Appendix I:

Geotechnical Investigation

GeoSolve Limited

GEOSOLVE

GEOTECHNICAL

WATER RESOURCES

PAVEMENTS

Geotechnical Investigation – Shannon Farm Private Plan Change

144 Ripponvale Road,

Cromwell

Report prepared for:

New Zealand Cherry Corp (Leyser) LP Ltd

Report prepared by:

GeoSolve Limited

Distribution:

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Town Planning Group (NZ) Ltd

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5	23/05/19	Client Revision Change	ELH	GAS

GEOTECHNICAL WATER RESOURCES PAVEMENTS

Contents

1 Introduction

1.1 General

As per your request we have undertaken a geotechnical assessment at the above property to support an application for a private plan change to be made to the Central Otago District Council.

Our investigation has comprised a site inspection, review of existing geological, geotechnical and natural hazard data and desktop review of 3D imagery and geomorphology at 144 Ripponvale Road, Cromwell. This report is intended to assist preliminary master planning in support of the new zone that seeks to enable a greater density of rural-residential development over the property.

More detailed geotechnical assessment for specific design will be required as part of future resource consent applications under the new zone framework and at the building consent stage.

Photo 1 – Property Boundary at 144 Ripponvale Road, Cromwell

2 Site Description

2.1 General

The property is located off Ripponvale Road, which is situated northwest of central Cromwell, as shown in Figure 1 below.

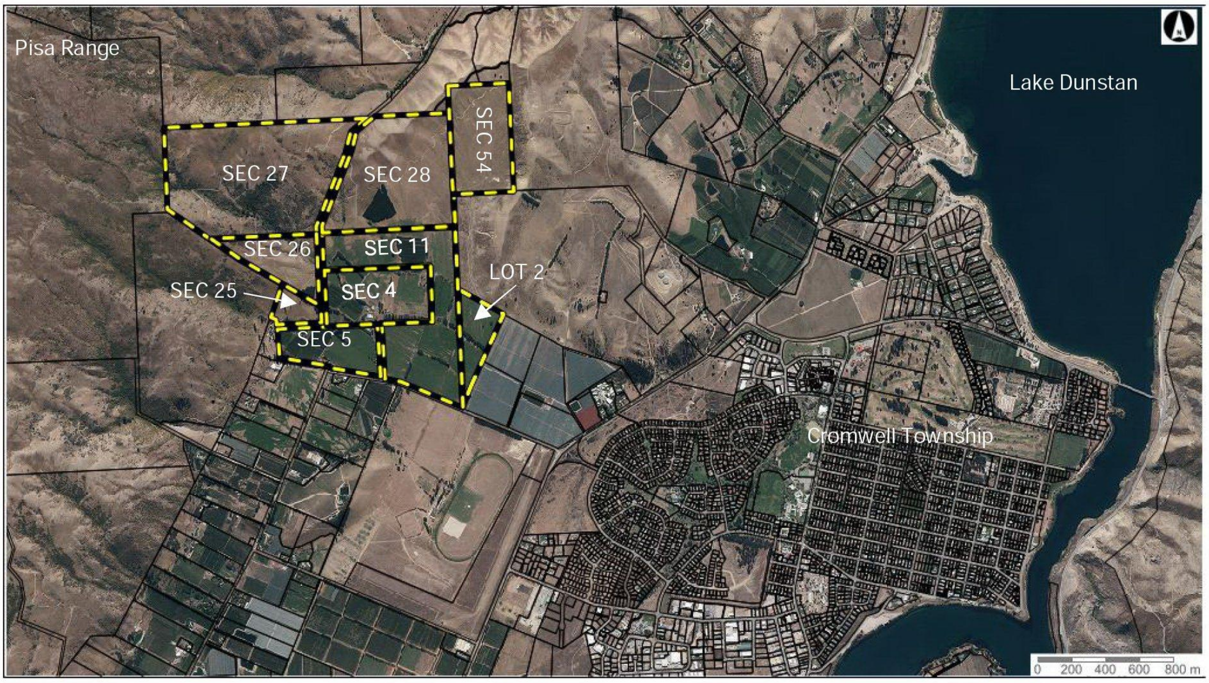

Figure 1 – Site location plan

It is accessed from Ripponvale Road and lies at the base of the foothills of the Pisa Range. It consists of nine legal properties including SEC 4, 5, 11, 25, 26, 27, 28, 54 of BLK III CROMWELL SD and LOT 2 DP 330709 as shown in Figure 1 above.

The site is currently a working farm with a range of farm buildings located on SEC 4 and SEC 5. There are orchards including apricot, pear and nectarines located on SEC, SEC 4, SEC 11 and SEC 25. Small forestry blocks of pine are located in SEC 28 and SEC 26 while the rest of the property is working farmland. Vegetation comprises pasture, trees and scrub.

The property is bounded to the south by Ripponvale Road. Farmland blocks lie to the north, west and northeast, with some cherry orchards bounding the southern end of the property to the east.

2.2 Proposed Development

We understand that the proposed zoning will enable rural residential development over much of the lower reaches of the property, as shown in the proposed Structure Plan shown in Appendix A, Figure 3.

No earthworks are proposed at this stage, as part of the zone change request. We expect that cut and engineered fill will be required as part of the earthworks design at the time of subdivision and development, should the zone request be successful and subsequent consents applied for.

The plan change request requires geotechnical assessment of the site to assess suitability for future development and to identify any geotechnical issues.

2.3 Topography and Surface Drainage

The southern part of the property, including the area of the existing buildings, is gently sloping (see Photo 1). Slopes increase from moderate to steep in the north and west.

Three large gullies are located within the site, here termed the western, northern and eastern. A small stream runs down the steep western gully, with the sides vegetated by scrub and trees. The northern gully has no active stream, with less vegetation then the western. The eastern gully is moderately to gently sloping with predominantly grass cover.

In addition, there is a series of moderate -steep minor gullies on the grassed eastern and western facing slopes of an Early Quaternary Gravel terrace at the northern end of the site.

Several water races run through the property, some of which are still actively used, while others such as the Early Settler's race are not currently in use. Blowouts in the water races have eroded a series of dry watercourses.

2.4 Geological Setting

The site is located at the southwestern end of the Upper Clutha Valley. Bedrock in the area is Haast Schist, which forms the Pisa Range to the west and underlies the site at depth.

In the Cromwell Basin the schist is overlain by Manuherikia Group fluvial and lake sediments and the Early Quaternary gravels. Prominent terraces of Pleistocene glacial outwash gravels overlie the older formations.

Extensive landslides developed during the Pleistocene on the schist slopes of the Pisa Range. Surficial deposits of post-glacial loess commonly blanket the ground surface in the region.

The active Pisa Fault is located at the foot of the Pisa Range which runs along the western extent of the property. However, due to the estimated 10,000-20,000 years average return period for earthquakes on this fault, the seismic risk is considered low. The Alpine Fault, located approximately 120 km to the northwest, runs along the western foothills of the Southern Alps, and is likely to present a more significant seismic risk. There is a high probability that a major earthquake of Mw 8 or more will occur along the Alpine Fault within the next 50 years, and such a rupture is likely to result in strong and prolonged ground shaking in the vicinity of Cromwell.

3 Groundwater

A water bore on the property (ORC - F41/0247) found the water table at a depth of 33.83 metres. This substantial depth is expected to be typical, hence discounting any mechanism for widespread liquefaction. A small seepage observed in the western gully is discussed in Section 3.2.1. The soils observed in southern areas of the property in small dig outs were predominantly moist in condition, likely attributed to irrigation and recent rainfall. There are several water races on the property and two irrigation ponds, one of which is fed by intermittent flows from the western gully.

4 Natural Hazard Desktop Assessment

4.1 ORC Hazard Mapping

A review of the ORC hazard mapping was carried out as part of the desktop study prior to the field assessment.

4.1.1 Regional Scale Alluvial Fans

As indicated in Appendix B, Figure 1, the regional mapping indicates that there are 'active debris-dominated' and 'active floodwater-dominated' alluvial fans within the property bounds. These are confined to the lower section of the property, where slopes are largely sub-horizontal with areas towards the far eastern bounds gently inclined.

4.1.2 Alluvial Fans – Fan Landform

The existing fan mapping from the ORC database as seen Appendix B, Figure 2, shows several fan landforms within the boundaries of the property. The northern extent is mapped as 'catchment gully erosion' in two gullies, identified in field mapping; with the area surrounding as 'catchment unspecified', a default term for areas not studied in detail. The eastern gully is mapped as a 'fan less recently active' which is described as areas with stream activity >300 years. The southern extent is mapped as 'fan undifferentiated', this refers to areas that were not studied in detail. A small section on the south-eastern boundary is mapped as 'fan recently active' in which there is relatively recent (<300 years) stream activity.

4.1.3 Seismic

The ORC database has marked an inferred location of the Pisa Fault which cuts through the property as seen in Appendix B, Figure 3. The southern area of the property is mapped as 'possibly susceptible' to liquefaction with a large area to the northeast 'low susceptibility'. However, these categories were apparently assigned without reference to watertable depths, which are discussed below.

4.1.1 Stereo Aerial Photography

A review of stereo photography from Wanaka- Cromwell, Run 2692, 1958 showed an active channel in the lower eastern gully, which is mapped in Appendix B, Figure 3 as 'fan recently active'. However, it is evident in the images that the fan is associated with a washout from the Early Settlers water race, where the scarp is still visible today. No other evidence of recent fan or landslide activity is evident in the stereo pairs.

5 Natural Hazard Field Assessment

A site inspection was undertaken, with mapping of the features relevant to hazard assessment.

5.1.1 Alluvial Fan Hazard Observation

The ORC hazard mapping shows a large area of the property as alluvial fan. The fans mapped on the property were thus closely examined (Appendix A, Figure 1).

The inferred boundaries of fans were mapped based on geomorphology. The slope of the western gully alluvial fan was measured at 2-4 degrees near the apex, reducing to <2 degrees in the vicinity of the buildings on the site.

The composition of the alluvial fan materials is largely unknown, due to lack of outcrop. However, minor exposures of fine-medium alluvial fan gravel were observed within a creek cut channel originating from the western gully, underlain by loess.

Scattered sub-rounded surface boulders of schist up to 300mm diameter were observed near the head of the fan and appeared to be derived from the adjacent schist debris landslide. The surface of the fan was smooth, with no geomorphic evidence to suggest debris flow deposits.

Topsoil thickness measured towards the apex of the fan was 250 mm, and there was no evidence of surface gravel deposits.

The alluvial fan surface below the small catchment of the northern gully is smooth, with no topographic evidence of debris flow deposits or recent activity.

The minor gullies on the face of the Early Quaternary Gravels are moderate to steep, but with only limited evidence of past alluvial fan development, and no evidence of recent activity.

5.1.2 Landslide Hazard Observations

There is evidence of schist debris landslides on the property, on the northern and western slopes. There are abundant surface boulders, with some larger outcrops. Rockfall risk from these exposures is typically low, with effects limited to steep gully areas.

The field evidence used for mapping the boundary is defined by the presence of schist boulders, with varying foliation attitudes, which are not in-situ confirming displacement and ground movement, consistent with the geomorphology. At the toe there is a change in geomorphology from gently sloping alluvial fan to hummocky hillside with large schist boulders as mentioned above. The inspection was conducted by a geotechnical engineer and engineering geologist who mapped the contact based on the descriptions above. Appendix A, Figure 1 shows the extent of the schist debris landslide. One area is noted as unconfirmed as the land use (Forestry Pines) has covered evidence of the boundary.

The presence of colluvium and subsequent vegetation on the slopes suggests that the activity is either dormant or very slow episodic creep, which is typical in similar landslides in the surrounding area. No evidence of recent slide activity was seen in the field, and survey monitoring would be required to quantify any long term creep movement, in areas identified with potential for development; prior to any application for resource consent being applied for to develop this location of the property.

5.1.3 Seismic Hazard Observations

The Pisa Fault is mapped as inferred, traversing the property, but no active fault scarps have been observed in the site area.

6 Geotechnical Considerations

6.1 Alluvial Fan Hazard

There is a large area of the property identified as historic alluvial fan (ORC Hazard Mapping). However, there does not appear to be any evidence of recent activity, and the risk of future debris flows or debris floods is considered to be generally low. No mitigation measures are required for active alluvial fan matters that won't be covered by surface water flooding. Flooding mitigation measures are further discussed in the flooding report.

The eastern gully which maps show as recently active, can be attributed to a water race blow out as identified in Section 3.2.4. The risk associated with this is low and is located on another property.

6.2 Landslide Hazard

Evidence of schist debris landslides are found in both the desktop and field assessment and discussed in previous sections. These are result of dip-slope failure, which occurs in many areas around Central Otago. Slope and groundwater largely control the rate of movement in schist debris landslides. Groundwater is usually present in the form of multiple perched aquifers and sometimes as sub-artesian or artesian systems.

The residual strength of schist defects is controlled by the friction angle. The friction angle of landslide gouge studied in the Cromwell Gorge stabilisation program was found to be in the range of 23 to 28 degrees, hence slopes of approximately 20 degrees or less in ancient yet inactive landslide debris can be considered for potential development.

Large schist debris landslides characteristically have a small depth to length ratio (less than 0.1) which on the slopes flanking the Pisa Range will still provide for thicknesses of many tens of metres to the "basal" shear surface which separates slide debris from gently inclined schist bedrock. Within this type of landslide, multiple slide lobes tend to develop, which may be superposed with depth, and/or contiguous in plan. Each individual shear surface continually becomes weaker both from attrition during movement and as a result of mineralogical decomposition of fines over time. For these reasons, creep movements tend to be ongoing even though many of the slides in this area have been dated with ages of many hundreds of thousands of years.

On the discrete shear surfaces, the slide "gouge" becomes several orders of magnitude less permeable than the bulk slide debris, and therefore acts as an aquiclude for infiltrating rainfall, enabling perched aquifers to develop and these tend to induce periodic creep movements of lobes after prolonged wet periods

Based on aerial photogrammetry comparisons and the extensive monitoring that has been carried out on schist debris landslides affecting Lake Dunstan, rates of movement of perhaps 10-100 mm per 100 years would be expected on the subdued slopes within the proposed subdivision. However, the form of creep movement in likely to be "stick/slip" ie no movement or minimal movement for many years then creep of a few mm during an extremely wet year – after perhaps several decades of no activity. For any dwelling constructed on the landslide, the associated risk of significant damage is therefore moderately low, but to be fit for purpose (obtaining a building consent with no caveat) a very low risk, quantified using recognised methods, is required.

In Central Otago, because the mechanics of schist debris landslides discussed above, is now well understood, enhancing the stability of slopes flatter than 20 degrees can be effectively achieved. The primary trigger (fluctuating aquifer levels) can be controlled through drainage or other methods. Stabilisation can be economic particularly when prime lots are influenced by an aquifer which can be readily accessed by either trenching and/ or horizontal drilling.

6.2.1 Assessment for Potential Development

An initial inspection of the terrain and existing scarps was used to identify slopes which could be suitable, followed by closer review using 3D imagery and Lidar to identify areas of concern. While slowly creeping schist debris landslides extend from the flats to the top of the Pisa Range, the slopes within the plan change area reduce to 20 degrees or flatter in places. In these locations the absence of distinct scarps or other signs of recent movement indicate either inactivity of very low rates of creep.

Areas with no potential for rural residential built form (i.e building sites) are shaded in purple on Appendix A, Figure 2. All terrain mapped as schist debris landslide in Appendix A, Figure 1 and Figure 2 shaded in red could be developed. An area which will require further clarification is the southwest forestry area which obscures identification of movement and the accurate location of the contact between landslide and alluvial fan as mentioned above.

Areas of the landslide that have the potential for development will require further monitoring and investigation would be required to confirm geotechnical requirements. It is expected that this information would form part of future applications for resource consent.

An alternative approach may be to stage the future land use and subdivision, initially establishing lots only on the flats, while for the longer term, lots on the existing landslide may be monitored for any movement in conjunction with a small number of piezometric installations to quantify groundwater fluctuations. This approach enables a decision on any remedial measures to be more informed and/ or deferred until benefit/cost is established.

For future building sites which are located on or in close proximity to schist debris landslides mapped in Appendix A, Figure 2, an investigation programme at selected locations with one or more vertical drillholes can be established to establish feasibility and quantify remedial measures.

Development is not considered feasible on the landslides slopes other than those identified with development potential in Appendix A, Figure 2 due to the steeper gradients and evidence of movement. Creep rates of these slopes are likely to be significant (possibly up to 100 mm in prolonged wet periods).

6.3 Liquefaction Hazard

Liquefaction risk in the area can now be recategorized as very low because the watertable, as discussed above, has been located at a depth at 33 metres. Perched water may be present locally after sustained rainfall, but materials highly susceptible to liquefiable (loose uniform sands) are not expected to be widespread in this terrain.

6.4 Seismic Hazard

Because the location of the active Pisa Fault is only inferred with no identified scarps, and the return period is substantial, no limitations are recommended for any structures apart from precautionary inspection of footing excavations, to ensure no subsurface evidence of the fault is present in the immediate vicinity. Risk associated with the Pisa Fault is considered very low.

A high seismic risk is present in the region from the Alpine Fault as discussed in Section 2.4. Appropriate allowance should be made for seismic loading during detailed design of any future buildings, foundations and retaining walls. Due to the varying nature of the site a range of seismic design classes may be required, for detailed design. Borehole data indicates soils to a known depth of at least 38.5 metres, from the deepest drillhole. Hence preliminary design should adopt Class D "deep" subsoil conditions in accordance with NZS 1170.5:2004 in the lower southern areas of the property. Refinement is required at the detailed design stage.

7 Conclusions

Assessment of the site indicates geotechnical hazards and risks are present within the property boundary but most will not provide any limitation on rural residential development, with a low risk attributed to most, and remedial measures available to reduce and remove others. Accordingly, the proposed zone can be supported from a geotechnical perspective.

Episodic creep of schist debris landslides may affect the western gully slopes at the base of the Pisa Range. This area shows areas susceptible to landsliding and within this a marginal zone of land (Appendix A, Figure 2) that could be subject to further investigations. There is a significant prospect that successful investigation and possible remedial measures, involving control of groundwater systems would enable rural residential development, in this area.

Alluvial fan activity has been identified in field investigations poses no risk to development as with no remedial measures required other than those for flooding mitigation as discussed in the flooding assessment.

8 Applicability

This report has been prepared for the benefit New Zealand Cherry Corp (Leyser) LP Ltd 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 and subdivision phase.

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Graeme Halliday

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Senior Engineering Geologist

Approved by:

Graham Salt

Graham Salt
Technical Director

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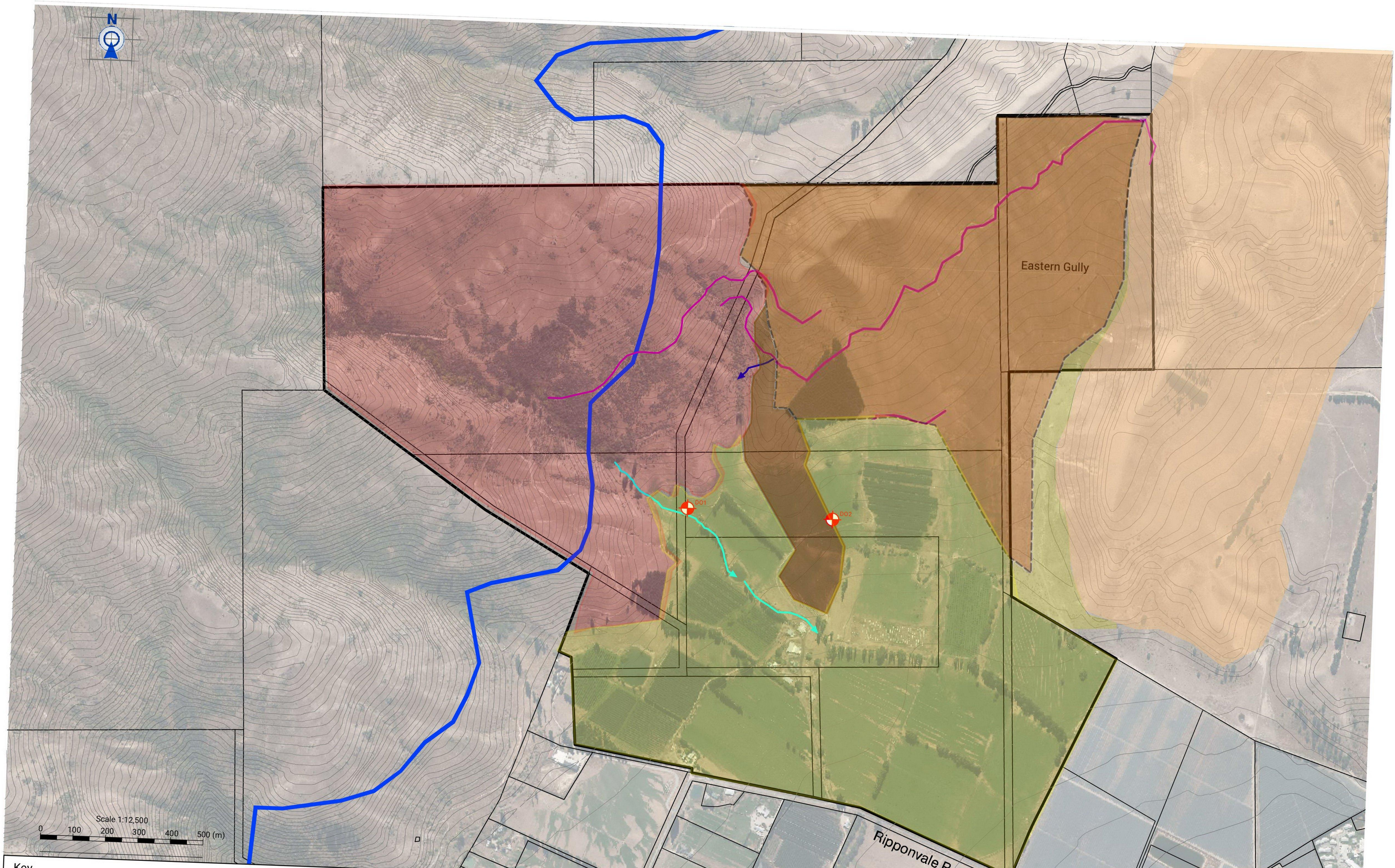
Appendix A: Site Plans



Key

- D01 = Hand Dug Pit
- = ONL Boundary (CODC)
- = Schist Debris Landslide
- = Early Quarternary Gravels
- = Creek Channel (Western Gully)
- = Alluvial Fan
- = Outwash Gravel
- = Water races (Active and Inactive)

CADFILE:	PDF	DRAWN	ELH	03/2018
SCALE (AT A3 SIZE):	AS SHOWN	DRAFTING CHECKED	GSH	03/2018
PROJECT No:	180137.01	APPROVED	FAW	03/2018

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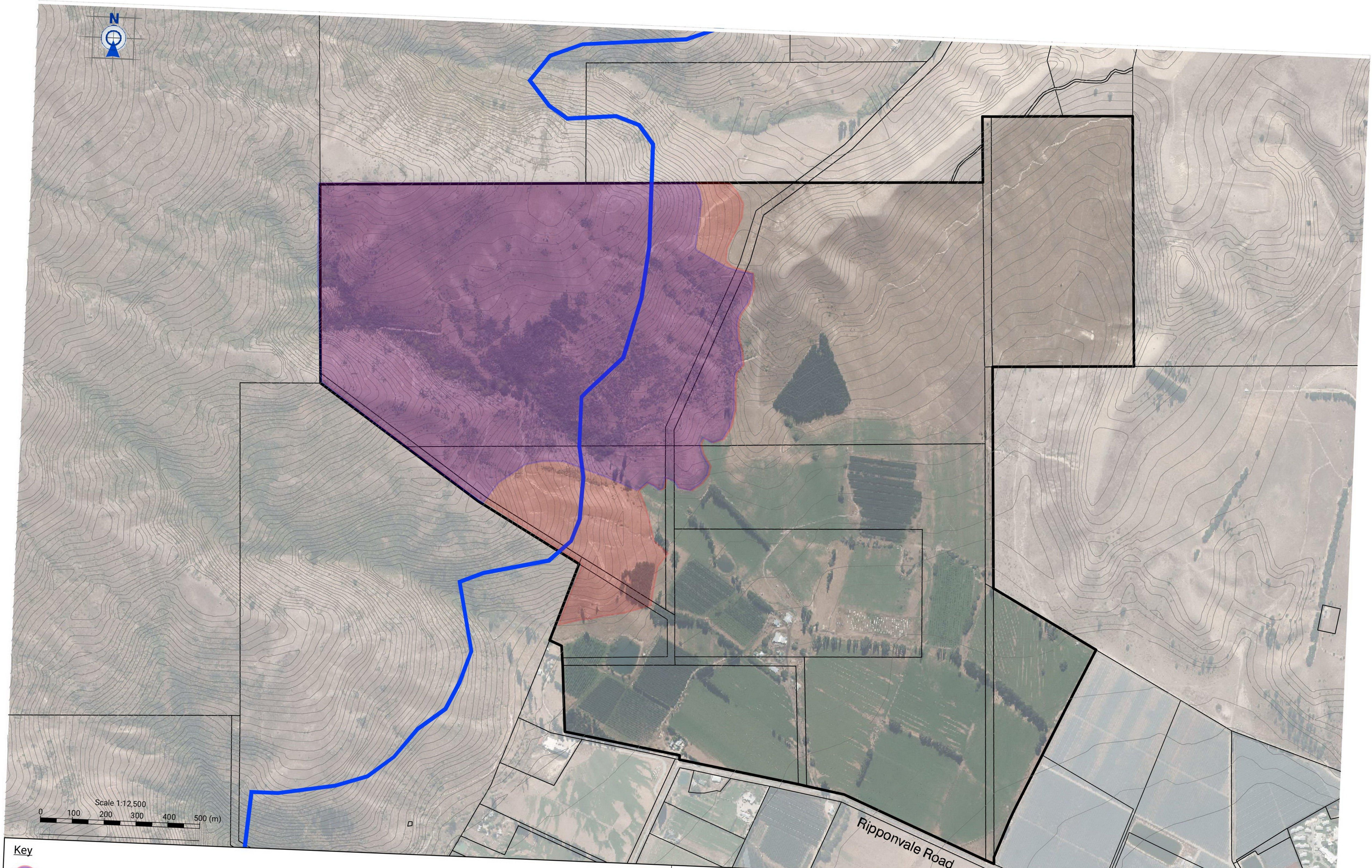
PAVEMENTS

New Zealand Cherry Corp (Leyser) LP Ltd
Geotechnical Investigation
144 Ripponvale Road, Cromwell
Field Investigations Plan

FIG No: APPENDIX A FIGURE 1

REV. 1



Key

= Schist Debris Landslide (No potential for development)

= Potential for Development

CADFILE:	PDF	DRAWN	ELH	03/2018
SCALE (AT A3 SIZE):	AS SHOWN	DRAFTING CHECKED	GSH	03/2018
PROJECT No:	180137	APPROVED	FAW	03/2018

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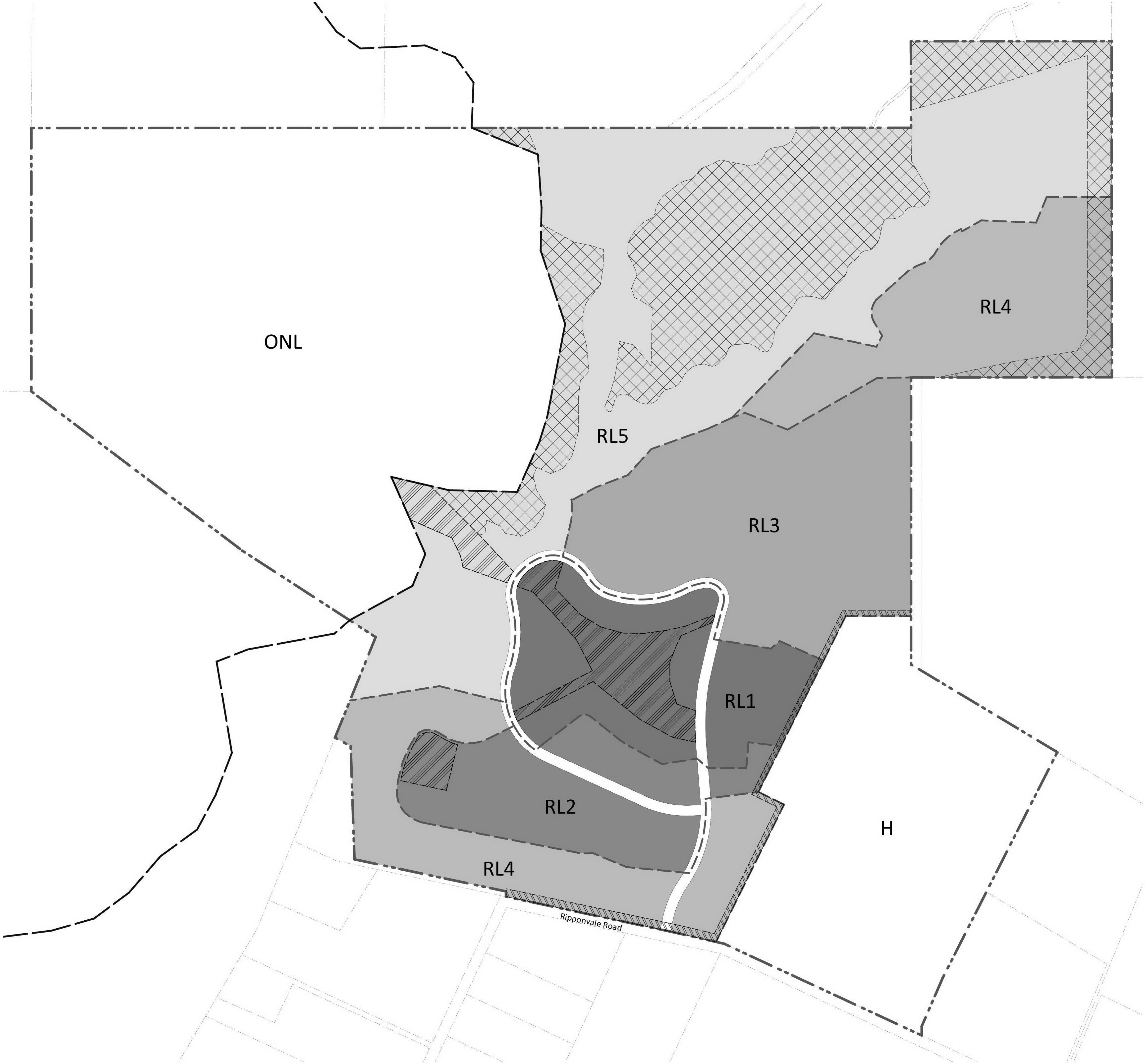
FIG No: APPENDIX A FIGURE 2

REV. 1



- Boundary
- Activity Area
- No Build
- Indicative Open Space and Stormwater Corridor
- Amenity Edge
- Indicative Road Network
- ONL Boundary

ONL	Outstanding Natural Landscape
H	Horticulture Area
RL1	Rural Lifestyle 1 Minimum Lot Size: 2000m2
RL2	Rural Lifestyle 2 Minimum Lot Size: 3000m2
RL3	Rural Lifestyle 3 Minimum Lot Size: 4000m2
RL4	Rural Lifestyle 4 Minimum Lot Size:1 ha
RL5	Rural Lifestyle 5 Minimum Lot Size: 3 ha

NORTH

draft

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Preliminary Structure Plan
Shannon Farm Development
144 Ripponvale Road
Cromwell

JOB No.	18065
SCALE	1:5000 @ A2
DATE	20/05/19
DESIGNED	TM
DRAWN	AN
CHECKED	TM
STATUS	FOR REVIEW
DRAWING No.	REVISION
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Appendix B: ORC Hazard Maps

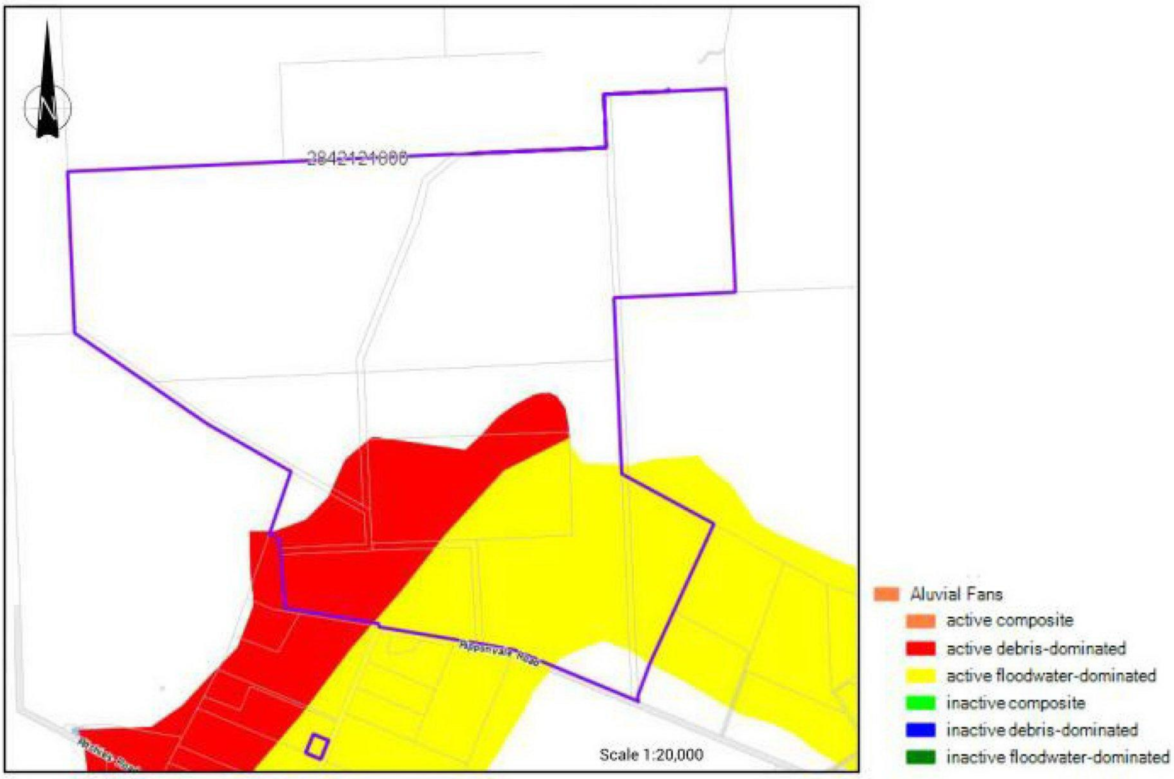

Figure 1 – Regional Alluvial Fan Mapping. Source: http://hazards.orc.govt.nz

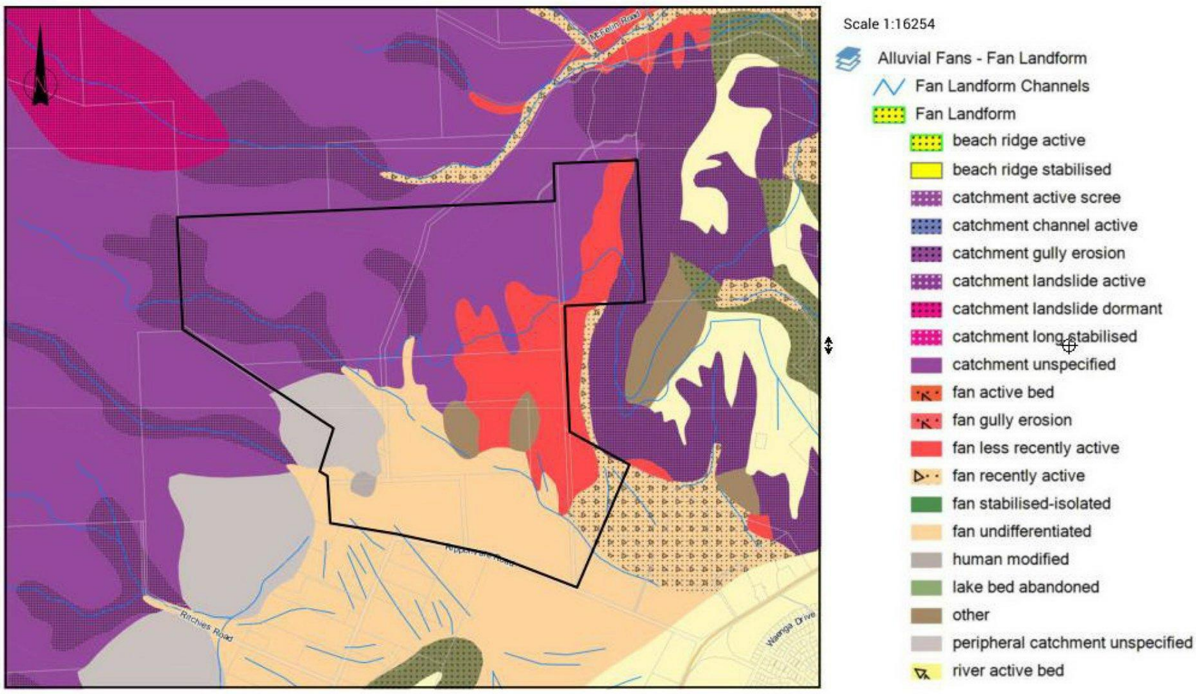

Figure 2 - Alluvial Fan- Fan Landform. Source: http://hazards.orc.govt.nz

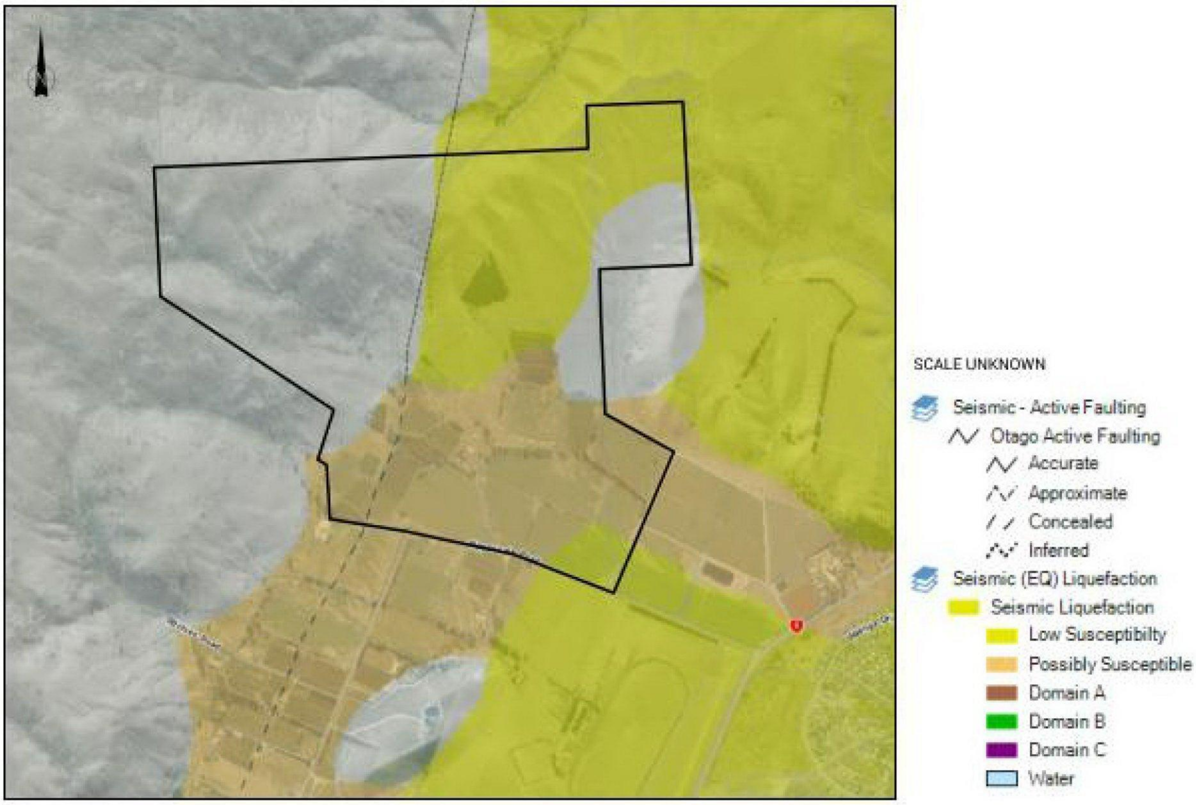

Figure 3 – Seismic and Faulting Mapping. Source: http://hazards.orc.govt.nz