investigation, there is the possibility for lake sediments and localized pond deposits, particularly on the lower terraces. These deposits are likely to be comprised of blue grey silts and fine sands that may exhibit dilatant and thixotropic properties. If present, their extent is expected to be minor and standard engineering solutions are available to deal with them.

GROUNDWATER

Groundwater was encountered in test pits on the lower terrace platforms T5 and T6 at depths between 0.8 and 2.1 m below the T5 surface. The depth tended to increase with increased elevation across Terrace 5 and indicate a nearly flat groundwater gradient on the lower sections of the site. A borrow pit in Terrace 5 near TP 2 had a static groundwater level 1.2 m below terrace level at the time of the site investigations.

Groundwater was near surface across Terrace 6 or exposed in the ponds and trenches to the west of the terrace.

Groundwater was not found in any of the higher terraces during the site investigations; however it is expected to have a slight upward gradient away from the Shotover River towards the east with a component rising towards the higher ground north of the Ladies Mile.

NATURAL HAZARDS

There are several natural hazards present both regionally and locally that could potentially affect the site as listed and discussed as follows:

- Oversteep, unstable slopes,
- Debris fans,
- Erosion,
- Flooding,
- Low bearing capacity soils,

- Liquefaction,
- Seismic ground shaking.

The river-eroded terrace slopes T1s to T6s are considered to have marginal stability as a result of their past oversteepening. Subsequent rain and wind erosion, gravitational creep and small, shallow slips have modified the slopes to a more stable angle and establishment of a good vegetative cover of grass, scrub and trees has further improved stability. The well-drained nature of the terrace edges is conducive to stable slopes although periods of prolonged or heavy rainfall may result in localized failures. No large-scale movements were observed from either the field work or examination of aerial photographs. Farming activities along the terrace slopes has removed whatever evidence may have been present for shallow instability.

Terrace edge erosion and the resultant deposition of debris fans has been an active process in the past and could potentially reactivate under appropriate conditions. The site walkover and aerial photos show the majority of these fans have established a good vegetative cover indicating they have been mostly inactive. The road and track formations help control surface water runoff and it is envisaged that the proposed developments would also utilize these fans. Construction of sealed roads and an engineered stormwater system should greatly mitigate any risks for the larger fans.

Erosion is a natural process occurring with each significant rainfall or wind event sufficient to activate the process. The loess soils present across the site are particularly prone to erosive forces and during intense periods can cause considerable damage. The debris fans present across the site are the result of erosive forces, as are the loess soils covering the site.

Flooding is identified as a hazard on the QLDC Hazard Map and is reproduced as a blue stippled area covering T5 and T6 on Figure 1. Flooding is to be dealt with in more detail by others but is included here as a recognized hazard for the site. Hand-dug pits on T6 showed layers of silt that indicated deposition during a prolonged period of submersion from two distinct flooding events. Similar silt layers were not identified on T5 suggesting that any past flooding across the terrace could have been either of short duration or the water channelled through the area and any such silt layers are localised.

Soils of low bearing capacity are those that contain a high organic content or soft, unconsolidated silts and are susceptible to load-induced consolidation and consequent settlement. The low-lying areas of T6 have elevated groundwater levels or surface ponding and are expected to flood frequently. Most of this area is marshland /swamp and is underlain by well-formed beds of peat and silts. The marshland is shown as a green stippled area on Figure 1.

Liquefaction is an earthquake-induced hazard present in some areas of the Wakatipu Basin. Recently deposited soils with uniform grading can be susceptible to liquefaction when saturated. The lowest lying terraces (T5 & T6) are the only areas likely to be underlain by elevated groundwater levels. The subsurface investigations indicate that well graded sandy gravels predominate suggesting this site is unlikely to be affected by liquefaction. No evidence was found either on the ground or from aerial photograph inspection of past liquefaction damage. Liquefaction is thus not considered a hazard for this site.

Seismic ground shaking (earthquakes) is a common hazard to the area due to close proximity of the tectonic plate boundary (Alpine Fault) on the West Coast and several active fault traces throughout the Wakatipu region. Predictions for a magnitude 7.5 or greater shaking event within the next 50 years for the Wakatipu (NIWA) and the 15,000 seismic events that New Zealand has each

year warrant this as a substantial hazard. Though significant, this hazard cannot be eliminated but can be mitigated by the appropriate application of the relevant standards and codes as is currently the practice for any development in the Wakatipu Basin.

GEOTECHNICAL CONSIDERATIONS OF THE NATURAL HAZARDS

This section is concerned with ground-related hazards and it is expected that detailed discussion on flooding will be found in companion reports.

Solutions for terrace slope instability would be determined by the final subdivision layout with specific solutions provided in the Geotechnical Investigation Report (GIR) as required by the QLDC subdivision standards and NZS4404:2004 and could include either or a combination of the following:

- Slope regrading and associated earthworks,
- Specific investigation and design for individual buildings,
- Subsoil drainage,
- Retaining and soil stabilization measures,
- Building restriction, setbacks or zoning.

Of these, the latter option in conjunction with a sensitive subdivision layout are the preferred means of controlling building development on the terrace slopes. Aligning roads near to the crest and toe of terrace slopes, zoning the slopes as reserve or green belt and applying building restrictions on slopes steeper than 25° are possible solutions to avoiding disturbance to the steeper slopes or to restrict building away from potential landslides or their runout zones.

Erosion and debris fan emplacement are considered to be dormant processes giving rise to a relatively minor hazard. Current subdivisional standards and resource management guidelines for development contain adequate stormwater control and disposal requirements. All roading in the vicinity of terrace crests should have kerb and channel to prevent runoff escaping over the edge and disposal into soak pits should not be allowed within 50 m of the terrace edge. The existing vegetative cover on terrace slopes should be retained and enhanced to encourage rainfall infiltration and to mitigate rainwash erosion.

T6 has soils of low bearing capacity and as such does not have "good ground" as defined in NZS 3604. Notwithstanding the flooding hazard of this area, development would require substantial earthworks and drainage operations, specific design of all infrastructure and dwellings and the likelihood of title certificates registering natural hazard susceptibility. The direct and indirect costs of such work are likely to make housing or infrastructure development in this area unattractive. It is considered the best option is to zone the land as reserve or some other use that is not sensitive to the particular hazards that affect the area.

Seismic ground shaking is an inevitable hazard for the area and as such any development works are to be designed according to the relevant standards, with the GIR specifically addressing this issue in more detail..

CONCLUSIONS

The site as defined in red on Figure 1 is considered geotechnically suitable for subdivision and building development provided the identified hazards are taken into consideration and appropriate subdivisional engineering standards and geotechnical mitigation works are adopted.

It must be appreciated that while the site is generally suitable for building development, the costs of mitigating some of the hazards may be considerable. Careful design of the subdivision layout is considered necessary to optimise the hazard controls. It is proposed that the T6 terrace be utilised as a stormwater attenuation area for the development.

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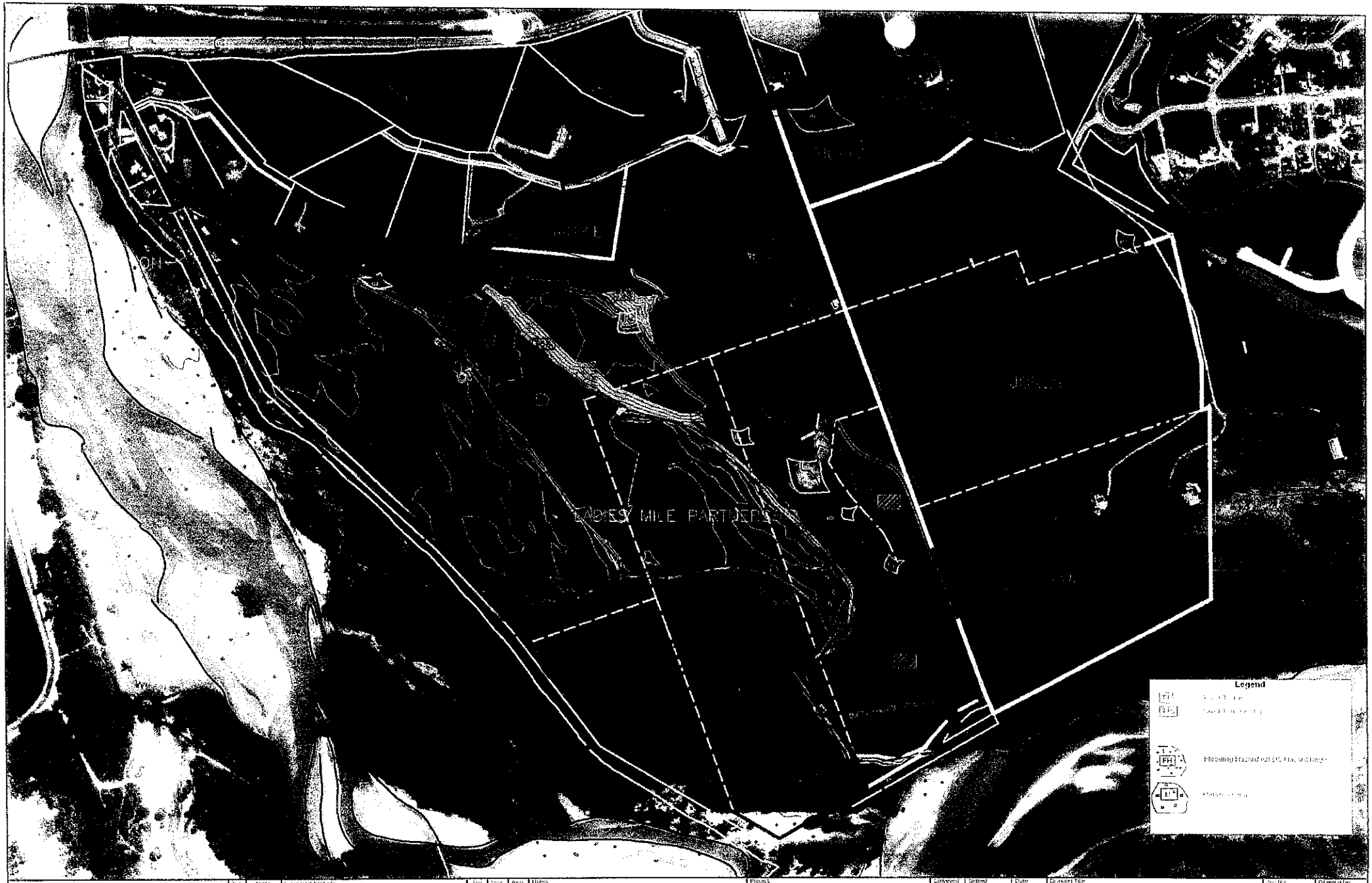
[i] Jeff Bryant Geoconsulting Ltd report "Lower Shotover Partnership: Assessment of gravel reserves" February 2006

APPENDIX A



CLARK FORTUNE MCDONALD & ASSOCIATES

No.	Date	Revision Details	By	Ver.	App.
1	15.12.07	Landuse and Hazards added			

Scale	Origin	Datum	By	Ver.	App.
A1					

Notes
1. All dimensions shown are in meters unless shown otherwise.

Project
PROPOSED PLAN CHANGE

SHEET 1 OF 1

Client
LOWER SHOTOVER PARTNERSHIP

	Surveyed	Signed	Date
Drawn	ESMD		3.10.07
Designed	DWR		15.12.07
Approved			

Drawing Title
LANDFORMS AND HAZARD MAP

Job No.

Drawing No.
Figure 1

Scale
1:3000 @ A1
1:6000 @ A3

Vertical Datum
MSL

Sheet
A

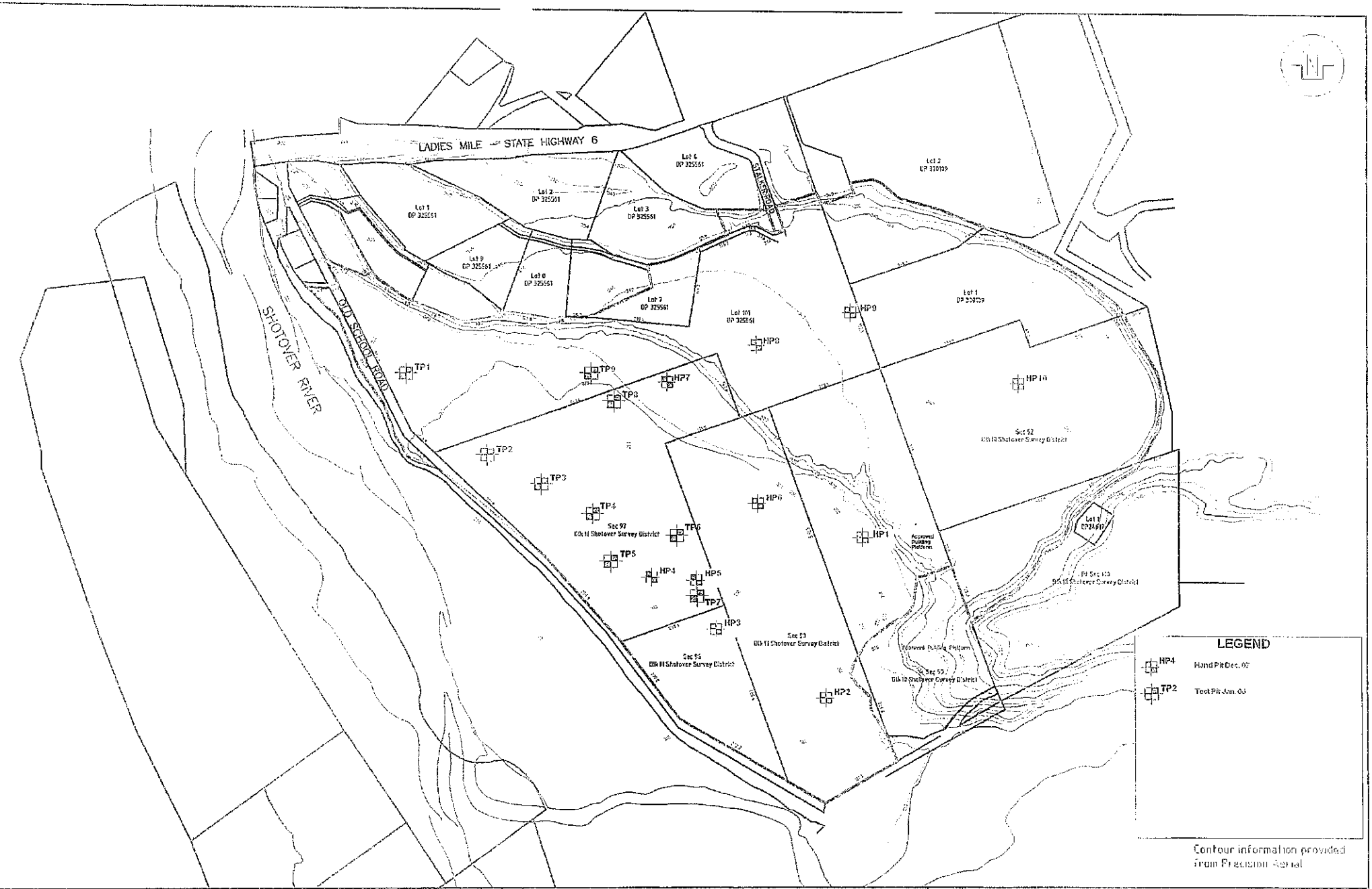

LADIES MILE – STATE HIGHWAY 6
SHOTOVER RIVER
OLD SCHOOL ROAD
STAKES ROAD
Lot 1 DP 325561
Lot 2 DP 325561
Lot 3 DP 325561
Lot 4 DP 325561
Lot 5 DP 325561
Lot 6 DP 325561
Lot 7 DP 325561
Lot 301 DP 325561
Lot 2 DP 330109
Lot 1 DP 330109
Lot 1 DP 22410
Sec 92 Blk III Shotover Survey District
Sec 93 Blk III Shotover Survey District
Sec 95 Blk III Shotover Survey District
Sec 97 Blk III Shotover Survey District
Approved Building Platform
TP1
TP2
TP3
TP4
TP5
TP6
TP7
TP8
TP9
HP1
HP2
HP3
HP4
HP5
HP6
HP7
HP8
HP9
HP10
LEGEND
HP4 Hand Pit Dec. 07
TP2 Test Pit Jan. 03
Contour information provided from Precision Aerial
CLARK FORTUNE McDONALD & ASSOCIATES
PLAN CHANGE
SHEET 1 OF 1
LADIES MILE PARTNERSHIP
ESMD
DWR
3.10.07
15.12.07
INVESTIGATION PLAN
1:3750 @ A1
1:7500 @ A3

Photo 1 of site looking down from the Remarkables Road

Note the paleochannels in T5 to the left, the swampy marshland of T6 in the lower center with the man made ponds, the well cultivated paddocks of T1 and T2 to the right and the current access track down the debris fan in the center of the site.

Photo 2 from the center of T6 looking across T6, towards the ponds and the bedrock outcrop to the southeastern side of the site

Photo 3 from the top of T3S in the center of the lower terraces looking North. Pine trees right of the [illegible] are near the top of T3S close.

Photo 4. Debris fan [illegible] gentle slope at the base of the terrace with [illegible] of T1S below the [illegible] and extending to the right of the photo.

ROYDEN THOMSON, GEOLOGIST

11 Leitrum Street
Cromwell
Phone 03 445 0025
Fax 03 445 0029

RECEIVED
2 8 FEB 2011

11 February'11

Chris Hansen
Clark Fortune McDonald and Assoc.
P.O. Box 553
QUEENSTOWN 9348

Dear Chris

PLAN CHANGE 41: REVIEW OF LIQUEFACTION ISSUES RAISED IN BRYANT REPORT OF FEBRUARY 2010

As requested, please find below pertinent comment on the materials underlying the proposed plan change area, their assessed genesis, and liquefaction potential. While I agree with Mr. Bryant's hazard assessment, I feel there are incremental aspects to the various physical and geological factors which can be utilised in support of his conclusion for the site; namely a non-issue.

a) Shotover Delta Genesis
Although alluded to in the Bryant text, it is not clear that the delta was once constructed as a significantly larger entity than can be appreciated from a present observation. In part in reference to the attached lake-change profile, it can be deduced that:

- Following the retreat of the last intrusive glacier into the area (18,000 years BP) a proto Lake Wakatipu infilled the cavity vacated by the ice. A long-duration lake level was established at about RL 355, and the outlet was at Kingston.
- During this lake establishment phase the Shotover River (and other tributaries) constructed a large delta which extended from Frankton to Lake Hayes, and south towards Jacks Point. Fines continued to flow further south, again. Note that at its maximum, during this phase much of the delta east of Frankton would have been above lake level, particularly near the aggradation axis of the Shotover River; this more-or-less includes the area of interest.
  Thus:
  - the Plan Change 41 area would have been wholly above RL 355; most likely in the vicinity of RL 360.
  - materials underlying the PC 41 area would be stratified alluvial sediments.
  - there is an expected grain size increase upwards in the local sequence. Fine sediments near the base in the glacial trough; coarser (sandy gravel, cobbly sandy gravel) debris should prevail nearer the fan tread. (Silty units, though, appear common in "Hendo's Hole".)
  - numerous major seismic events would have been experienced locally during the period of delta construction. Some settlement and consolidation expected.

- preloading of sediments (to RL 360?) would have occurred within the Plan Change 41 zone during this period, as well.

- Perhaps 5,000 years, or so, ago (section suggests 7,500 years; my present views reflect a younger time) the Kawarau River again captured Lake Wakatipu, with a consequent stepped but relatively rapid degradation of the Kawarau River along the toe of The Remarkables slopes, and the abandonment of the outflow channel at Kingston. A set of beaches on the edge of the delta at Frankton attest to a stop-start degradation process and the same temporal phenomenon occurred on the true left of the lower Shotover River i.e. the construction of a series of terraces by a degradation process. At its lowest, Lake Wakatipu drained to an estimated mean level about 2m below the current equivalent, and it is likely that the thalweg of the effective modern Shotover River did likewise.
- Mr Bryant discusses the PC 41 terraces in terms of dimensions and describes the lower remnants as "being geologically younger". While this may be true for the diminishing tread heights, it does not apply to the underlying materials, in my view.

General Conclusions for the section are:

- All terraces (perhaps with the exception of T6) appear to have been cut within a formerly large delta by degradation of the Shotover River, in association with degradation of the Kawarau River.
- Materials underlying terraces within the PC 41 area are relatively old and have undergone preloading by saturated alluvium up to an approximate RL 360 elevation.
- The few exposures I saw with yourself suggest the local alluvium will be a well-graded, sandy gravel. In part, there will be a cobble content (i.e. coarsening), but expect some silt-rich units of uncertain thickness. Sand units, if present, should be local.
- Numerous seismic events will have occurred during the life of the delta. Expect a consequent settlement, and increase compaction, for the host alluvial sediments.
- T6 has aggraded slightly due to past inundation.

b) Water Table Location
I concur with Mr. Bryant's interpretation that the water table through the PC 41 area should be low as a consequence of drainage through alluvial units to the Shotover River in a westerly direction and to the Kawarau River to the south-east. This is reinforced by the lack of any seepage from terrace risers above T6, and the flat water table established beneath T5.

c) Anomalous Terrace Tread Distress
A scrutiny of relevant stereopair photos failed to locate any unusual patterns which could suggest past liquefaction of underlying sediments. This accords with the observations described in the Bryant report.

d) T1 Surficial Deposits

Stereopair aerial photos display an anomalously proud ridge and adjoining areas at the east side of the tread. (Reference annotated Bryant plan.) I suspect this is an aeolian deposit (i.e. wind blown – saltation and aerial) that originated on the Shotover floodplain during earlier degradation. As such, it may be largely sand/silty sand, but it should be dry and not, therefore, subject to liquefaction.

Note this implied deposit may be equivalent to the hummocks which previously existed on the north side of nearby S.H. 6.

e) Offsite Features

i/ Graeme Stewart (McNeill Drilling) has kindly supplied logs for bores for Grant Stalker and Russell Jones; see attached Bryant plan for location. Although to the north of the PC 41 area, they do:

- show a dominance of "gravel", with a varying finer content. This is well to the left of the effective fan axis, where finer sediments would accumulate, in any case.
- indicate the presence of only minor silty sand.
- show the water table near S.H. 6 is slightly deeper than 50m.
- suggest liquefaction is not an issue.

ii/ Anecdotal information on drilling, with SPT tests, at the Remarkables Park indicates liquefaction here was discounted by the site specific investigations. it is expected that QLDC will have this data on file.

iii/ There should be a direct correlation between the physical properties in the alluvium at Remarkables Park and the highest terrace just east of T 1 i.e. they are both part of the primary fan surface. Terraces are assumed to have a reduced liquefaction potential, while Terrace 5, known to be underlain by coarse alluvium, should have no liquefaction susceptibility. However, T.P. 5, in the southern segment, did encounter sand units to 0.6m thick; if of concern, such lenses could be defined to some extent by test pitting.

I trust the above has suitably augmented the Bryant conclusion with regard to liquefaction.

Regards

GRANT ~~GRANT~~ STALKER 4" BORE

LOWER SHOTOVER 9-9-87

TOTAL DEPTH BORE	64.850 G/L
TOP LEADER	63.540 G/L
S.W.L	50-100 G/L
SCREEN 80 SLOT	1.000
SCREEN/LEADER	1.310
TOTAL CASING USED	64.275

PUMPED AT 900 GPH

4.400 D/DOWN

BORE LOG

0.000 - 0.500	SILT
0.500 - 19.700	SILTY GRAVELS
19.700 - 21.000	SILTY SAND
21.000 - 22.600	SILTY GRAVELS
22.600 - 25.800	SILTY SAND SOME GRAVEL
25.800 - 65.000	SILTY SANDY GRAVELS

MCNEILL DRILLING

MCNEILL DRILLING CO. LTD

WATER BORE/WELL SUMMARY FORM

CLIENTS NAME: RUSSELL JONES	BORE SIZE: 125
FULL ADDRESS: LANE LADY'S HILL LOWER SHOTOVER R/TOWN	START DATE: 23 - 8 - 99
RAPID NO:	FINISH DATE: 25 - 8 - 99
GRID REFERENCE:	
DRILLER: M. SIMMONS	MACHINE: TH 60
MEASURED FROM: G/L	DRILL METHOD: TUBEX
TOTAL DEPTH BORE: 66 - 530	
TOP LEADER: 65 - 390	
SWL: 51 - 100	
SCREEN: SLOT: 100	LENGTH: 1 - 000
TYPE: STAINLESS STEEL	SIZE: 100
PVC SLOTTED: TOP:	BASE:
SCREEN/LEADER/SUMP: 1 - 140	SUMP SIZE:
TOTAL CASING USED: 65 - 740	
AIRLIFTED/PUMPED AT: 73 LPM - 960 GPH	
TEST PUMP PERIOD: 1 HOURS 30 MIN	
DRAWDOWN FROM SWL: 1 - 040	
AIR/PUMP INTAKE: 61 - 500	
BACTERIAL WATER TEST: INVERCARGILL	
CHEMICAL WATER TEST: INVERCARGILL	

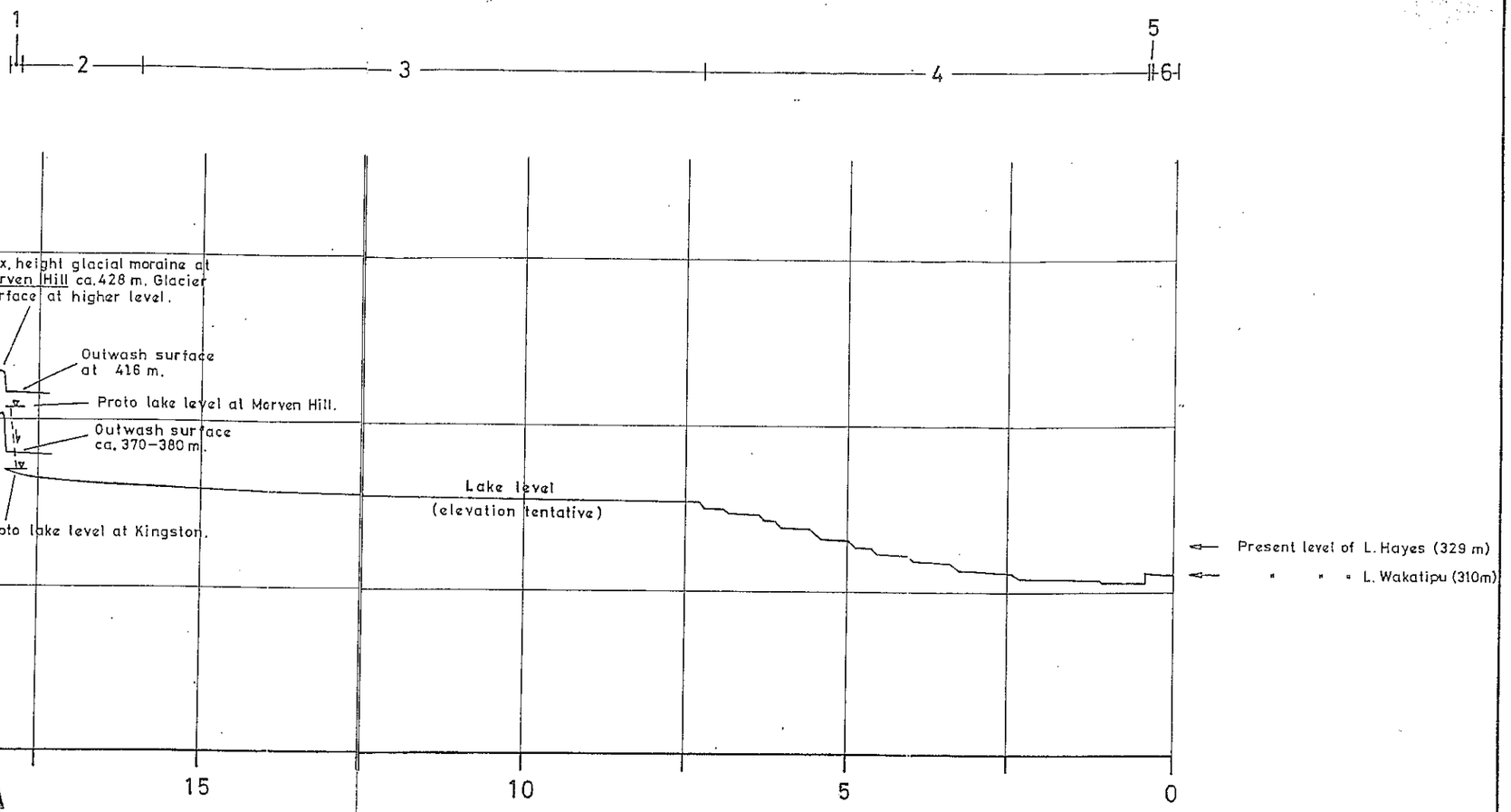
EXTRA NOTES:

BORE LOG:

00.000 - 1-100 SILTS
1-100 - 17-600 SMALL SANDY GRAVELS
17-600 - 22-100 SAND SOME GRAVELS
22-100 - 46-700 VERY SANDY SMALL GRAVELS
46-700 - 66-800 DARK GREY SANDY GRAVELS MAINLY SMALL

Phases of Lake Level Changes

(Refer text)



General Comment

Second last glacial advance culminated approx. 23,000 years BP. Ice height and lateral dimensions slightly greater than those of last advance glacier.
Post-glacial cycle of lake formation following ice retreat, progressive lake infilling with river sediment, then valley occupation by last advance glacier.

Last glacial advance reached maximum limits approximately 18,000 years BP.

Shotover Delta and other high-level deltas constructed by L. Wakatipu tributary streams formed during Phases 2 and 3.

Lake drainage switches from Mataura River to Kawarau River. Timing of catchment capture uncertain.

Prominent lakeshore terraces (e.g. Frankton township) formed during Phase 4.

Lake surface possibly as low as 305 m. Indication of small, right bank landslide blocking the right-hand and deepest channel at the Kawarau Falls outlet. Lake Wakatipu raised as a consequence. Timing of slide event uncertain.

Changes in the Level of Lake Wakatipu Since the Retreat of the Last Major Wakatipu Glacier

Drawn : R. Thomson
Checked: I. M. Turnbull
Date : Feb.'96
Scale : As shown

Figure 1

From report to ORC, Feb. '96

Original terrain had dune-like morphology. Largely now obliterated.

Irregular, dune-like terrain. Presumed aeolian deposit — fine sand with some silt (?).

LADIES MILE — STATE HIGHWAY 6

SHOTOVER RIVER

OLD SCHOOL ROAD

STALKER ROAD

Stalker Bore

Jones Bore.

Lot 1 DP 325561

Lot 2 DP 325561

Lot 3 DP 325561

Lot 4 DP 325561

Lot 5 DP 325561

Lot 6 DP 325561

Lot 7 DP 325561

Lot 101 DP 325561

Lot 1 DP 300109

Lot 2 DP 300109

Lot 1 DP 24619

Sec 92 Blk III Shotover Survey District

Sec 97 Blk III Shotover Survey District

Sec 98 Blk III Shotover Survey District

Sec 96 Blk III Shotover Survey District

Sec 99 Blk III Shotover Survey District

Pt Sec 160 Blk III Shotover Survey District

Approved Building Platform

T1

T2

T3

T4

T5

T6

Subsid. river terrace

TP1 TP2 TP3 TP4 TP5 TP6 TP7 TP8 TP9

HP1 HP2 HP3 HP4 HP5 HP6 HP7 HP8 HP9 HP10

LEGEND

HP4 Hand Pit Dec. 07

TP2 Test Pit Jan. 06

Contour information provided from Precision Aerial.

CLARK FORTUNE McDONALD & ASSOCIATES

REGISTERED LAND SURVEYORS LAND DEVELOPMENT & RESOURCE MANAGEMENT CONSULTANTS

309 Lower Shotover Road, P.O. Box 553 Queenstown
Tel. (03)442-0960, Fax (03)442-1066, Email admin@cfma.co.nz

21 Reece Crescent, P.O. Box 560, Wanaka
Tel. (03)443-4663, Fax (03)443-4665, Email admin@cfma.co.nz

Level 01, Kensington Mall, P.O. Box 5060, Dunedin
Tel. (03)470-1662, Fax (03)470-1663, Email admin@cfma.co.nz

Iss	Date	Revision Details	By	Ver	App
1	18.12.07	Investigation Plan			

Rev	Date	Revision Details	By	Ver	App
A	?? ?? ??	??			

Notes:
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SHEET 1 OF 1

Project: PLAN CHANGE

Client: LADIES MILE PARTNERSHIP

	Signed	Date
Surveyed		
Drawn ESMD		3.10.07
Designed DWR		18.12.07

Drawing Title: INVESTIGATION PLAN

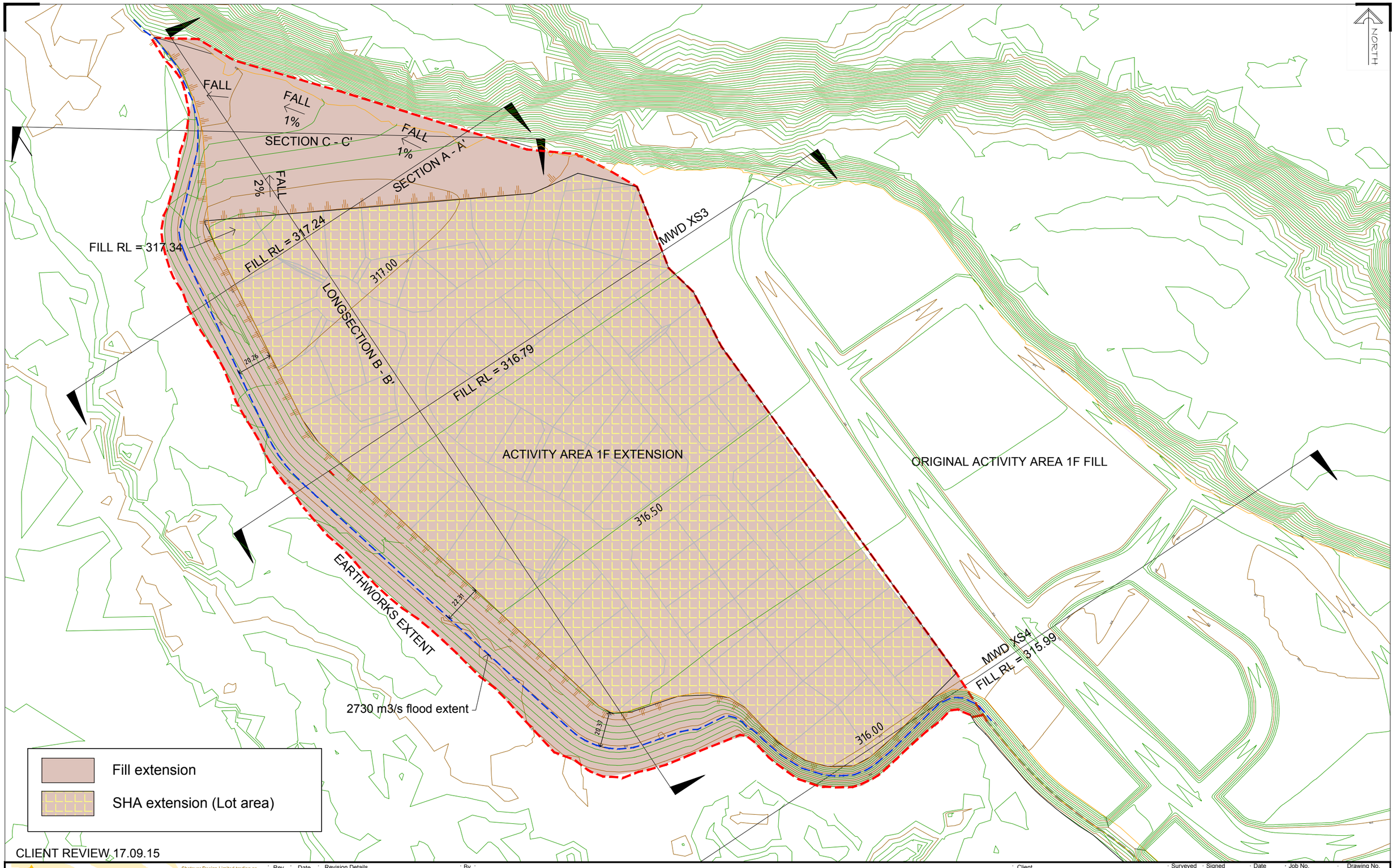
Job No.

Drawing No. Figure 2

Scale 1:3750 @ A1
1:7500 @ A3

Datum & Level

Rev.



CLIENT REVIEW 17.09.15

Shotover Design Limited trading as
Clark Fortune McDonald & Associates
Licensed Cadastral Surveyors - Land Development - Planning Consultants
309 Lower Shotover Road, P.O.Box 553 Queenstown
Tel. (03)441-6044, Fax (03)442-1066, Email admin@cfma.co.nz
Shop 2, Otago House, 475 Moray Place, P.O. Box 5960
Tel. (03)470-1582, Fax (03)470-1583, Email admin@cfma.co.nz

Rev.	Date	Revision Details	By
A	15.09.15	Change batter to 1 in 8 to provide buffer	RB

SPECIAL HOUSING AREA
FILL EXTENSION

Client: SHOTOVER COUNTRY LTD	Surveyed: -	Signed:	Date: -	Job No.: 11494	Drawing No.: 11 Sheet 001
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	Designed: -	Signed:	Date: -	Datum & Level: Mt Nic 2000 & MSL	Rev.: A

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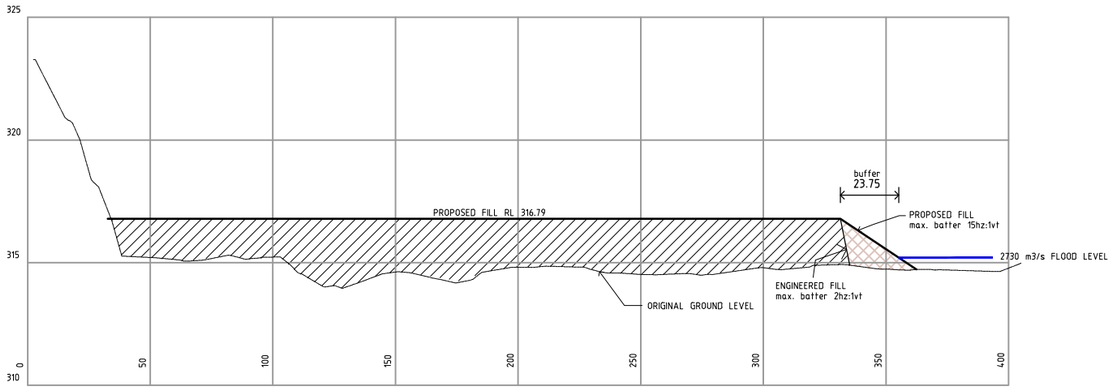

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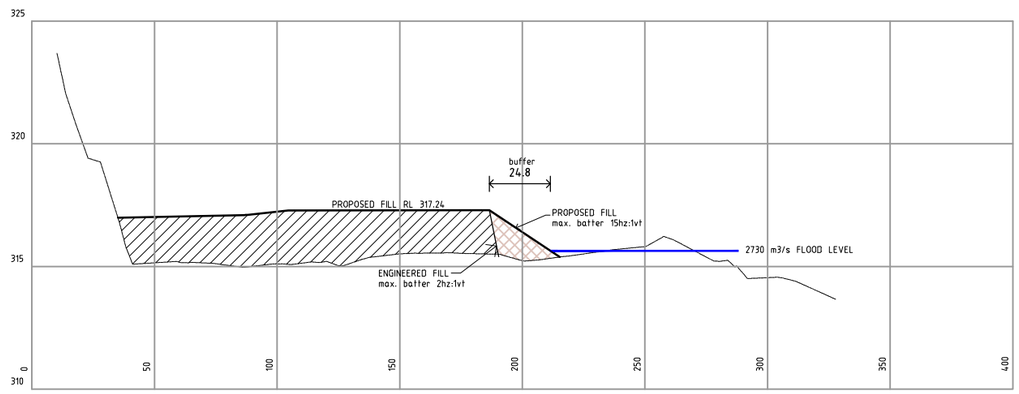

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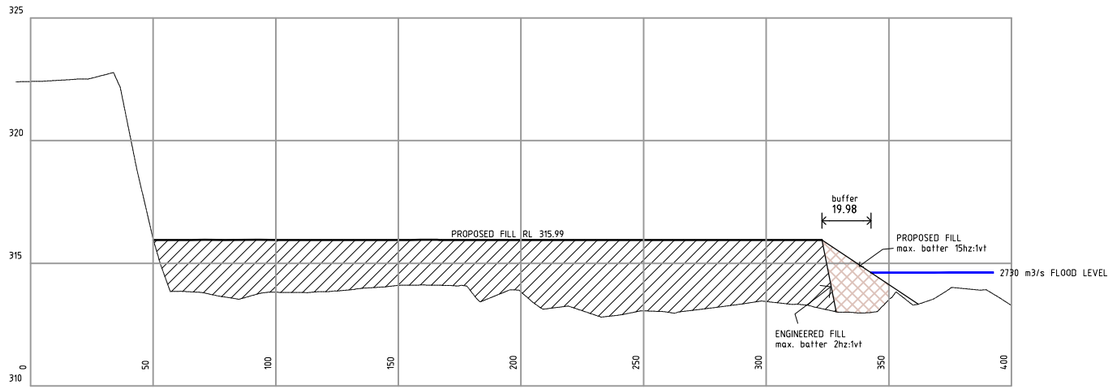
10 x VERTICAL EXAGGERATION



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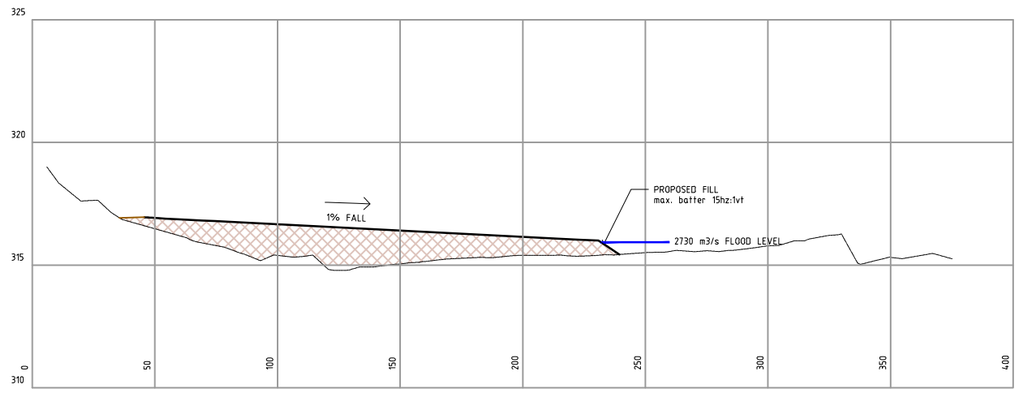

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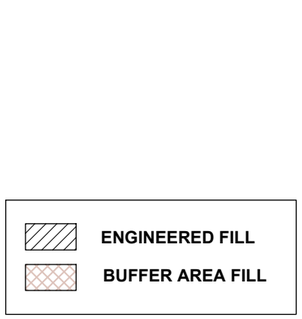

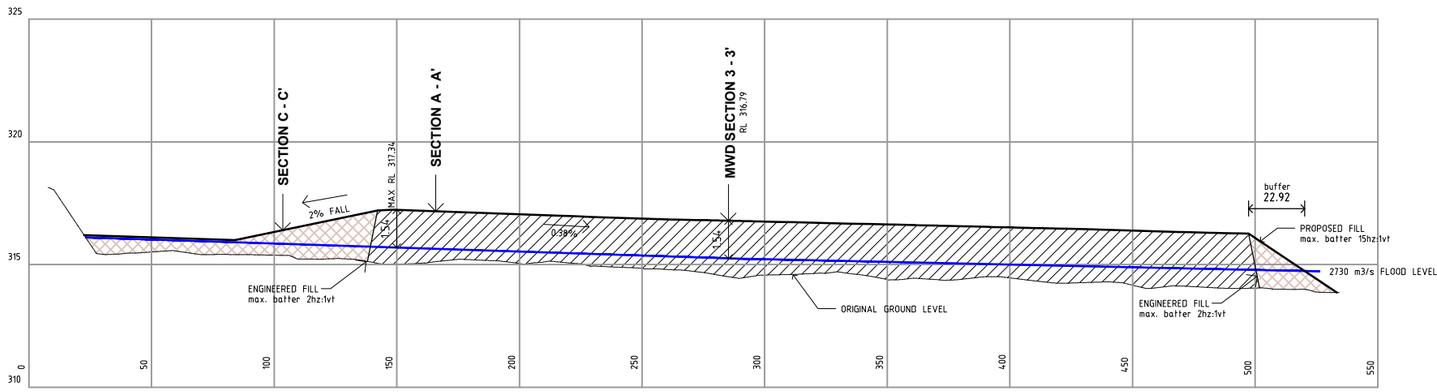

LONGSECTION B - B'

A1 SCALE: 1:1000hz 1:100 vt
A3 SCALE: 1:2000hz 1:200 vt
10 x VERTICAL EXAGGERATION

CLIENT REVIEW 17.09.15

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Rev.	Date	Revision Details	By
A	15.09.15	Change batter to 1 in 8 to provide buffer	RB

SPECIAL HOUSING AREA
FILL EXTENSION - SECTIONS

Client: SHOTOVER COUNTRY LTD

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Surveyed	Signed	Date	Job No.	Drawing No.
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Drawn	**Signed**	**Date**	**Scale**	
RWB		20.08.15	1:1250 @ A1 1:2500 @ A3	
Designed	**Signed**	**Date**	**Datum & Level**	**Rev.**
-		-	Mt Nic 2000 & MSL	A

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