Geotechnical Hazards – Preliminary Assessment

Proposed Mt Cardrona Station Private Plan Change

Report prepared for:

Brown and Company Planning Group

Report prepared by:

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1 Introduction

This report presents the results of an assessment and historic site investigations carried out by GeoSolve Ltd in the context of a proposed private plan change to incorporate a golf course to the proposed development. The objective is to assess the suitability of the subject area, in terms of geotechnical hazards, for the proposed plan change and new development.

2 Site Description

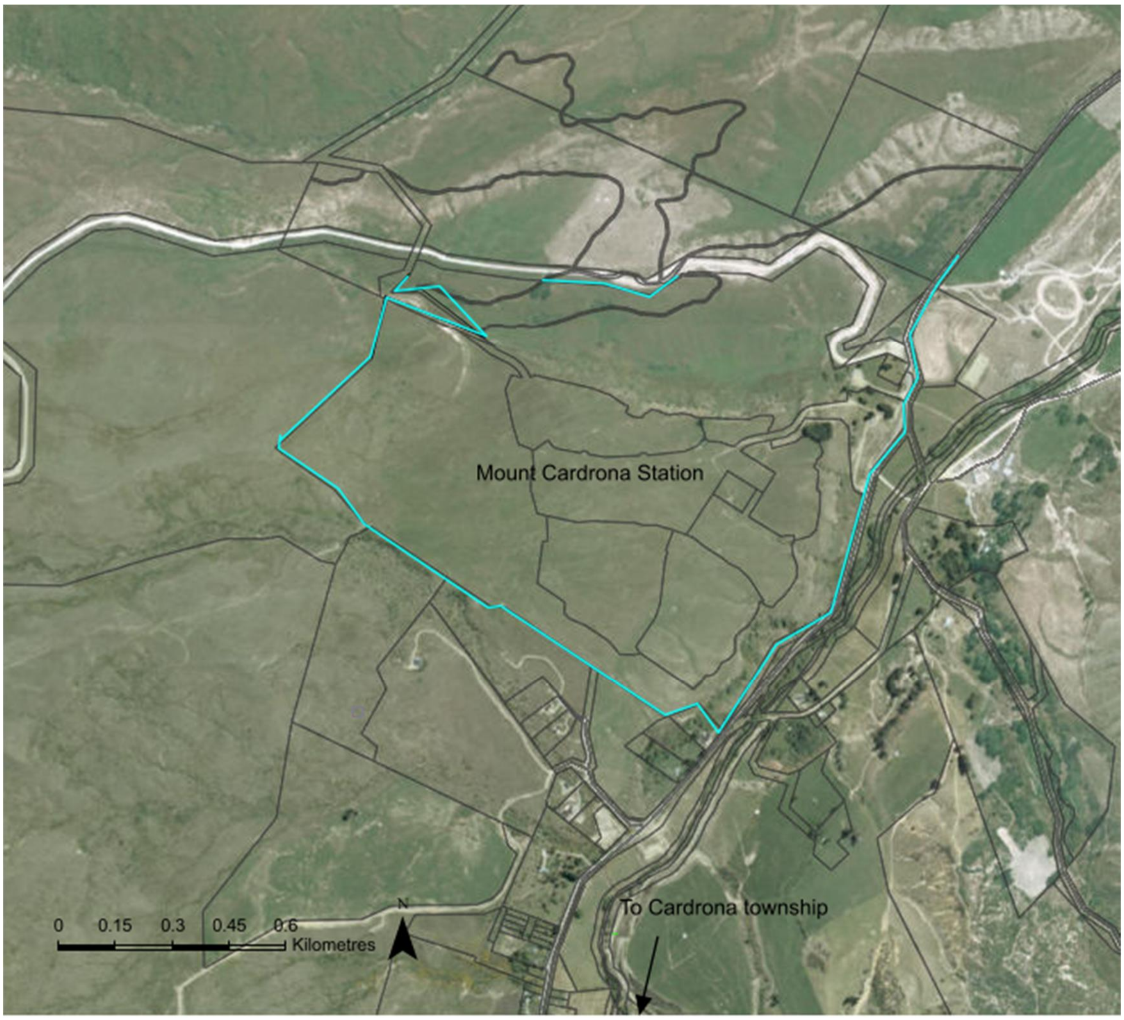

Figure 1: Locality Plan

The property is located on the western side of Cardrona Valley Rd (Figure 1), south of the existing Cardrona Skifield access road.

Access to the site is off the Cardrona Valley Road. Several structures currently exist in the eastern extents of the site, including remnants of the site's only farmhouse, sheds and a wool shed.

The site is covered in grassed paddocks and sparse scrub and trees. The Cardrona Skifield access runs beyond the northeast corner of the site. Several farm tracks and a driveway to the farmhouse site also exist.

The site has a predominantly easterly aspect.

2.1 Topography and Surface Drainage

The site has been surveyed and topographic contours are shown in Appendix A.

The site topography can be generalised as a gently sloping (~5-10°) alluvial fan surface.

Upslope and west of the main fan surface is a pronounced increase in gradient (slopes of up to 25°) which coincides roughly with the alignment of the Cardrona Water Race. This escarpment is considered to be a geomorphological expression of the NW Cardrona Fault Zone. A second water race (Little's Water Race) follows the approximate level of the 610 m contour and bisects the terrace surface.

The alluvial fan surface has been offset by the NW Cardrona Fault Zone, and upslope of the escarpment has a similar orientation and slope as the fan surface below. A minor ephemeral creek dissects the upper escarpment, and is directed down the escarpment and over the lower terrace surface (swampy in places) before joining with a small creek.

The southwest margin of the site area is aligned with part of Pringles Creek, a major watercourse that has caused considerable incision of the terrace surface. The valley slopes of Pringles Creek are moderate to steep (up to 35°).

The eastern boundary of the site area adjoins Cardrona Valley Road and corresponds to a steep slope (~35°) that represents an erosional terrace edge formed by the Cardrona River. This has subsequently been partially modified by quarrying activity adjacent to Cardrona Valley Road.

The development area (as shown in Figure 1, Appendix A) is a gently sloping alluvial fan surface that is relatively unmodified by incision. It is essentially a planar topographical feature that slopes at a gentle grade (~5-10°) to the east with minor undulations resulting from eastward flowing ephemeral drainage paths. These would be expected to act as overland flow paths only during periods of extended heavy rainfall.

The fan surface has been incised by two significant creeks beyond the site proximity. North of the site Homestead Creek flows in a west to east direction. In its lower reaches constitutes a sub-horizontal, swampy valley floor with a slight inclination towards the east. The upper reaches of the creek have an increased gradient and some flow was observed. Homestead Creek has caused incision of the alluvial fan terrace and the resulting valley sides slope at around 20° adjacent to the northern boundary of the development area. Similarly, Pringles Creek has incised the fan surface towards the southwest of the site.

3 Site Investigation Data

3.1 Site Investigations

Sufficient subsurface investigations have been undertaken to ascertain the required information for the purposes of the plan change report.

Site investigations have included the excavation of twenty-nine test pits to a maximum depth of 5 m. A number of these test pits cover the proposed development area.

An engineering geological appraisal has also been undertaken to assess geomorphology and surface conditions. Geomorphological mapping was completed, including outcrop mapping of the exposed soil materials (see Figure 2, Appendix A).

Scala penetrometer tests were undertaken to determine strength parameters for the subsurface soils. Test results are contained in Appendix B.

Locations of test pits are shown in Figure 1, Appendix A. All test pit logs are contained in Appendix B.

We understand that the Otago Regional Council has previously raised concerns about hazards associated with the Pringles Creek catchment and the Nevis Cardrona Fault Zone, and that these aspects have been investigated independently by Royden Thomson, Geologist (Appendix C).

3.2 Geological Setting

The regional basement rock comprises the ice-scoured Haast Schist Group. Sedimentary cover consists of Early Quaternary outwash gravels overlain by alluvial fan deposits. More recent alluvial sediments have been deposited from the Cardrona River and smaller local watercourses. The alluvial deposits have been eroded and deposited during post-glacial times.

Published geological maps show the Nevis-Cardrona Fault in close proximity to the west of the site but it does not traverse the plan change area. This fault is considered to be positioned upslope of the water race. The Nevis-Cardrona Fault is a major active fault system with a reverse sense of movement and a 5,000-10,000 year recurrence interval. The date of the most recent surface rupture has not been established but field investigations found no evidence to suggest any recent movement locally. A report by Mr Royden Thomson (Geologist) also found no evidence that the alluvial fan has been tectonically deformed since its formation (assessed as 23,000 years before present).

A more significant seismic risk exists in this district from potentially strong ground shaking, likely to be associated with a rupture of the Alpine Fault, located along the West Coast of the South Island.

There is a high probability that an earthquake with an expected magnitude of over 7.5 will occur along the Alpine Fault within the next 50 years, which will subject the site area to strong, prolonged ground shaking.

3.3 Stratigraphy

The plan change area is situated on a large alluvial fan surface with only minor modification to the existing morphology by ephemeral stream activity. Consequently, alluvial deposits dominate the subsurface in this area with overlying surficial topsoil and loess.

The topsoil comprises soft brown organic silt.

The loess comprises firm silt with some loose fine sand. Loess was typically observed to depths no greater than 0.5 m, however in one location loess was observed to 1.1 m indicating that pockets of deeper loess may be locally present on the terrace.

The alluvial fan deposits are typical of such environments of deposition and comprise interbedded fine and coarse-grained alluvium. The following soil types are represented within the interbedded sequence:

Alluvial silt and sand – firm to very stiff silt with rare to some clay, silt with minor gravel and gravelly pockets, firm to stiff/loose to medium dense silty fine sand, gravelly silt with minor sand, sandy silt, etc.

Alluvial gravel – medium dense to dense sandy gravel with cobbles and boulders, silty gravel with minor cobbles, dense large boulders in a silt matrix with lenses of silty gravels, etc.

Additional stratigraphic data was obtained from engineering geological mapping. A gravel quarry situated on the eroded margins of the alluvial fan northeast of the Golf Course Villas observed sandy, fine to coarse gravel with minor silt and rare boulders composed of angular to sub-angular schist and quartz.

Further detailed description of the alluvial fan deposits can be obtained in the test pit logs contained in Appendix B.

3.4 Groundwater

Test pits observed that the alluvial terrace deposits are generally in a moist condition with no seepage (i.e. percolation of water through soil).

Some seepage was noted on the ground surface and in test pits (TP 26 & 27), excavated near the base of the upper escarpment. Seepage is occurring on the face of the escarpment and is probably related to the proximity of the Nevis-Cardrona Fault.

The static watertable is likely to be at depth (15 m+) in the development area. However, local surface seepages have been observed as above.

4 Natural Hazard Assessment

4.1 General

Current QLDC and ORC mapping identifies alluvial fan hazard and active faulting hazards within and near the proposed site area (Figure 3, Appendix A). Detailed geological mapping has also identified shallow landslide and mining hazards in the site area (Figure 2, Appendix A).

Owing to the terrain and the site location, it is appropriate to assess for a range of geotechnical hazards including landslide, liquefaction, erosion, debris flow, and flooding.

A site inspection and mapping was undertaken with relevant features observed and mapped (Figure 2, Appendix A).

4.2 Alluvial Fan Flooding and Debris Flow Hazards

Watercourses run either side of the site, Pringles Creek to the south and the smaller Homestead Creek to the north, with catchment areas of 435 ha and 86 ha and estimated (NIWA) 100-year flows of 4.6 m^3/s and 1.8 m^3/s respectively. Two small artificial water races traverse the upper site, flowing from north to south.

The modern watercourses are well incised, with the site generally elevated by at least 5 to 10 m above the streambeds. The channels are hydraulically steep and it is estimated that Pringles Creek can convey its 100 year flow at a typical depth of about 1 m. Thus, it is clear that there is negligible probability of storm runoff alone causing flooding onto the site from these streams. However, the possibility must be addressed of debris events causing channel avulsion, which might direct floodwater and debris onto the site. The site is shown as 'stabilised/isolated' and 'inactive' alluvial fan in ORC/QLDC hazard mapping. This classification is supported by observed alluvial fan deposits underlying most of the site; these are ancient as indicated by overlying horizons of loess and topsoil.

Royden Thomson, Geologist (June 2006 report attached as Appendix C) has undertaken a comprehensive geological and hydrological investigation into this site with particular reference to alluvial fan hazards including debris flow. Thomson concluded that the fan surface has last experienced alluvial activity approximately 23,000 years ago under a substantially different geological setting than that of today. Thomson notes *"…the major 1999 storm event had no significant influence on the active channel and no impact at all… downstream from the Skifield Road crossing. It can be assumed, therefore, that… no debris flows were generated… existing landslides are not particularly susceptible…* "

Thomson also references an ORC assessment (April 2006) which involved modelling of a dam break scenario for a proposed snow making pond associated with the Cardrona Skifield in the upstream catchment. Based on the ORC results and his own interpretation, Thomson concludes that in this vicinity: "*A worst case scenario would generate a maximum flood/debris flow level 2m above the channel thalweg… When the overall channel dimensions are considered this is a negligible impact… No incursion onto the flood plain is depicted… The risk of channel overtopping and stream avulsion on the left bank is considered to be effectively zero…*"

Thomson's work is considered thorough and his conclusions robust, therefore our position is that there is negligible risk to the site from flooding and debris flow.

Small seepages and locally sourced runoff may affect the site; these will be minor and easily addressed with local drainage arrangements.

4.3 Landslide Hazards

Geological mapping has identified active landslides on steeper slopes north and south of Homestead Creek and on the face of the upper escarpment west of the proposed development area (see Figure 2, Appendix A).

These are considered to be slowly creeping slides, probably developed in underlying Early Quaternary Gravels. Movement appears to be associated with groundwater seepages.

It is recommended that development be avoided in these areas, and that detailed landslide investigations be carried out for any proposed developments in their immediate vicinity.

4.4 Seismic Hazard – Active Fault

This issue has been addressed in detail in a report by Royden Thomson (Appendix C).

A north/south trending active fault scarp associated with the Northwest Cardrona Fault has been identified crossing the upper escarpment west of the proposed development area (see Thomson, Figure 3a, Appendix C). It has undergone multiple phases of movement in the past 140,000 years, and has an uncertain relationship with the Northwest Cardrona Fault. The timing of the last movement is unknown.

The average return period on the NW Cardrona Fault is in the range of 5,000-10,000 years. It is recommended that development be avoided in the immediate vicinity of the fault scarp shown on the Thomson Figure 3a, Appendix C.

4.5 Liquefaction

Seismic liquefaction occurs when excess pore pressures are generated in loose, saturated, generally cohesionless soil during earthquake shaking, causing the soil to undergo a partial to complete loss of shear strength. Such a loss of shear strength can result in settlement and/or horizontal movement (lateral spreading) of the soil mass. The occurrence of liquefaction is dependent on several factors, including the intensity and duration of ground shaking, soil density, particle size distribution, and elevation of the groundwater table.

Within this site, the potential for liquefaction under seismic shaking is considered relatively low. The vulnerable combination of fine grained sandy/silty soils with a shallow groundwater table is unlikely to be extensive within the development area. The low liquefaction risk is due to the combination of a deep static water table and coarse granular deposits associated with the alluvial fan deposits.

Investigations to confirm soil type and groundwater depths will be required at detailed design phase to assess foundation options.

4.6 Historic Mining Activity

A gold mining tunnel hosted by Early Quaternary Gravel was observed northeast of the Golf Course Villas (see Figure 2, Appendix A). There is a possibility that further tunnels are present as the interface between the Early Quaternary Gravel and the overlying alluvial fan deposits was a widely targeted gold-bearing horizon during the gold rush era. The tunnels are however likely to be of limited length (perhaps 10 m maximum) and restricted to the incised margins of the fan deposits. Tunnels are therefore not expected to present any geotechnical concerns for the plan change area (subject to localised verification and checking of final plans).

The mining tunnel east of the Golf Course Villas will need to be traced to confirm its extent (including any drives that feed from it). If construction is proposed in the tunnel the area it should be backfilled to the required foundation level using suitable engineered fill placed in accordance with NZS 4431:1989.

4.7 Groundwater and Surface Drainage

Good natural drainage of the development area is expected and no major remedial drainage measures are expected. If future development extends to the vicinity of the upper escarpment drainage will be required.

If groundwater or springs are identified during construction, then subsoil drainage or similar remediation will be required.

Flow within ephemeral watercourses in the development area is expected in times of high rainfall and consequently cut off drains upslope of the development is recommended.

5 Conclusions and Recommendations

Based on this preliminary assessment, the majority of the site is considered to be acceptably safe from geotechnical hazards. A minor level of geotechnical hazard may be present at isolated locations within the proposed development area, and site-specific investigation will be required to assess building platform locations. However, we consider that the extent and degree of any such hazards will be minor, such that they can be readily mitigated by standard planning and engineering measures.

We conclude that, from a natural hazards perspective, the area is suitable for the proposed land use; noting that site-specific assessments will be required and localised mitigation measures may be necessary.

6 Applicability

This report has been prepared for the benefit of Brown and Company Planning Group with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Further geotechnical investigations and reporting will be required at the detailed design phase after development plans are completed.

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Reviewed for GeoSolve Ltd by:

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Appendix A: Site Plans

- Figure 1 – Site Investigation Plan
- Figure 2 – Geological Site Plan
- Figure 3 – QLDC Hazard Map
- Figure 4 – Aerial Site Plan
- Figure 5 and 6 – Site Photos

Key

= Test Pit location

= Scala Penetrometer location

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Geotechnical Assessment

Mt Cardrona Station Plan Change

Site Investigation Plan

FIG No. Appendix A - Figure 1

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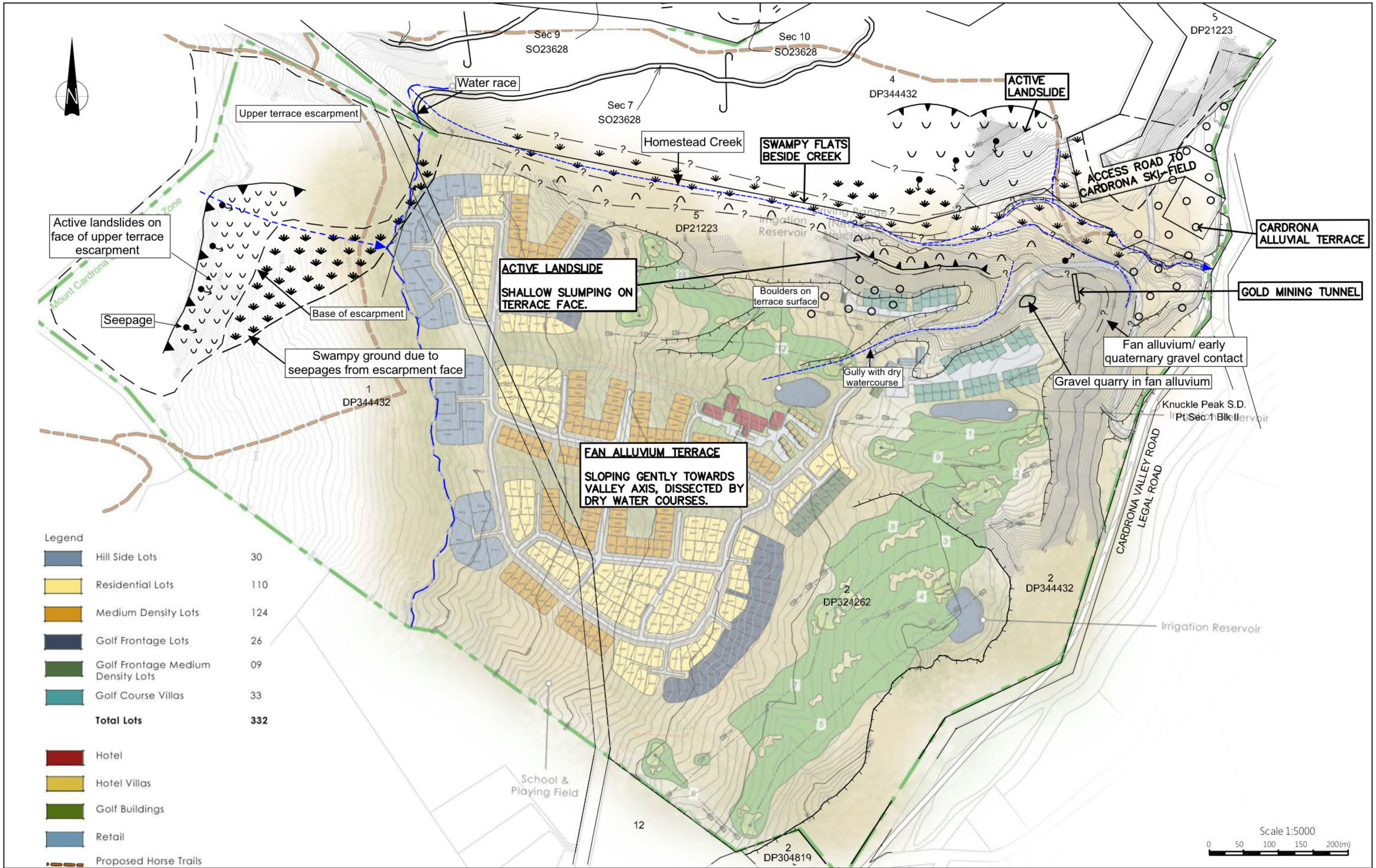

Key

= Landslide scarp

= Landslide area

= Swampy area

= Seepages

—?— = Fan alluvium/ early quaternary gravel contact

= Boulders

= Stream

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Geological Site Plan

FIG No. Appendix A - Figure 2

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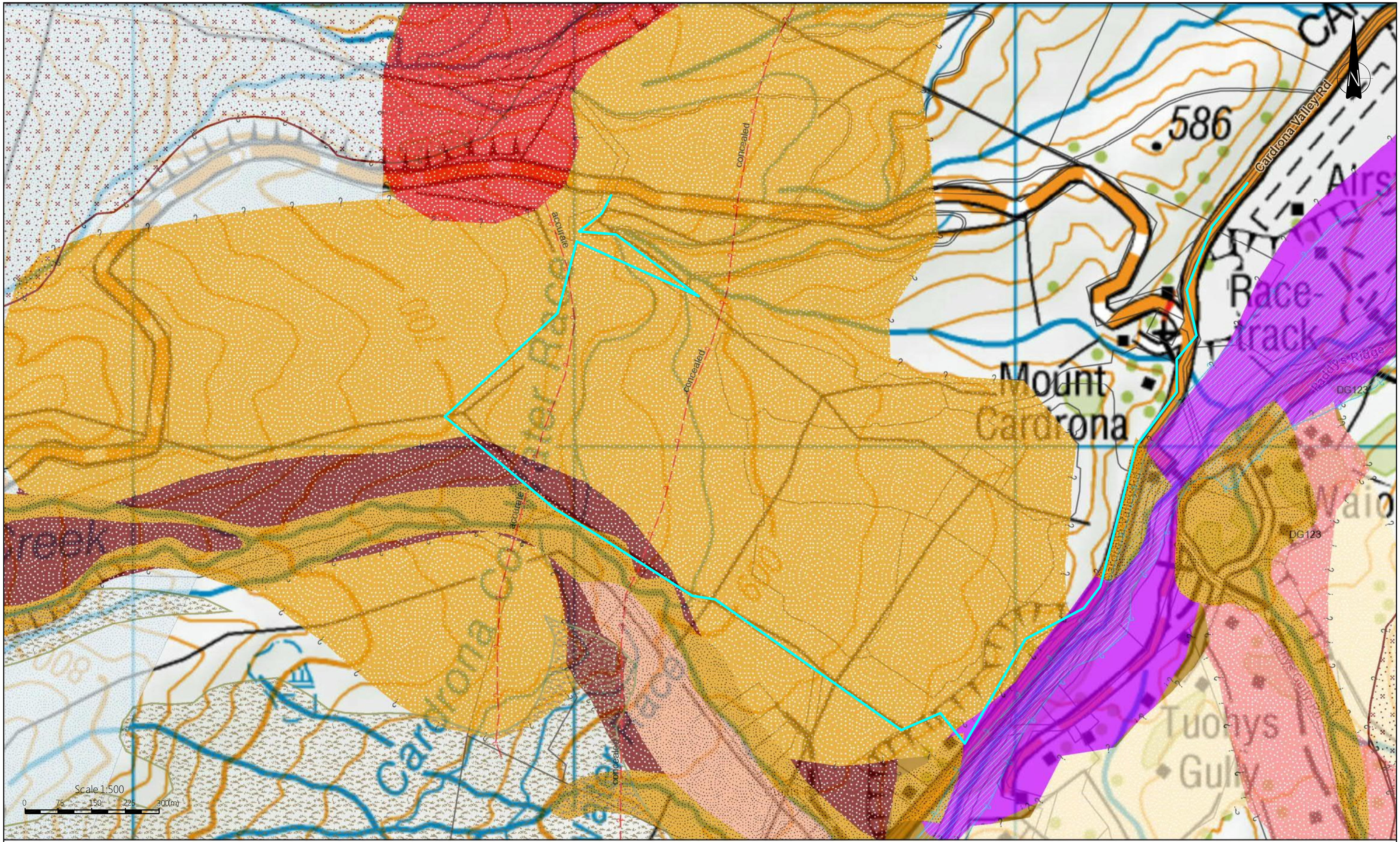

Key

= Active Fault - Location Approximate

= Alluvial Fan, Inactive Composite (Regional Scale)

= Alluvial Fan, Active Composite (Regional Scale)

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QLDC Hazard Map

FIG No. Appendix A- Figure 3

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Aerial Site Plan

FIG No. Appendix A - Figure 4

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Figure 5 - Site Photo

Figure 6 - Site Photo

Appendix B: Test Pit Logs and Scala Penetrometer Logs

Appendix C: Royden Thomson's Geological Hazard Report