



ROYDEN THOMSON, GEOLOGIST

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*The second stage was  
never requested.  
∴ it doesn't exist,  
obviously, unless  
done by T+T.*

Dear Brett

**HENLEY DOWNS: GI**



Please find below a pertinent discussion on issues perceived as relevant to your due diligence assessment. A more complete geological report will follow.

**General Geological Factors**

Rock Types

The hilly terrain west of the central valley is schist with a patchy cover of glacial till (Fig. 2). Foliation in the schist strikes approximately east-west and dips to the south at moderate angles. Schist outcrops appear competent.

In the valley there is a prominent low relief area which is mantled by variable thickness of lake sediments which have settled out of a higher level lake following flooding in the Shotover River. Note the lake outlet was to the south for a long period of time and there was little degradation in the Kingston channel (Attachment D). After catchment capture the lake dropped and there is a prominent set of beaches at various levels.

Between the valley and S.H.6 there are

- remnant glacial till deposits.
- "old" fluvio-glacial (river) sediments.
- fans at different elevations and of different ages. Lowering of lake levels generated a contemporaneous sequence of fans at decreasing levels. (Note: fans appear to be bedded 'gravel' and fine sediments, including loess.)

Hazards

Tectonic

- No evidence for surface displacement anywhere in property. Assumed no late Quaternary fault movements have occurred, as per earlier reports.
- Seismic shaking hazard and risk common to Q.L.D.C. region. Therefore not a specific site issue.

### Landslides

- No observed mass movement features on property.
- One small slide on the western lakeshore (Fig. 2) lies south of the property.

### Liquefaction

- Q.L.D.C. Hazard Map 13 depicts an elongate zone that is apparently susceptible to liquefaction along the west flank of the property. It is presumably linked to an elevated beach that is merely an erosion surface on hard, competent till. This is not susceptible to liquefaction.
- Another Q.L.D.C. designation is along Woolshed Road. It presumably refers to lake sediments that are present to the west of the road. This will be discussed further in the development area section.

### Rockfall

- No potential to impact on the site from the east as The Remarkables are too remote (Photos 1, 3) and the schist is competent.
- The terrain to the west is too benign to present rockfall hazards to proposed development areas.

### Flooding

- No prospects from the west.
- Dry gullies trend into the property from the south-east but catchments here have been truncated. No issues.
- The only stream which intrudes into the proposed development area has a bicatchment source on the face of The Remarkables. It is prone to flooding on a small scale but is largely incised into a deep to moderate channel through the areas of interest. Further comment offered below.

### Debris Flows

- No observed evidence for past events.
- The only obvious conduit with impact potential is the stream channel mentioned above. Assessed as a very low risk, moderate level hazard to only a very small segment of the proposed development area.

## Development Zones

### R1

#### a) Hazards

- The north-east tip of the zone is plotted as entering the flood channel of the one "live" stream that impacts on the site in total. Constrain the boundary slightly and this issue dissipates.

Through the farm building region the stream is well-incised and there is no potential for flooding by avulsion in the local fan area until north of the zone. Therefore, in summary, flooding is not an applied hazard under existing natural conditions.

- Liquefaction is a hazard highlighted by Q.L.D.C. for the area in general. My response is:

- a) Most of the basin encompassed by the zone is, admittedly, underlain by a significant thickness of lake sediments and in that sense the Q.L.D.C. concerns are valid.
- b) The sediments tend to be weak and test pits indicate saturation levels a few metres below the surface.
- c) Exposures to the north of the zone indicate the position of the silt base (Figure 3b, Cross Section DD').  
Silt thicknesses in the basin are likely to be significantly less than 10m and there will be an underlying coarse, clastic deposit.
- d) The primary water table is likely to be at least 10m below the silt base. (Am awaiting a log of the nearby water bore.)
- e) There is no evidence for past liquefaction in the zone. The land has not been modified and beach morphologies remain intact.
- f) Given the age of the lake deposits, they will already have undergone many cycles of severe seismic shaking. Consolidation must have occurred as a consequence.
- g) Collective inferences and observations suggest the sediments should not be now susceptible to liquefaction.

#### b) Construction and Foundation Issues

Figure 3a tentatively defines the boundary of significantly thick silt with minimal overburden. It is admitted that raised beaches comprise 'gravel' but this should not influence the outcome for the zone in general.

With minor exceptions, unique engineering solutions will be required to construct roads, install services, and prepare building platforms in R1. There will be a substantial cost to this as it is not practicable to haul-to-waste several metres of 'silt' and backfill with a well-

graded, clastic substitute. A reasonable cost estimate could be assessed from experiences with similar materials in the Jacks Point site.

## R2

### a) Hazards

- T.P.7 indicates only a thin lake sediment sequence overlying interpreted till so liquefaction should not be an issue in the west half of the zone  
There are some uncertainties with the area near T.P.6, however, as the latter intersected weak, saturated, fine-grained sediments of unknown thickness. Further investigations required, perhaps
- Flooding is prospective in the north-east corner of the zone as the stream channel, east of T.P.6, is only incised about 1.5m below the flanking terrace margin.  
Require some bunding in this area.

### b) Construction and Foundation Issues

The only obvious concern relates to the wet area near T.P.6 which links to a streambank spring just to the north.

Drainage necessary for sites at this location.

## R3

### a) Hazards

Liquefaction is a potential problem as the western half of the zone will have several metres of the lake sediment near the surface. Further east the 'silts' should be thin and interbedded with clastic units. As for R1, I haven't seen any evidence for liquefaction and I don't anticipate the phenomenon will occur here in the future.

### b) Construction and Foundation Issues

Unique engineering solutions will be required, at least in the western half where 'silts' are prevalent. Test pitting in the central section is recommended to establish boundaries for the surficial deposits.

## R4

### a) Hazards

Most of the zone occupies elevated terrain which incorporates fluvio-glacial deposits with a glacial till cap. No perceived hazards in this region.

However, the northern tip extends down onto the floodplain/stream bed of the single "live" waterway in the area of interest. If occupancy is desired here then significant earthworks will be required to mitigate the groundwater/surface flow problems and flooding potential.

### b) Construction and Foundation Issues

Apart from the northern tip of the zone, all roads and platforms are expected to be on dry, stable materials in areas of low to moderate relief.

## Village

### a) Hazards

Approximately 50% of the zone is occupied by a proud knob that is clearly a glacial till remnant, but the low relief slopes to the north and east of the knob will be underlain by beach deposits and lake sediments of varying thicknesses.

While liquefaction is a potential hazard in the latter segment there is no clear evidence for past occurrences (note a single closed depression – Photos 8/9) and the risk is therefore very low.

### b) Construction and Foundation Issues

As for other areas underlain by lake sediments, there will be engineering issues in relation to roading and platform foundations. The affected area can be approximately defined by test pitting using predetermined criteria for strength parameters and stripping potential.

## Material Sources

### Building Stone

Schist forms most of the exposure west of the development area. A reconnaissance of the lower to mid relief schist outcrops indicates that the foliation surfaces tend to be warped, it is poorly fissile, and joints are very widely spaced. In my view, such outcrops are not suitable for the production of good quality construction materials.

However, to the west and north-west of the north end of Zone R1 the schist foliation tends planar and there is a moderate fissility. If this material is suitable for masonry purposes it may be appropriate to develop a quarry in the gully further to the west, essentially on strike from the more visible outcrops.

### Roading Aggregate

The only prospective area is within the undulating terrain between the central valley and S.H.6 and south of the 'live' creek. Here glacial till caps fluvioglacial sediments. An indication of material types can be viewed in an old borrow pit 400m south-east of the site office; bedded river alluvium is present.

Unfortunately, the region is earmarked for development purposes so any borrow operation would have to be balanced against modifications to the terrain in the short term and implications for layout in the longer term. Clearly an economic decision required here; your call, in reality.

## Conclusions and Recommendations

- a) Roading aggregate resources are limited to the small region of elevated terrain between the site office and S.H.6. Potential interference with proposed development suggests a borrow operation is unlikely to proceed.
- b) Extensive areas of schist are present in the west half of the property. Most outcrops have undulating foliation, poor fissility and very widely spaced jointing but an area displaying planar foliation and moderate fissility north-west of Zone R1 may be prospective for

building stone. I suggest an initial prospect with an excavator followed by the selection of a suitable quarry site, should the rock quality be acceptable.

- c) Extensive areas in the central valley are underlain by lake sediments. While liquefaction is probably a non-issue, they will cause engineering complications in Zones R1, R2 and the Village.

A refinement of the sediment extent, depths and characteristics should be undertaken to assess implications and incremental costs for development.

- d) Flooding is a prospective issue at the northern tip of R4 (as currently proposed) and the north-east corner of R2. The latter is also effected by saturated ground.

Flood mitigation and drainage works need to be considered here.

I trust the above discussion has addressed all pertinent issues in the sense that they have been raised, but not necessarily resolved. Lake sediments have the greatest adverse impact with consequential incremental costs in providing engineering solutions.

Regards

A handwritten signature in cursive script, appearing to read "Raydon".

## ATTACHMENT A

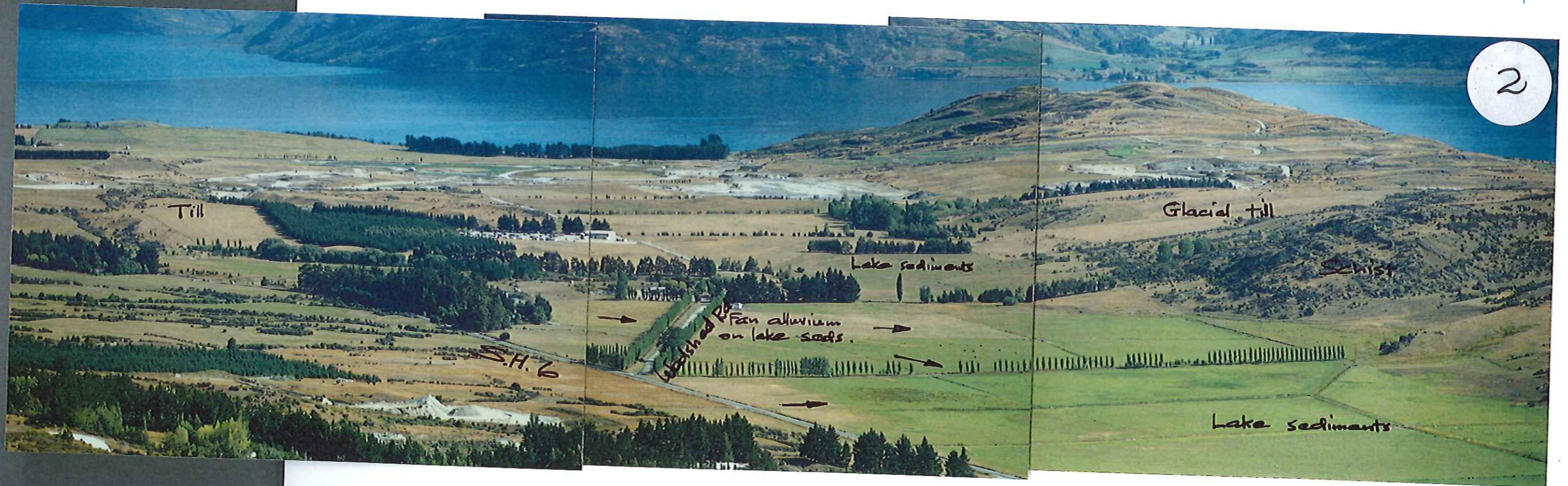
Captions for miscellaneous photos of the site. Those illustrating valley floor features in detail are located on Figure 3a

| Photo Nbr. | Description  |
|------------|--|
| 1          | General view of property from the north-east.<br>Proposed development areas are in the central valley at photo centre. Stream catchments are all to the east, draining off The Remarkables, at left.   |
| 2          | Annotated photo of the valley floor through the interest area. Lower relief areas are mantled by fine lake sediments or relatively young fans.   |
| 3          | General view of property and surrounds from Precipice Hill.  |
| 4          | North flank of the prominent, transverse ridge in the north-west corner of the property (Figure 2). In situ schist is capped by glacial till.  |
| 5          | The proposed development occupies a band across the full width of the photo, including the pine tree plantation at left. Most of the terrain has a low relief.   |
| 6          | Axial valley region that spans parts of R1, R3 and the Village development zones.<br>Lakeshore beaches are prominent features and the smooth terrain is mostly underlain by fine grained lake sediments, of varying thicknesses.<br>Test pit locations are circled.  |
| 7          | Coverage of parts of R2, R3 and R4 zones. The stream channel left of centre lies to the north of proposed development areas.   |
| 8          | Low relief terrain just east of the pond. View to the south.<br>Beach morphologies are subtly preserved and explanations for other features are offered. Present at Test Pit 2 is a 0.3m thick soil over 3.1m thick, bedded lake sediments that in turn cap coarse, clastic detritus; assumed alluvium or ablation till. |
| 9          | View north across the same terrain as illustrated by Photo 8.<br>Beaches form the intermediate distance skyline.   |
| 10         | Beach-type morphology in the southern part of the R1 zone.<br>It is evident that beach structures comprise poorly graded 'gravel' but this is merely a veneer on several metres of fine lake sediment.   |
| 11         | Reverse view to Photo 10, largely within the R1 zone.  |
| 12a, b     | Looking east across the R1 zone in the foreground and the R2 zone at rear in Photo 12b.<br>Storm beaches are subtle but prominent. Interbeach areas, and the low flat paddock at left (12b), have no significant clastic detritus on the lake sediments, however.  |









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