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Preliminary Geotechnical Hazards Assessment

Waitiri Development

Crown Range & Gibbston Valley, Queenstown

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Distribution:

Oaks Living Limited

GeoSolve Limited (File)

April 2026

GeoSolve Ref: 260204

DRAFT

Revision	Issue Date	Purpose	Author	Reviewed
1	02.04.2026	Draft issue for fast-track resource consent referral	HJN/NW	FAW/PGF

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1 Introduction

1.1 General

A preliminary geotechnical assessment has been undertaken by GeoSolve to assess the proposed subdivision of five sites across the Crown Range and Gibbston/Kawarau Valley in Queenstown. This report has been completed to support a referral application under the Fast-track Approvals Act 2024 (FTAA). Further geotechnical assessment inputs will be required at the substantive application stage, if the project is referred into the Act's process.

This assessment has been completed for Oaks Living Limited in accordance with the GeoSolve proposal dated 11 March 2026, and includes the following scope of works:

- A walkover inspection and mapping of the sites by an engineering geologist and senior water engineer;
- A review of historic information currently held on the GeoSolve database;
- A review of the Queenstown Lakes District Council (QLDC) and Otago Regional Council (ORC) natural hazard register maps;
- A review of the published 1:250,000 GNS geological map[1] for the region;
- Interpretation of the supplied topographic survey; and,
- High-level qualitative assessment of the relevant natural hazards based on the above.

1.2 Development Overview

The drawings appended depict the proposed development area locations and the proposed layout schemes for each site.

Development of the sites named Ara Tihi (Eastburn), Mania (Glenlee Glenroy), Karapuke (Drystone), Taiheke (Riverside) and Kurae (Waitiri) include combinations of low to high density lots, large lot residential and rural living lots as well as designated reserve areas and community areas such as village precincts, schools and a golf course.

At this stage, no civil plans or earthworks plans are available.

[1] GNS Geology Web Map <https://data.gns.cri.nz/geology/>

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2 Site Description & Geological Setting

2.1 General

The sites are located through the Kawarau/Gibbston Valley from Eastburn on the Crown Range through to the Waitiri Peninsula. Appendix A, Figures 1-7 depicts the site contour and the general landform. The sites are largely undeveloped (greenfield) and exist as pasture or vineyard aside from several existing residential and commercial buildings and various water storage infrastructure.

The topography is dominated by outwash and fan terraces elevated above the Kawarau River, with several prominent deeply incised gullies and ravines flowing into the Kawarau Valley sourced from the catchments on the northern and southern hillsides. At the extent of the development areas on the Kawarau River side, the terrace crests drop abruptly down some 100-200 m into the riverbed.

Numerous ephemeral gullies across the properties drain localised catchment areas towards the Kawarau Valley or into local deep ravines.

2.2 Geology

No confirmatory subsurface investigations have been undertaken as part of our preliminary assessment. We have reviewed the GNS 1:250,000 scale geology map and inferred the geology based on field mapping and historic data review.

The sites are underlain by regionally extensive Schist bedrock. Uplifted schist bedrock forms the hillsides to the north and south of the Kawarau Valley and underlies the development areas at depth. Glacial outwash gravels derived from former glacial periods form the terraces above the Kawarau River, while degraded alluvial fan landforms (bedded silts, sands, gravels) are present overlying the older formations at the distal extents of the southern and northern hills. A Pleistocene-aged landslide deposit is mapped on the GNS map in the Glenlee Glenroy site, however its presence was not confirmed by Geosolve's assessment as it appears to have been obscured by more recent alluvial deposits and colluvium. More recent alluvium and colluvium are present within gully and ravine areas. Superficial deposits of existing fill, topsoil and windblown loess are present in some areas.

Observations of outcrops within the sites were generally consistent with the GNS geology maps for the area.

2.3 Seismicity

NW Cardrona Fault

Three splays of the NW Cardrona Fault trace are inferred to traverse through the Glenlee Glenroy site as shown on the appended plans, locations of which have been extracted from the ORC hazard maps database. The only definite known trace of this fault is present where it crosses the Kawarau Valley, where an offset terrace is present and trenching was mapped in 1988[2]. To the south, and through the Glenlee Glenroy site, the fault trace is not expressed to moderately expressed as it has been obscured by geologically younger alluvial and

[2] DJA Barrell (2019). General distribution and characteristics of active faults and folds in the Queenstown Lakes and Central Otago districts, Otago. GNS Science Consultancy Report 2018/207

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colluvial processes. Recent documents[3] estimate the recurrence interval of the NW Cardona Fault to be approximately 13,200 years. To the north the fault trace passes east of the Eastburn site.

Roaring Meg Fault

The Roaring Meg Fault trace passes immediately east of the Waitiri Development, following the Kawarau River bed. Recent publications indicate that the trace is not expressed and its location is primarily based on schist shears mapped on the river floor in the 1980s. The 2019 GNS publication estimates the Roaring Meg Fault has a recurrence interval of approximately 40,000 years. Due to the long recurrence interval of the Roaring Meg Fault, its rupture is considered highly unlikely throughout the proposed lifetime of the subdivision and therefore this fault has not been considered further.

Alpine Fault

Strong ground shaking throughout the South Island is likely to be associated with a rupture of the Alpine Fault, located along the West Coast of South Island. Recent research[4] suggests there is a 75% probability of an Alpine Fault earthquake occurring within the next 50 years and an 82% probability that the next earthquake on the Alpine Fault will be of magnitude 8 or greater.

2.4 Groundwater

New Zealand Geotechnical Database (NZGD) water bores located in the Eastburn (NZGD ID #107679) and Glenlee Glenroy (NZGD ID #107684) sites recorded the groundwater table at 53 m and 82.51 m below ground level, respectively. Additionally, the ORC wells database records levels ranging between 8 to 53 m below ground level at/near the Eastburn and Drystone sites.

It is expected that the groundwater table will generally follow the schist rock head level, dropping down to the Kawarau River level when it reaches the Kawarau Valley. This substantial depth to regional groundwater is expected to be typical of the sites, However, shallow localised perched seepages are likely in areas where depth to rock is shallow or at locations adjacent overland flowpaths and/or ponds, or springs such as within the hills north of the Waitiri site.

3 Natural Hazards

3.1 General

Desktop geomorphological and natural hazards field mapping of the development sites have been completed by an engineering geologist and senior water engineer. We have concluded that the following natural hazards may affect the proposed development areas:

- Alluvial fan.
- Landslides.
- Rockfall.

[3] DJA Barrell (2025). Review and update of active geological fault and fold characterisation in the Otago region. GNS Science Consultancy Report 2025/48

[4] Howarth, JD, *et al.* (2021). Spatiotemporal clustering of great earthquakes on a transform fault controlled by geometry. Nature Geoscience; doi: 10.1038/s41561-021-00721-4

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- Seismic shaking from faults – Alpine Fault and NW Cardrona Fault.
- Liquefaction.

Each site has been assigned preliminary geotechnical risk levels (low to very high) as defined below based on the natural hazards present, which will need to be considered for future planning and preliminary subdivision design. These definitions are in line with the National Policy Statement for Natural Hazards (2025)[5].

- **Low risk (green) areas** – low risk where conventional geotechnical design and construction techniques are likely to be able to be utilised.
- **Medium risk (yellow) areas** – specific geotechnical design required to mitigate minor hazards.
- **High risk (orange) areas** – specific geotechnical design required to mitigate hazards, with greater cost implications due to more robust mitigation requirements. May require complex and commercially intensive engineering and mitigation to allow development in these areas.
- **Very high risk (red) areas** – areas susceptible to large-scale hazards that may cover large areas across multiple lots. Will require no-build zones/avoidance. Repositioning of building platforms and civil infrastructure will likely require consideration.

Detailed modelling may modify the extents of the assigned zones.

Appendix B depicts the assigned risk designations and annotations across the sites and further general discussion is provided in the sub-sections below including potential mitigation options. The mapped risk zones should be reviewed as the project progresses and their extents will require revision when investigations and analysis are undertaken.

Areas outside of the proposed lots (such as reserves) were not mapped and should be considered very high risk at this stage unless specified otherwise.

3.2 Alluvial Fan and Flooding

3.2.1 Eastburn / Ara Tihi

There are three main alluvial fan/gully features with regard to the Eastburn site, termed the western, central and eastern fans/gullies below:

The western gully has a moderate catchment of ~0.59 km², and transitions to a fan within the site, with the fan head ~200 m upslope of Eastburn Road. The fan is mapped as 'Fan Recently Active' on ORC natural hazards mapping (based on the Otago Alluvial Fans Project 2009, which appears to be based on GNS reporting). Site inspection undertaken by GeoSolve in March 2026 agreed with this designation, although it is noted that the construction of the Crown Range Road has effectively created a small check dam/bund (with a ~1.2 m culvert) which will affect further development of the fan. The preliminary site layout provided to GeoSolve shows the nearest proposed dwelling to be ~400 m from the fan head, which is likely to be feasible, however further assessment is recommended to confirm a suitable location and potential mitigation measure requirements.

[5] National Policy Statement for Natural Hazards 2025 (December 2025). New Zealand Government.

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Figure 3-1: The western gully/fan below Crown Range Road, looking south towards the site

The central gully has a small catchment of ~0.07 km², and transitions to a fan within the site, with the fan head approximately level with (but ~200 m east of) the western gully fan head. The fan is mapped as 'Fan Stabilised/Isolated' on ORC natural hazards mapping. Site inspection undertaken by GeoSolve in March 2026 agreed with this designation. The preliminary site layout provided to GeoSolve shows the nearest proposed dwelling to be ~350 m from the fan head, which is likely to be acceptable. Further assessment to confirm that (potentially in conjunction with the further assessment of the western gully/fan recommended above) would be prudent.

The eastern gully has a comparatively larger catchment of over 1 km², though the exact area is less straightforward to define as the gully continues past the site without transitioning to a fan, and joins the Kawarau River ~450 m downslope of the site. Based on the preliminary site layout, that gully does not have building platforms proposed within it, which GeoSolve considers to be the appropriate approach.

With regard to potential flood hazard there are numerous channels/gully features running through the site that have small to moderate catchment areas and would convey a significant amount of water in extreme rainfall events. These channels/gullies are generally obvious features, and given the low density of the proposed residential lots/building platforms the potential flood hazard zones should be easily avoidable. It is noted that if that density were to increase mitigation measures are more likely to be required. It is recommended that further assessment is undertaken to confirm suitable building platform locations and potential mitigation measure requirements at detailed design. Earthworks

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should be undertaken in a way that does not significantly impede or concentrate natural drainage paths.



Figure 3-2: The western gully/fan above Crown Range Road, looking north away from the site

With regard to stormwater and drainage from proposed developed surfaces, it is noted that concentrated surface water runoff being outlet to the steep downslope channels/gullies has the potential to cause significant scour and erosion. It is recommended that infrastructure and residential stormwater is drained to ground wherever possible, e.g. soak pits, swales, wetland channels, and/or potentially ponds.

It is noted that a residential property has already been developed within the subdivision area (address shown to be 34-36 Preservation Lane on Google Maps), which appears to have been performed in a way that meets the above recommendations (TBC) and could potentially be used as an example for future development of the site.

The above recommendations are visually indicated by the natural hazard risk mapping drawing included as Appendix B.

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Figure 3-3: The eastern gully (left) and central fan below Crown Range Road, looking south towards the site

3.2.2 Glenlee-Glenroy / Mānia

There are multiple alluvial fan/gully features with regard to the Glenlee-Glenroy site. This is the largest of the proposed sites, and has been separated into East and West sections in the description below.

With regard to stormwater and drainage from proposed developed surfaces, it is noted that concentrated surface water runoff being outlet to the steep downslope channels/gullies has the potential to cause significant scour and erosion. It is recommended that infrastructure and residential stormwater is drained to ground wherever possible, e.g. soak pits, swales, wetland channels, and/or potentially ponds.

The below recommendations are visually conceptualised by the natural hazard risk mapping drawing included as Appendix B.

Glenlee-Glenroy/Mānia East

In general, the eastern portion of the site (i.e. east of Toms Creek) is relatively subdued and terraced gullies with significant catchments are deeply incised below the proposed residential lots, and no building platforms are proposed within them. Some well-defined channels/gullies do exist, however these have relatively small catchments, and given the relatively low density of the proposed lot layout it appears achievable to place building platforms outside of potential hazard zones.

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It is noted that if the lot density were to increase mitigation measures are more likely to be required. It is recommended that further assessment is undertaken to confirm suitable building platform locations and potential mitigation measure requirements at detailed design. Earthworks should be undertaken in a way that does not significantly impede or concentrate natural drainage paths.

A notable feature of Glenlee-Glenroy/Mania East is the artificial watercourse running south-west to north-east across the site, leading to the existing artificial water body/pond shown on current aerial imagery and the preliminary site layout drawings. From site inspection this watercourse is a water race fed by a diversion from Toms Creek to the south-west (which appears to be at the same location as the water supply for Gibbston Valley Winery). Where the diversion enters the site a flow measurement weir with telemetry was observed during the site inspection.

An abandoned section of the water race then leads towards the south-east corner of the site, however the current channel conveys the water to the artificial pond. An adaptation of the current channel is shown on the preliminary site layout drawings, however the overflow from the pond that currently spills down the gully below the pond is not shown, and will need to be allowed for in the location of building platforms at detailed design. Potential for the water race to spill from its traversing line above the pond should also be considered/addressed at detailed design. An alternative would be to disconnect the diversion from Toms Creek, however this would then cause the feature pond to drain.



Figure 3-4: The artificial water course leading to the man-made pond. Outflow is visible at the pond's left corner

Glenlee-Glenroy/Mānia West

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The western portion of the site (i.e. west of Toms Creek) also has terraced features and incised channels, however some of the terraced areas are located on alluvial fans at the base of range fronts with catchments containing active erosional features. In general this means that there is a greater level of alluvial fan flooding hazard than the eastern portion of the site, which is reflected by the increase in yellow/orange/red areas on the natural hazard risk mapping drawing included as Appendix B.

The most notable alluvial fan features are those immediately west of Toms Creek, and in the middle of the main terrace ~800 m further west. These are both shown as flow paths on NZ Topo Maps and the natural hazard risk mapping drawings, and are fed by 'Catchment Gully Erosion' as mapped by ORC. Differing areas of the fans have different mapping on the ORC mapping, ranging from 'Fan Active Bed' and 'Fan Recently Active' to 'Fan Less Recently Active' and 'Fan Stabilised/Isolated'.



Figure 3-5: Looking south up the western main-terrace fan and eroding upper catchment

Site inspection undertaken by GeoSolve in March 2026 generally agreed with these designations, although the areas of the central fan that were active/less recently active appeared less clearly defined than the ORC mapping, and further assessment is recommended at detailed design to determine if/where an appropriate building platform could be placed, and potential mitigation measures required.

In addition to the alluvial fans present, the deeply incised channel separating the 10 most western lots from the rest of the site is an active feature, with extensive erosion and sediment transport apparent. Access to those 10 lots is proposed via an access road which would cross that gully, which is likely to produce debris flow and/or debris flood events

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during heavy rainfall, potentially compromising access to those lots. Further assessment is recommended to determine the measures required to mitigate that risk, which is considered feasible but potentially costly. The lots themselves have also been assessed to have a relatively high hazard level from a geotechnical perspective (see the relevant sections of this report).



Figure 3-6: Looking north down the deeply incised gully that the access road crosses (and continues on left)

3.2.3 Drystone / Karapuken

The primary alluvial fan and flooding feature at the Drystone site is Franks Creek, which runs south-west to north-east across the north-west portion of the site. Franks Creek has two branches, the western (minor) branch, and the eastern (major) branch, which meet just as the river enters the site near its western boundary. Immediately downstream of that confluence, a small dam has been constructed on a private property, which appears to contain up to ~5,000 m^3 of water. A dam containing over 20,000 m^3 of water would be required to be officially assessed by a dam safety engineer under NZSOLD guidelines.

GeoSolve has previously inspected that dam on behalf of ORC and made some recommendations regarding maintenance and upgrade work (GeoSolve reference 250155). The importance of those recommendations (and compliance with consent conditions) would be increased if development is to be undertaken downstream of it. It is noted that the channel downstream of the dam (but upstream of proposed development) is shallow in places, with limited capacity to convey flood flows. Franks Creek has a significant catchment area above the dam (~3.5 km2), and is mapped by ORC to be an 'Active' channel with regard to alluvial fan hazard mapping.

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Figure 3-7: Looking north at upstream dam embankment



Figure 3-8: Looking south at downstream dam embankment

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The catchment of the western (minor) branch of Franks Creek appears to have been partially cut off by the construction of a water race, reducing the amount of flow reaching the natural channel. This may have a minor effect on flood flows in the area, less during smaller rainfall events, potentially with a stepped increase in events large enough to cause the water race to spill (or rupture). The lower reaches of Franks Creek (but still upstream of SH6) have culverts installed under the existing access roads, which may be under capacity for extreme flood events. This has the potential to affect existing properties/roads and other proposed development (such as Riverside/Taiheke), and may be exacerbated by the proposed development of the site.

Another, smaller alluvial fan/channel exists near the south-east corner of the site, which will also require consideration and appropriate mitigation at detailed design. It is mapped as an 'Active' channel/fan on ORC hazard mapping. The catchment is relatively small above the site (~0.2 km^2), and existing structures are present on the same fan without obvious significant mitigation measures.

The site has relatively dense residential development proposed, and stormwater drainage should be designed in a way that does not overwhelm (e.g. scour) existing natural flowpaths. There are steeper slopes downstream of the proposed development, which would be especially susceptible to scour. Stormwater disposal to ground is recommended wherever possible. It is recommended that further assessment is undertaken to confirm suitable building platform locations and potential mitigation measure requirements at detailed design. Earthworks should be undertaken in a way that does not significantly impede or concentrate natural drainage paths.



Figure 3-9: The Franks Creek channel shortly downstream of the dam, note the shallow channel characteristics

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Figure 3-10: Culverted water race that appears to have cut off the western branch catchment of Franks Creek



Figure 3-11: Looking north down the dry channel of the western branch of Franks Creek

The above recommendations are visually conceptualised by the natural hazard risk mapping drawing included as Appendix B.

3.2.4 Riverside / Taiheke

Riverside is immediately downstream of Drystone and conveys Franks Creek from SH6 to the Kawarau River. Franks Creek is mapped as 'Fan Active Bed' on the ORC Natural Hazards Mapping through that area, and becomes increasingly incised into the surrounding terrace. Potential channel aggradation (and capacity reduction) as a result of sediment deposition during flood events should be considered at detailed design. Maintaining excavator access to key areas of the channel (e.g. upstream/downstream of culverts, and at sharper bends where sediment/debris may deposit) in the final subdivision design is recommended.

The culvert that conveys Franks Creek under SH6 (from the Drystone to Riverside) is ~1.2 m in diameter, and may be undersized for the catchment that it drains (~3.9 km^2). If the culvert were to back up (or block) then flow would spill over SH6 (with the potential to scour the downslope embankment) and into the Riverside area. Properties near Franks Creek and downslope of SH6 may be affected. Further assessment is recommended at detailed design to determine the extent of mitigation measures potentially required. It is noted that if Drystone is developed the flood flow rate of Franks Creek may be increased.



Figure 3-12: The ~1.2 m diameter culvert under SH6, draining the ~3.9 km^2 Franks Creek catchment

As Franks Creek nears the Kawarau River, it deposits into a pond/dam that appears to have been created by the construction of a fill embankment on the downslope (northern) side of the terrace. The surface are of the retained water is ~2400 m^2, and the average depth of the

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pond is estimated to be 1.5-2.5 m, meaning that the estimated volume of water contained is 3600-6000 m^3. As previously stated, a dam containing over 20,000 m^3 of water would be required to be officially assessed by a dam safety engineer under NZSOLD guidelines.

The preliminary development layout shows six structures downslope of that dam, at least some of which would be impacted by a failure of the dam. Appropriate assessment and design of the dam/downstream structures/mitigation measures is recommended at detailed design.

Flood risk to the proposed development from the Kawarau River is considered to be very low.

The proposed residential development of Riverside is relatively dense, and with regard to stormwater and drainage from proposed developed surfaces, it is noted that concentrated surface water runoff being outlet to the steep downslope channels/gullies has the potential to cause significant scour and erosion. It is recommended that infrastructure and residential stormwater is drained to ground wherever possible, e.g. soak pits, swales, wetland channels, and/or potentially ponds.

Some drainage channels exist adjacent to lower Rafters Road (leading down to Rum Currie's Hut) which appear to be of limited capacity, and it is considered that these are likely to require upgrades if they are to convey runoff from the proposed development.

The above recommendations are visually conceptualised by the natural hazard risk mapping drawing included as Appendix B.



Figure 3-13: Looking south at the artificial pond/dam near the Franks Creek/Kawarau River Confluence

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Figure 3-14: Looking south-east at the proposed dwelling locations downslope of the artificial pond/dam

3.2.5 Waitiri / Kūrae

The Waitiri site is located on an elevated peninsula protruding into a bend in the Kawarau. It is generally relatively flat, however falls away steeply towards SH6/the Kawarau River on the southern and eastern sides. The northern and western sides have steep slopes rising up away from the site, the western slopes being relatively open, while the northern slopes are steeper and more channelised. The channelised northern slopes tend to the east and drain to the north-east corner of the site. No other significant flow paths were observed during the site inspection. Multiple ponds exist on the site, which are likely to be artificially fed irrigation ponds, as they have limited natural catchments.

During the site inspection it was noted that water was being pumped to near the top of the northern slopes, and flowing from there downslope towards the northernmost pond. It appeared that it was flowing from the pumped location into a constructed water race, which may have previously led to the other ponds. However, that water race appeared to have failed (potentially overtopped and back scoured), meaning that the channel had avulsed and re-routed a more direct path to the northernmost pond, including depositing a significant amount of sediment upstream of and into that pond.

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Figure 3-15: Outlet point of pumped water to near top of northern slopes

The preliminary site layout shows residential lots near the base of the northern slopes, including in close proximity to the existing pond. Significant engineering works would be required to enable that (assuming it is feasible), including more detailed assessment, defined building platform locations, and specific engineering design of the access and dwellings. It is likely that the existing pumped water supply would need to be shut off, and rehabilitation works undertaken on the avulsed channel.

The proposed residential development is relatively dense, especially on the southern half of the site. With regard to stormwater and drainage from the proposed developed surfaces, it is noted that concentrated surface water runoff being outlet to the steep downslope channels/gullies has the potential to cause significant scour and erosion. It is recommended that infrastructure and residential stormwater is drained to ground wherever possible, e.g. soak pits, swales, wetland channels, and/or potentially ponds. If stormwater is drained to ground it should be determined whether it is likely to daylight downslope, as if this occurs on a steep face above SH6 it has the potential to cause back-scour.

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Figure 3-16: Artificial pond (left), avulsed channel (centre) and abandoned water race (centre-right)



Figure 3-17: Transported sediment caught in farm fence

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Figure 3-18: Sediment deposited into pond (foreground) and back-scour of avulsed channel (background)



Figure 3-19: Looking west across the flatter (southern) area of the site and non-channelised western slopes

3.3 Landslides / Slope Instability

The ORC hazard mapping database depicts existing landslide features on the Glenlee Glenroy and Waitiri development sites, extents of which are based on the GNS 1:250,000 scale geology mapping and included in Appendix A, Figure 3c, 6a and 6b. The “Resta Road” landslide is labelled in Appendix A, Figure 3c and is shown on the ORC hazard maps as well as in the GNS geology maps.

Based on our field mapping, the highest slope instability hazard is associated where development is proposed near the crest of a steep slope, such as the main valley slope to the Kawarau River and local deeply incised gullies that cut through the terraces. Here, the slopes are elevated greater than 100 m above the valley in some cases. Ongoing erosion and slumping are evident and there is potential for large-scale instability to occur particularly in a seismic event. The largest scale existing instability was observed in soil slopes where a combination of ongoing toe erosion and concentrated catchment flows are present. Photograph 4.1 provides an example of this. Slopes where rock is present are susceptible to schist debris avalanche and rockfall regression, however these tend to be more isolated in nature as they are a function of weathering and structural defects rather than erosion. The Waitiri site has mapped schist debris landslides on the Kawarau River facing slopes.

Accordingly, adjacent to these high crests, a very high risk (red) level has been assigned where a “no-build” zone will likely be required. The setbacks have been nominally selected purely from field mapping, slope height and interpreted ground conditions. Confirmation of rock levels from the crests of these slopes combined with seismic stability modelling will assist in determining the actual required setbacks and mitigation options. Deep investigations (e.g., cored boreholes) may be required in some cases.

High risk (orange) zones have been assigned to comparatively lower slopes and where mid-slope scarps were identified within the sites, which are likely the function of slope height, steepness, the presence of soil vs. rock and water seepage, or combinations of these. Based on observations on the Glenlee Glenroy site, static instability is already present on some soil slopes that are generally steeper than 2(H) : 1(V).

Additionally, the ORC mapped Resta Road slip area has been designated as an orange zone that requires further assessment to determine if it is still currently active.

Mitigation of very high risk zones will likely be unfeasible, and repositioning of platforms to lower risk zones and avoiding entirely should be considered. High risk zones may be addressed with techniques such as construction of palisade piles and extensive subsoil drainage, and may be challenging and costly but still achievable. Medium risk zones may require localised drainage and foundation piling. Assessment of seismic cases will likely be a governing factor of mitigation designs and final setback requirements.

Due to the highly erodible nature of the soils, robust stormwater disposal design will be necessary to direct concentrated flows away from slope crests and control outflow velocities.

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Figure 3-20: Example of ravine/valley crest instability (Glenlee Glenroy site).

3.4 Rockfall

The ORC hazard maps show rockfall hazard awareness areas in the Eastburn, Glenlee Glenroy and Waitiri sites.

Rock outcrops were observed on the hillsides immediately south of the western portion of the Glenlee Glenroy site, however in many instances they are positioned near crests of deep ravines and therefore their trajectories are estimated to be confined to gully alignments. Areas within the gully bases have been assigned very high risk, however building areas elevated above the gullies have been assigned medium risk, unless governed by other hazards. In some other areas on the southern hillsides, rock outcrops were observed however no rockfall debris was identified. Here there is potential for rockfall in a seismic event, and accordingly these have been assigned high risk zones (refer to annotated risk zoning plan).

An isolated rock outcrop was mapped in south-west Waitiri with a possible trajectory downslope to the east posing risk to the lots below. Boulders of up to 1 m^3 were observed near these lots and a specific assessment will be required to determine future runout distance and risk. Due to the isolated nature of the outcrop and comparatively smaller source area, the lots likely affected have been assigned a high risk (orange). Two proposed lots at the far south end of Waitiri adjacent SH6 have been designated as rockfall awareness areas on the ORC maps. No outcrops were observed here on the slopes above, however the area has been designated as a high risk zone as the slope is currently obscured by vegetation and no existing information is available.

Designated very high risk areas should be avoided entirely as source areas are often broad and located beyond the site boundary. Mitigation options for high-risk areas may include

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positioning of building platforms away from rockfall areas, construction of engineered earthfill protection bunds, rockfall fences/nets, spot bolting or scaling where accessible.

Rockfall may also cause downslope regression of cliff faces, however crest instability as described in Section 3.3 will likely govern the setbacks.

3.5 Seismicity

3.5.1 Seismic Shaking from Faults

Splays of the active NW Cardrona Fault traverse through the Glenlee Glenroy site as described in Section 2.3 above. The framework described below has been used to determine if development within the active fault areas is considered a permitted activity.

A recently published Otago Regional Council (ORC) committee report (2025) has introduced Fault Awareness Areas (FAAs) for all mapped active faults within the Otago region. However, the report does not provide specific guidance on how FAAs should be applied to land-use planning. In the absence of such guidance, industry practice typically follows the Ministry for the Environment (MfE) guidelines[6], which are widely regarded as the standard framework. The FAAs have been applied 250 m either side of the fault traces on the ORC maps.

Section 11 of the MfE guidelines provides guidance on Resource Consent activity status for greenfield sites based on fault recurrence intervals and fault complexity. Through the site, the traces are classed as having a likely certainty with no to moderate expression and therefore, according to Table 5.1 of the 2019 GNS paper, the fault deformation/complexity is classed as “uncertain”, which can be applied to Table 11.1 from the MfE guidelines presented below.

6 Kerr, J., Nathan, S., Van Dissen, R., Webb, P., Brunsdon, D., & King, A. (2003). Planning for development of land on or close to active faults: A guideline to assist resource management planners in New Zealand. Ministry for the Environment

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Table 11.1: Resource consent activity status for greenfield sites

Building importance category	1	2a	2b	3	4
Fault complexity	**Activity status**				
Fault recurrence interval class I less than or equal to 2000 years					
A – Well defined	Permitted	*Non-complying*	*Non-complying*	*Non-complying*	Prohibited
B – Distributed	Permitted	*Discretionary*	*Non-complying*	*Non-complying*	Non-complying
C – Uncertain†	Permitted	*Discretionary*	*Non-complying*	*Non-complying*	Non-complying
Fault recurrence interval class II greater than 2000 but less than or equal to 3500 years					
A – Well defined	Permitted	*Non-complying*	*Non-complying*	*Non-complying*	Prohibited
B – Distributed	Permitted	*Discretionary*	*Non-complying*	*Non-complying*	Non-complying
C – Uncertain†	Permitted	*Discretionary*	*Non-complying*	*Non-complying*	Non-complying
Fault recurrence interval class III greater than 3500 to but less than or equal to 5000 years					
A – Well defined	Permitted	Permitted*	*Non-complying*	*Non-complying*	Non-complying
B – Distributed	Permitted	Permitted	*Discretionary*	*Discretionary*	Non-complying
C – Uncertain†	Permitted	Permitted	*Discretionary*	*Discretionary*	Non-complying
Fault recurrence interval class IV greater than 5000 but less than or equal to 10,000 years					
A – Well defined	Permitted	Permitted*	Permitted*	*Non-complying*	Non-complying
B – Distributed	Permitted	Permitted	Permitted	*Discretionary*	Non-complying
C – Uncertain†	Permitted	Permitted	Permitted	*Discretionary*	Non-complying
Fault recurrence interval class V greater than 10,000 but less than or equal to 20,000 years					
A – Well defined	Permitted	Permitted*	Permitted*	Permitted*	Non-complying
B – Distributed	Permitted	Permitted	Permitted	Permitted	Non-complying
C – Uncertain†	Permitted	Permitted	Permitted	Permitted	Non-complying
Fault recurrence interval class VI greater than 20,000 but less than or equal to 125,000 years					
A – Well defined	Permitted	Permitted*	Permitted*	Permitted*	Permitted*
B – Distributed	Permitted	Permitted	Permitted	Permitted	Permitted**
C – Uncertain†	Permitted	Permitted	Permitted	Permitted	Permitted**

Figure 3-21: Annotated table extracted from the Ministry of the Environment showing the Resource Consent activity status for greenfield sites based on fault recurrence intervals of the NW Cardrona Fault.

Under these guidelines, buildings classified under Importance Categories 1, 2a and 2b are treated as permitted activities within FAAs where the fault location is uncertain and the recurrence interval falls between 10,000 and 20,000 years. The FAAs have been overlain onto Appendix A.

3.5.2 Topographic Amplification

During earthquake shaking seismic waves radiate out from the source and converge along steep topography at the Earth's surface such as cliff edges or ridge tops. Evaluation in the Port Hills following the Christchurch earthquakes observed well demarked areas of increased damage near the crests of steep slopes which indicated zones of seismic amplification.

Areas potentially susceptible to topographic amplification have been included in the high risk slope instability zones and will require consideration in seismic stability assessments at future analysis stage.

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3.6 Liquefaction

The ORC hazard maps depict all sites to be classed as “Domain A” with respect to liquefaction, which is based on the 2019 GNS regional analysis for liquefaction susceptibility. Domain A is defined as areas where land damage is unlikely from liquefaction.

The regional groundwater table is expected to lie well below the development areas and the proposed building sites are generally in elevated positions, therefore the overall liquefaction risk is considered to be low. However, a perched groundwater table may be present in areas proximal to watercourses such as gullies or adjacent to ponds. Localised low-lying areas adjacent to watercourses may be susceptible to liquefaction to a certain degree where recent loose alluvial deposits are present, however it is not expected to be greater than medium risk (yellow) and readily addressed with standard mitigation techniques such as construction of reinforced rafts and ground improvement for residential dwellings. Other hazards such as alluvial fan/flooding hazards are expected to govern higher risk levels in these areas.

Liquefaction risk should be assessed on a case-by-case basis initially via subsurface investigation to determine groundwater levels and soil strengths.

3.7 National Policy Statement for Natural Hazards

As the project progresses, an assessment as per the requirements if the National Policy Statement for Natural Hazards (NPS-NH 2025) is expected to be required, and will include specific hazard analysis and detailed mitigation review. The below points summarise the key hazards that will need to be considered for the assessment:

- **Alluvial fan/flooding** – some areas will require revision of building platform locations and others specific engineering structures such as diversion bunds and swales, with extents depending on the proposed residential lot density. Modelling and review of final layouts will confirm required extents.
- **Ravine/valley crest stability** – slope stability assessments will confirm the required setbacks and mitigation structure options.
- **Rockfall risk areas** – a detailed assessment will determine extent of affected zones. Red zones will require avoidance, whereas high to medium zones may be mitigated by detailed design depending on cost restraints.
- **Seismicity** – adoption of the FAA framework is likely sufficient to address this matter. Other seismic effects, such as slope instability (landslide and rock fall) and liquefaction, are addressed separately under each specific hazard.
- **Liquefaction** – likely to be low risk, however, may require specific foundation assessment on a case-by-case basis.

As described above and presented in the preliminary risk zoning plans in Appendix B, several areas on the sites are considered very high risk. However, it is anticipated the majority of these areas could be optimised via subdivision scheme design, such as revising building platform locations and/or lot boundaries. Medium to high risk areas are likely able to be mitigated through detailed design.

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4 Historic Mining Activities

Historic and more recent mining activities occurred within the Gibbston Valley. Alluvial tailings and modified landscapes are present intermittently along the margins of the Kawarau River.

An archaeology report from 2008 for the Gibbston Valley Station[7] presented the following information:

"Evidence of alluvial gold mining was found intermittently along most of the Kawarau River through the survey area…", "This type of gold mining (ground-sluicing) *leaves distinctive traces in the landscape; a network of head-or feeder-races above the workings, an area of worked ground bounded by an escarpment, internal piles of stacked tailings, and tailraces leading away from the workings".*

The study area for that report is adjacent to the Kawarau River immediately north of the Glenlee/Glenroy site.

Another record of mining undertaken from 1984 to 1988 included northern areas of the Riverside development, however this information was "drawn from memory", which highlights the inherently unreliable nature of historic records.



Figure 4-1: Approximate extent of alluvial gold mining undertaken on the northern Riverside area from 1984-1988.

[7] P.G. Petchey, 2008. Appendix X: Archaeology Report, Gibbston Valley Station.

Mindat.org references a historic coal mine south of the Drystone site at Coal Pit Saddle, which is understood to have been mined via pit and tunnel techniques; however, this site is located away from the development areas.

During the field mapping, evidence of stacked stone tailings were observed within the banks of two eastern gullies on the Waitiri site within designated reserve areas, however it should be noted that in many instances evidence of mining activities can become obscured by subsequent farming operations or vegetation. Areas where historic mining is recorded or mapped are annotated on the appended risk zoning plans.

Although a detailed assessment of historic mining is recommended, our initial research and knowledge of the area indicate most of these activities are surficial in nature and it is unlikely that any underground workings were undertaken within the sites. However, it is recommended that a detailed assessment is undertaken followed by subsurface investigations to determine the extents of mining remnants and the locations relative to the proposed developments.

5 Preliminary Engineering Considerations

Preliminary engineering recommendations are provided below. The recommendations and opinions are based upon existing available information and our site observations to date. The ground conditions and associated geotechnical engineering issues will vary across the sites and are not able to be confirmed until specific engineering assessment is undertaken at the future stages of the project.

- All earthworks proposals (i.e., cuts and fills) will require geotechnical assessment o confirm they do not exacerbate hazards, e.g. slope stability. Placement of fill at a slope crest can detrimentally surcharge the slope and worsen prevailing conditions. Any earthworks should preserve natural drainage paths and avoid concentrating flows. Overland flow detention, e.g. ponds, may be required to maintain natural run-off response times.
- Subdivision preparation and earthworks activities should be undertaken in accordance with the provisions of NZS 4431:2022. Any existing uncontrolled fill in building areas will require removal.
- Civil infrastructure (roading, three waters, pipe work etc.) will need to consider the hazard risk zoning, and mitigation structures may be required where they cross through critical areas. There will be options to reroute alignments away from very high risk zones in some areas.
- A severe seismic risk is present in the region, as discussed above, and as per building code requirements and recognised engineering practice, appropriate allowance should be made for seismic loading during detailed design of all structures, retaining, foundations and earthworks.
- Building areas located on alluvial deposits may be subject to a reduced bearing capacity in loose silts, sands and gravels. Conventional construction techniques are readily available to improve bearing capacity such as undercut and replacement with engineered fill or foundations can be designed for reduced bearing capacity.
- On-site stormwater soakage is subject to subsurface investigation and testing; however, may not be feasible where shallow rock or dense glacial deposits are

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present. Disposal in deep alluvial gravels will likely be the most feasible disposal option. Assessment of potential downslope daylighting of water will be required.

- In general, natural flowpath channel capacities must be maintained, which will require channel and culvert maintenance. Maintaining excavator access to key points of alluvial channels is likely to be required. Culverts may require upsizing.

6 Further Work

In order to confirm natural hazard risk levels in accordance with the National Policy Statement for Natural Hazards 2025, hazard zoning can be refined by further assessment and analysis as part of finalising subdivision engineering, and as part of the substantive resource consent and engineering approval process.

Subsurface investigations such as test pits, rotary core boreholes, hand augers and cone penetration tests will be undertaken to confirm the ground model as the project progresses.

Recognised analysis methods are available to allow detailed assessment of the identified hazards outlined in this report to be completed.

7 Conclusions and Recommendations

- This report is based on desktop review and field mapping across the five sites. Preliminary hazard zoning indicates some areas on the sites are subject to very high and high risk natural hazards, as depicted on the appended maps. The hazard zoning has been aligned with and should continue to be reviewed with regard to the National Policy Statement for Natural Hazards (2025) framework as the project progresses, which will include subsurface investigations.
- Very high risk zones are best avoided while medium to high risk zones are likely able to be mitigated via repositioning of building platforms or analysis and design of mitigation structures. The following four points provide possible mitigation options for hazards in medium to high risk areas.
- Slope instability mitigation may include palisade walls, subsoil drainage and foundation piling. This mitigation in high risk zones will likely be laterally and depth extensive.
- Rockfall mitigation may include specific positioning of building areas away from high risk zones or design of protection bunds or fences.
- The sites contain a range of drainage features including alluvial fans, incised gullies, artificial water races, and constructed ponds/dams. These features have the potential to convey significant flows, sediment, and debris floods/flows during extreme rainfall events. However, in many areas the proposed low-density development layouts appear to allow building platforms to be located outside of the alluvial hazard areas, meaning that risks are considered manageable for the majority of proposed lots. Some lots may not be developable or are likely to require hazard mitigation measures such as bunding, which may require Defence Against Water consenting. This bullet point is regarding alluvial/flooding risk only, and is subject to further assessment and appropriate detailed design.
- Liquefaction risk is considered to be low overall due to the regionally mapped ground conditions and regional groundwater table depth, however site-specific analysis may

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be required in localised areas subject to subsurface investigations. Liquefaction hazards of medium risk level, if encountered, are expected to be readily mitigated with specific foundation design or ground improvement.

- The Glenlee Glenroy site is traversed by splays of the NW Cardrona Fault, however development in these areas is assessed as a permitted activity based on the framework outlined in Section 3.5.1 of this report.
- A regional seismic risk is present from the Alpine Fault.
- Stormwater disposal design will be a critical aspect as to not concentrate or dispose of water over sensitive areas such as at slope crests. Potential downslope daylighting of water from infiltration/soakage features is to be assessed/mitigated.
- Existing water features introduce overtopping/avulsion risk, erosion/scour risk and dam safety considerations, which will require further assessment at detailed design.
- Historic mining activities are known on some of the sites however they are anticipated to be surficial in nature. Detailed review is recommended to estimate likely tailings extents and whether they are located within proposed building areas.
- See Preliminary Engineering Considerations for further recommendations.

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8 Applicability

This report has been prepared for the sole use of our client, Oaks Living Limited, with respect to the particular brief and on the terms and conditions agreed with our client. It may not be used or relied on (in whole or part) by anyone else, or for any other purpose or in any other contexts, without our prior review and written agreement.

No subsurface investigations have been undertaken for this scope of works and therefore the actual subsurface stratum and groundwater conditions may differ or vary across the sites.

Report prepared by:





....

Henry Nagel
Engineering Geologist

Neil Williman
Senior Water Engineer

Reviewed and Authorised for GeoSolve Limited by:





....

Fraser Wilson
Principal Engineering Geologist

Paul Faulkner
Principal Engineering Geologist

Appendices: **Appendix A – Geomorphology Maps – Figures 1 to 6**
Appendix B – Geotechnical Risk Zoning Map – Figures 1 to 6

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Appendix A: Geomorphology Maps

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Waitiri Development, Gibbston Valley
Geotechnical Assessment
Site Overview Plan

Figure No.: Appendix A, Figure 1a
Revision: 0

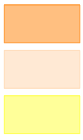
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Otago Active Faults
(GNS 1:250k Regional Mapping 2016-2021):



Otago Fault Awareness Areas (FAA's)
(GNS 1:250k Regional Mapping 2016-2021):



Otago Mapped Landslides (ORC Spatial Data Portal):

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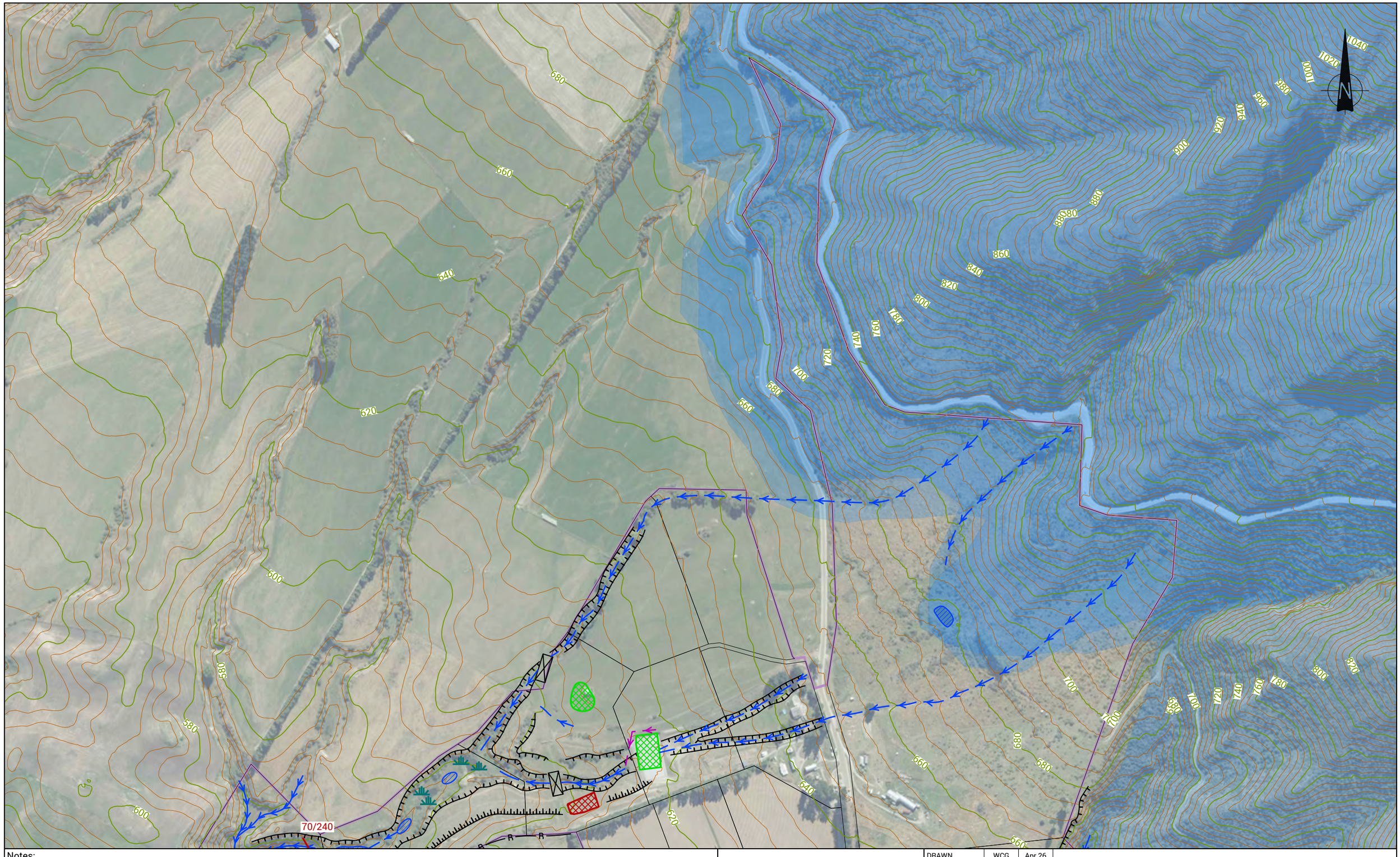
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Geotechnical Assessment

Legend

Figure No.: Appendix A, Figure 1b

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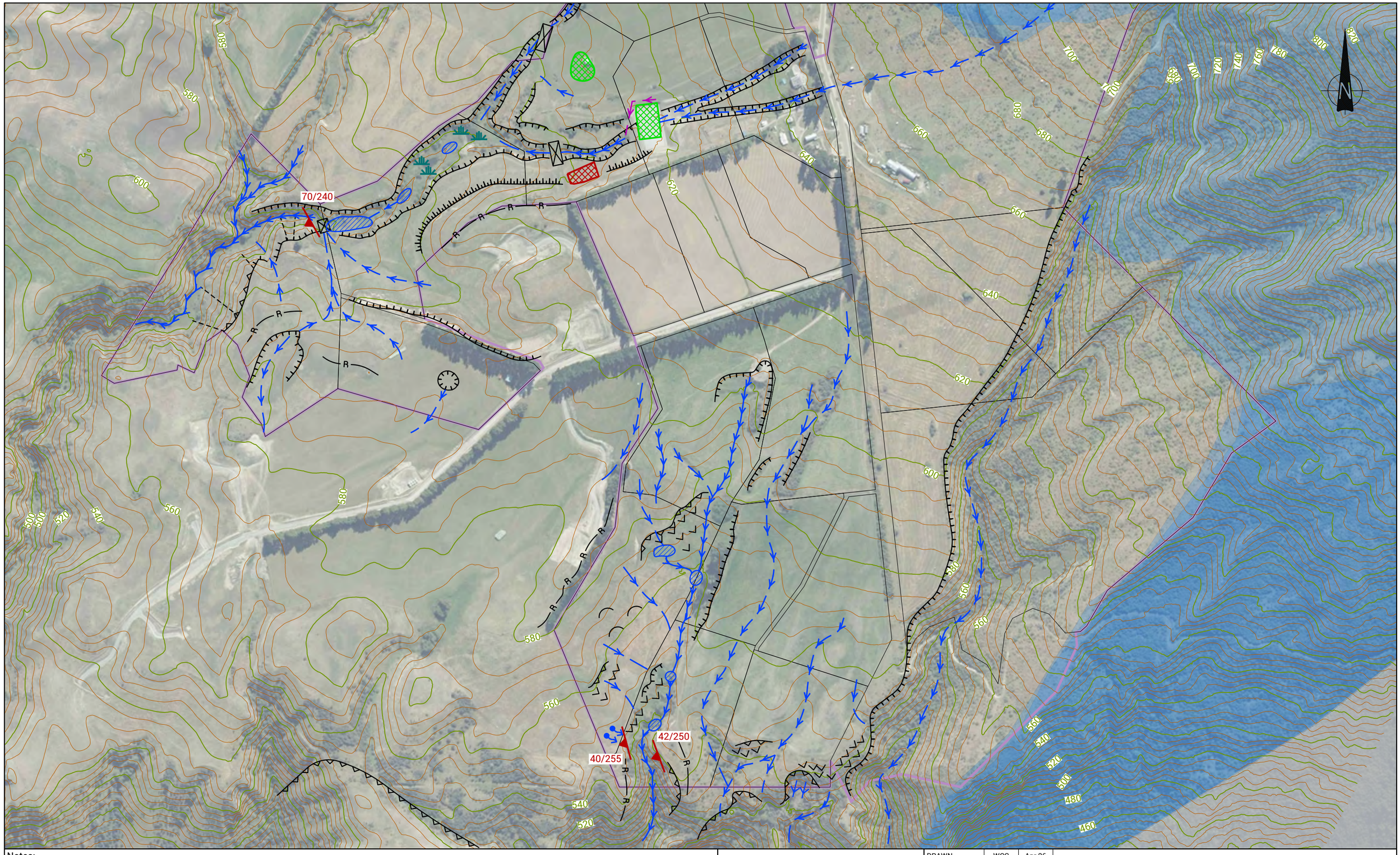
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Geotechnical Assessment

Ara Tihi - Eastburn Geomorphology Plan (North)

Figure No.: Appendix A, Figure 2a
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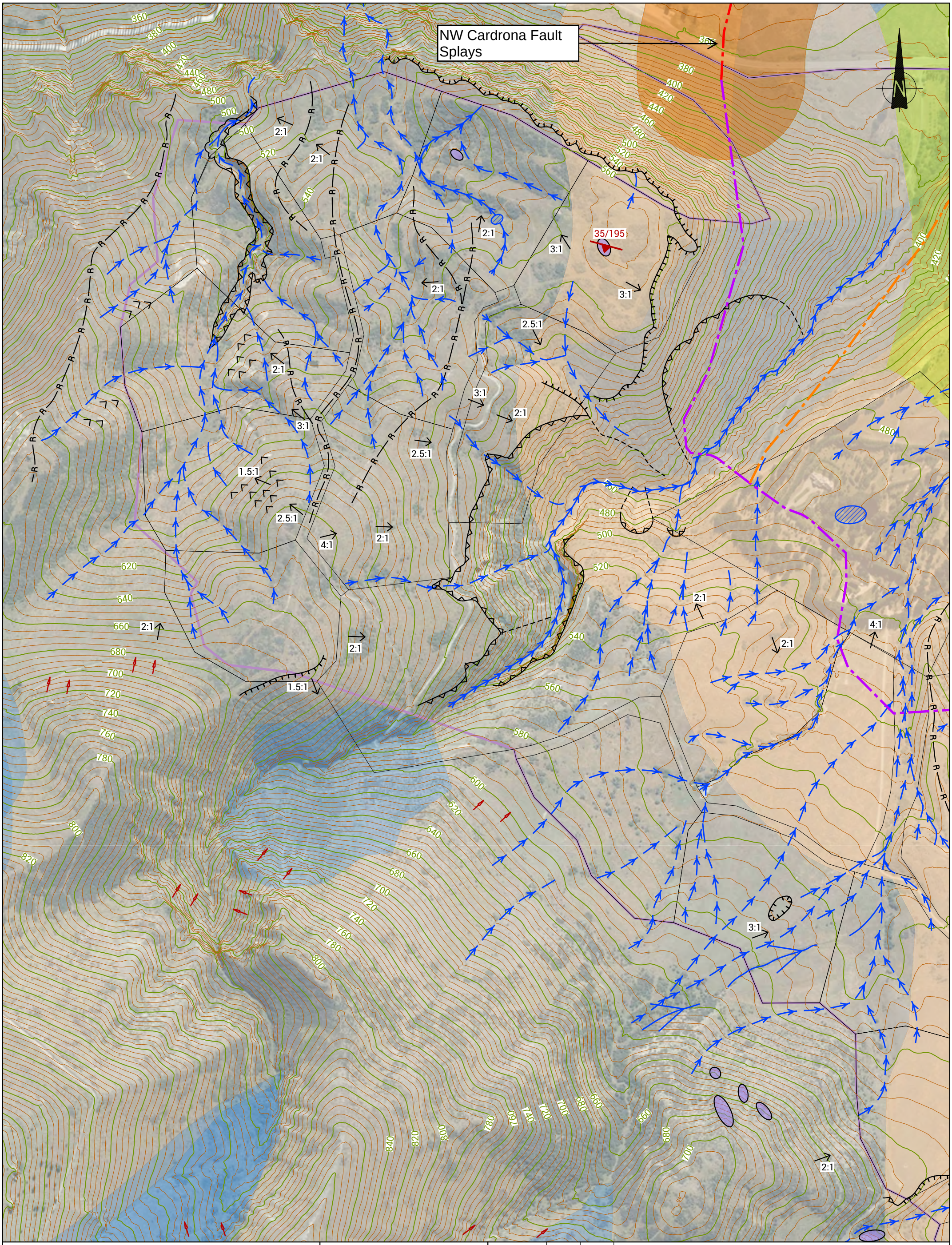
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Ara Tihi - Eastburn Geomorphology Plan (South)

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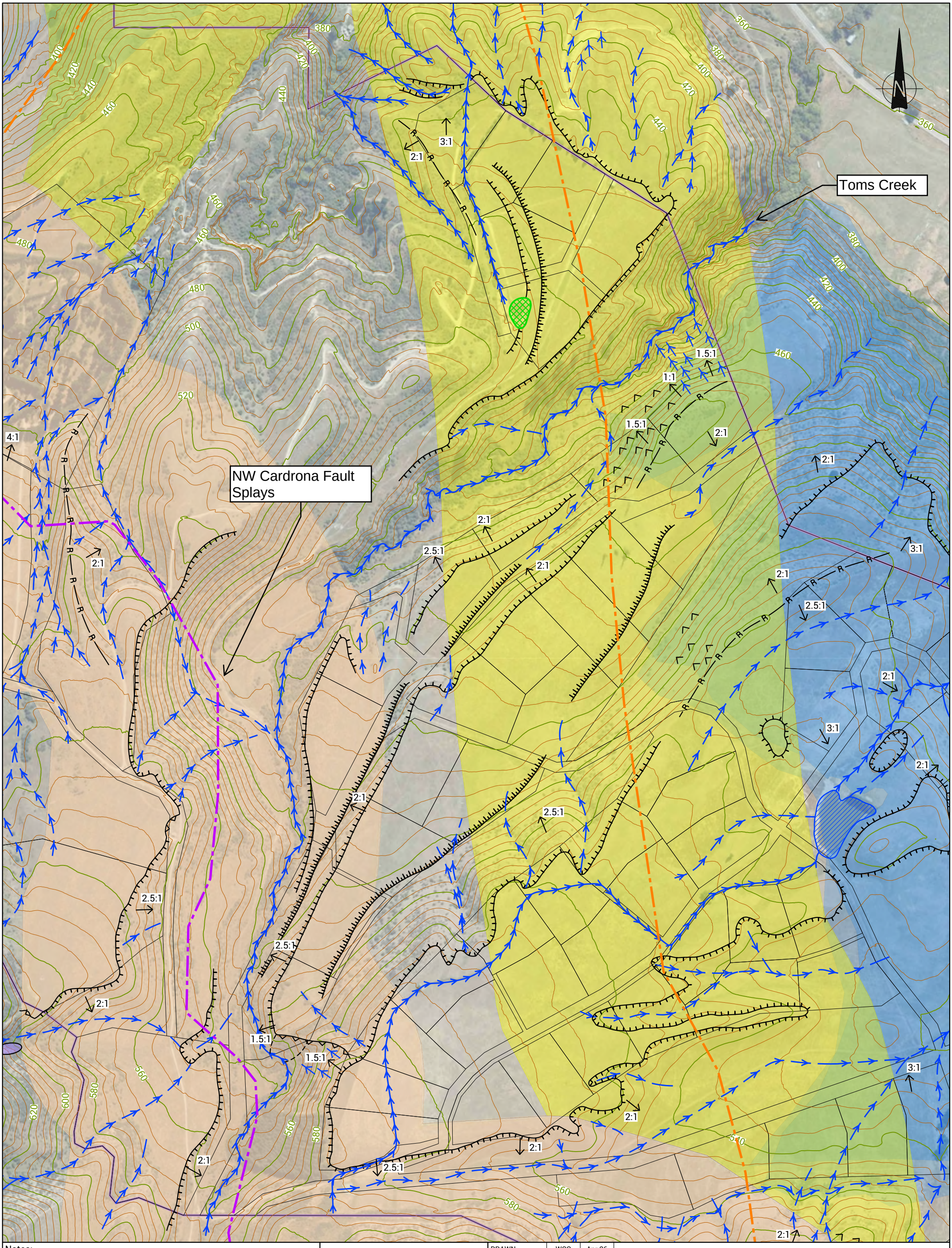
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Geotechnical Assessment

Mānia - Glenlee Glenroy Geomorphology Plan (North)

Figure No.: Appendix A, Figure 3a

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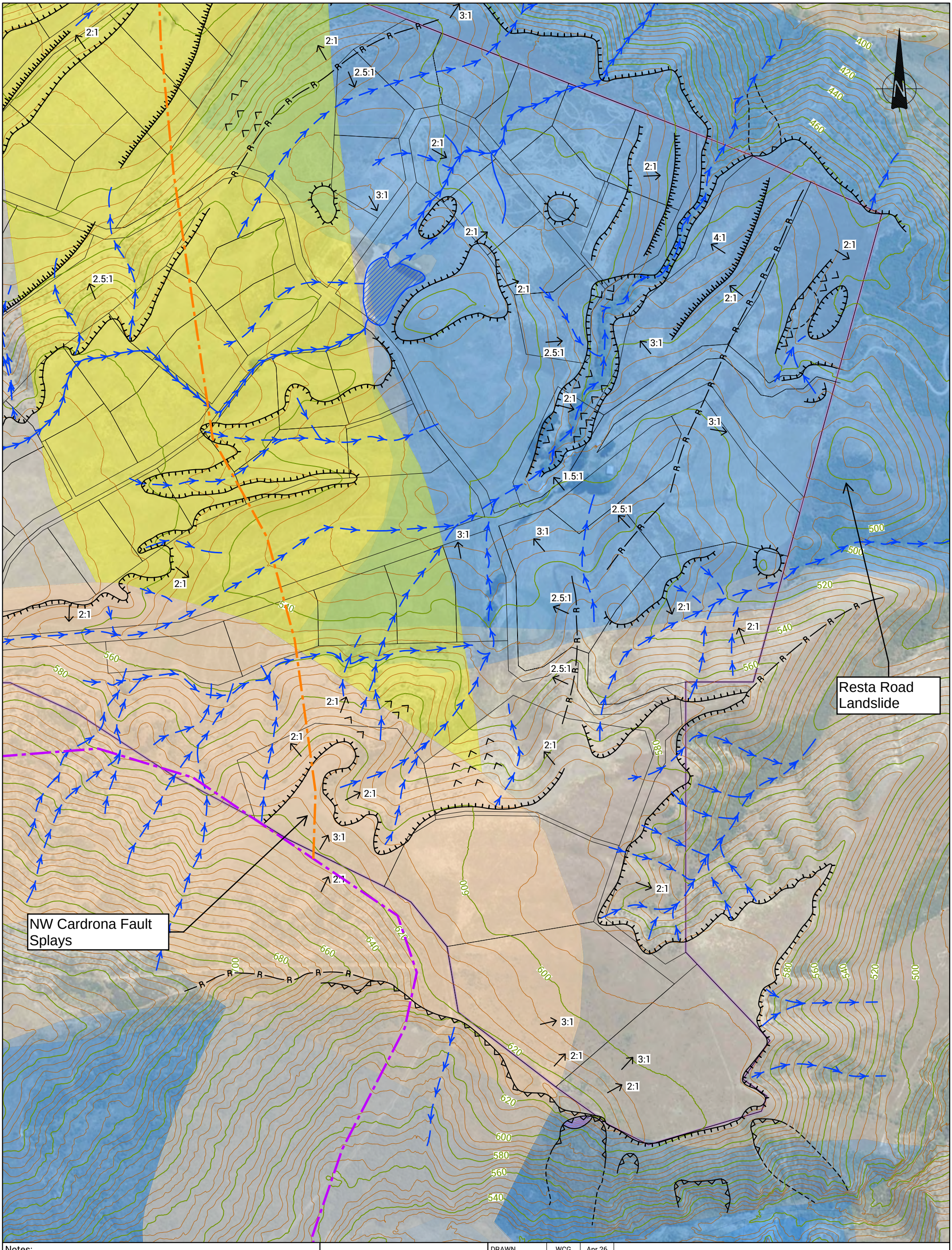
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Geotechnical Assessment

Mānia - Glenlee Glenroy Geomorphology Plan (Centre)

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Mānia - Glenlee Glenroy Geomorphology Plan (South)

Figure No.: Appendix A, Figure 3c

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Karapuken - Drystone Geomorphology Plan

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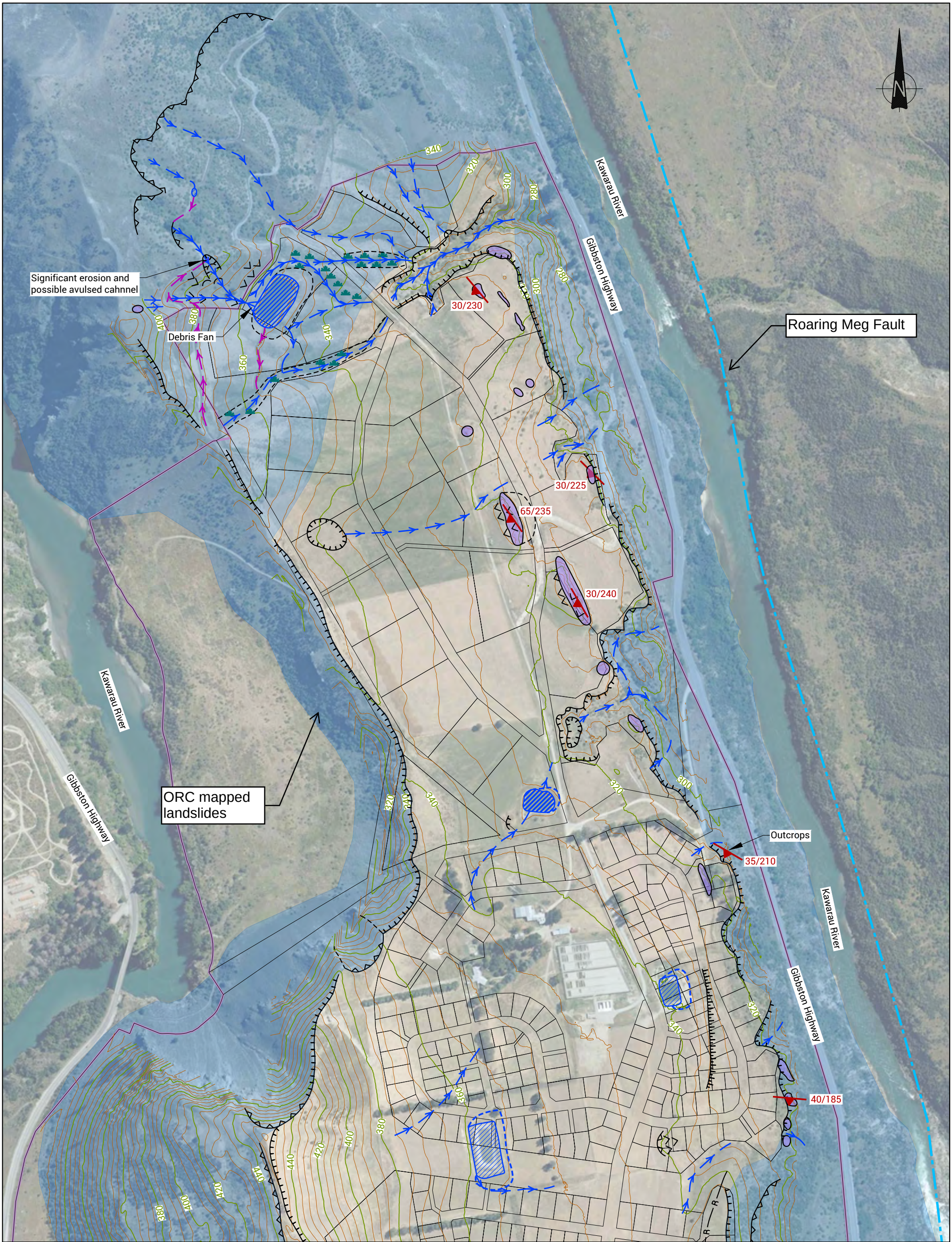
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Taiheke - Riverside Geomorphology Plan

Figure No.: Appendix A, Figure 5

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Geotechnical Assessment

Kūrae - Waitiri Geomorphology Plan (North)

Figure No.: Appendix A, Figure 6a

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Geotechnical Assessment

Kūrae - Waitiri Geomorphology Plan (South)

Figure No.: Appendix A, Figure 6b
Revision: 0

Appendix B: Geotechnical Risk Zoning Maps

Risk Zone Legend:

Low risk (green) areas - low risk where conventional geotechnical design and construction techniques are likely to be utilised.

Medium risk (yellow) areas - specific geotechnical design required to mitigate minor hazards.

High risk (orange) areas - specific geotechnical design required to mitigate hazards, with greater cost implications due to more robust mitigation requirements. May require complex and commercially intensive engineering and mitigation to allow development in these areas.

Very high risk (red) areas - areas susceptible to large-scale hazards that may cover large areas across multiple lots. Will require no-build zones / avoidance. Repositioning of building platforms and civil infrastructure will likely require consideration.

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Geotechnical Assessment

Zoning Plan Glossary

Figure No.: Appendix B, Figure 1

Revision: 0

Annotated mitigation options are indicative and subject to detailed assessment.

Localised stream erosion and bank instability.

Alluvial fan area.

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Waitiri Development, Gibbston Valley

Geotechnical Assessment

Ara Tihi - Eastburn Risk Zoning Plan (North)

Annotated mitigation options are indicative and subject to detailed assessment.

Locally low lying area with several separate catchments above. Flooding risk.

Ravine is ~ 50m deep - large-scale instability at crests.
Orange and red crest setbacks 50 m.
Mitigation option: orange - palisade piles

Shallow overland flowpath. Mitigation option: local subsoil drains, raised platforms

Minor perched seepages and surficial soil creep instability on shallow rock.
Mitigation option: local subsoil drains, shallow foundation piles

Lower catchment area and significant perching on schist. Several ponds present in this area.
Mitigation option: orange - significant subsoil drainage

Ravine is ~ 50m deep.
Orange and red crest setbacks 50 m.
Mitigation option: orange - palisade piles

Evidence of deep soil and scarps. Slope is at least ~200 m high above Kawarau Valley.
Orange and red crest setbacks 100 m. Stability modelling will refine these zones.
Mitigation option: orange - palisade piles

Notes:
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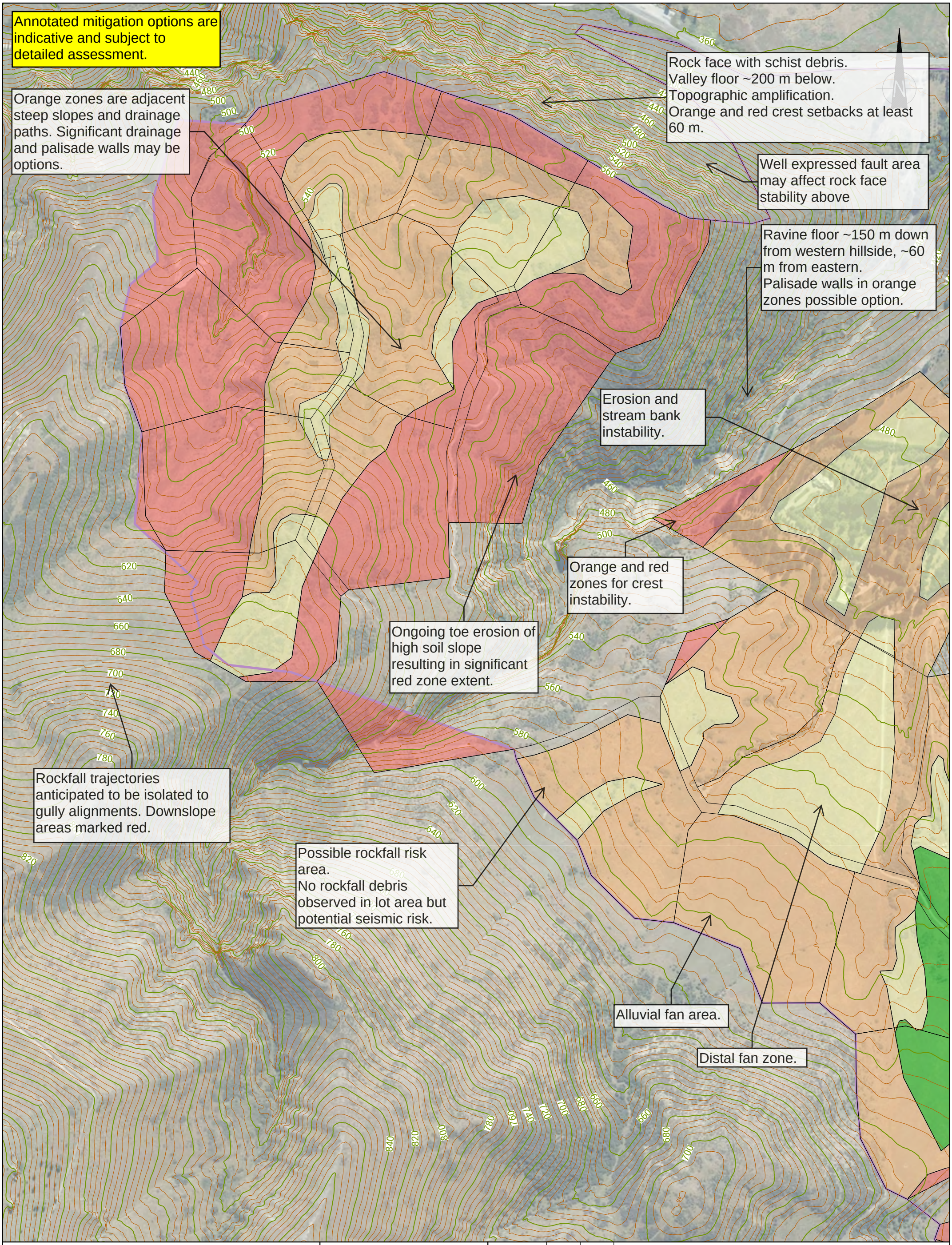
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DRAWN	WCG	Apr.26
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APPROVED	FAW	Apr.26

CAD File: 260204.dwg
Scale (at A3): 1:5,000
Project No.: 260204
Figure No.: Appendix B, Figure 2b
Revision: 0

Oaks Living Limited
Waitiri Development, Gibbston Valley
Geotechnical Assessment
Ara Tihi - Eastburn Risk Zoning Plan (South)



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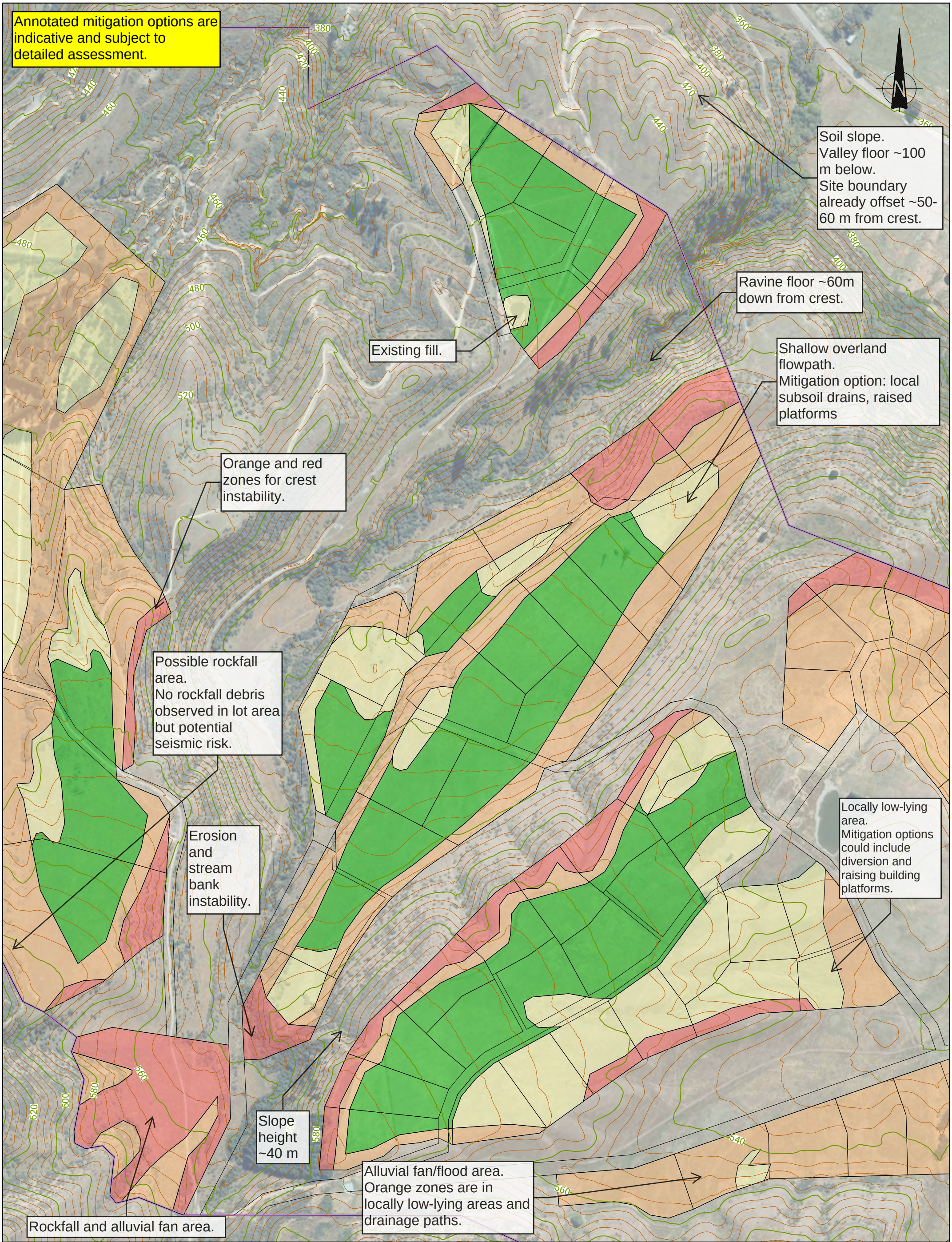
Waitiri Development, Gibbston Valley

Geotechnical Assessment

Mānia - Glenlee Glenroy Risk Zoning Plan (North)

Figure No.: Appendix B, Figure 3a

Revision: 0



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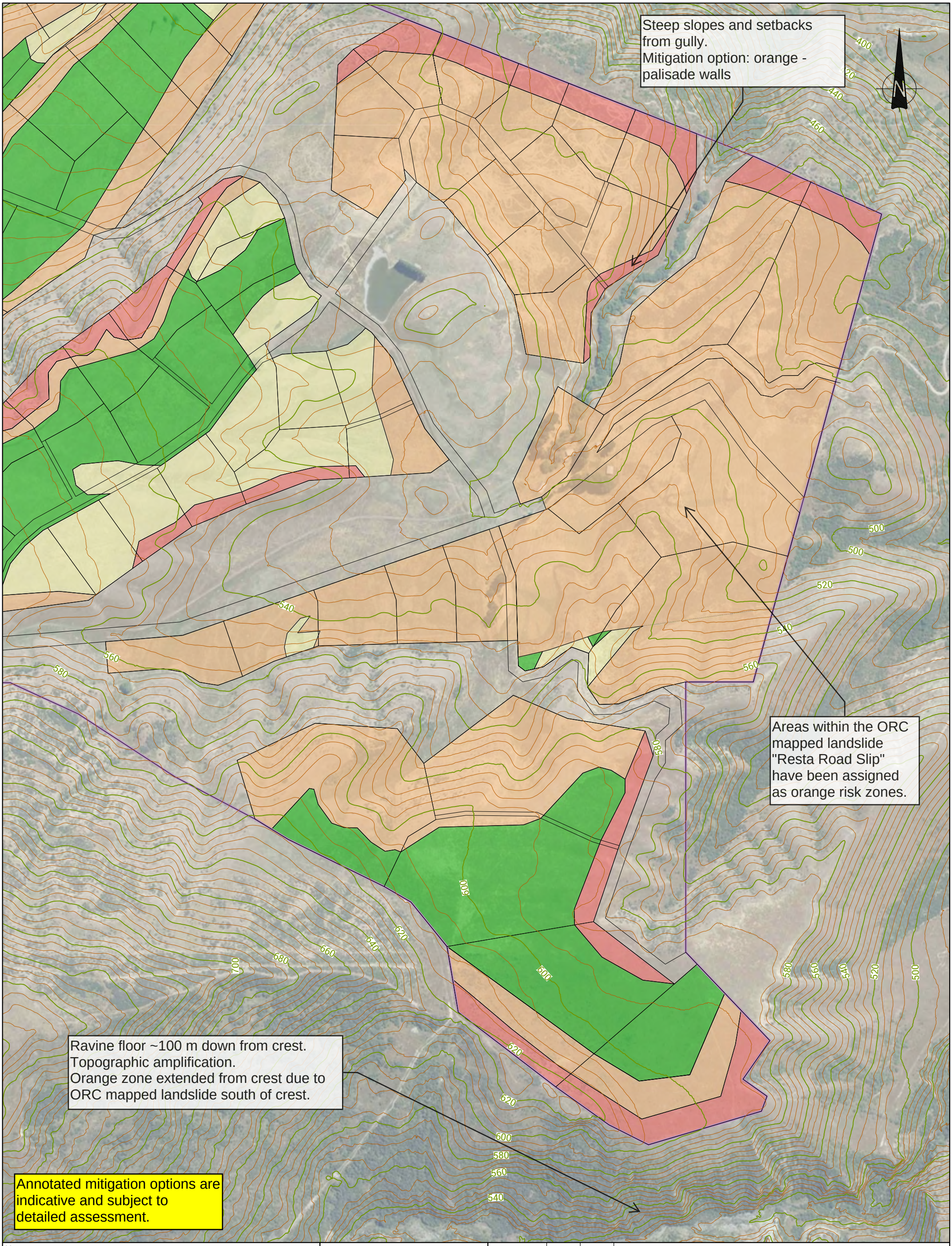
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Geotechnical Assessment

Mānia - Glenlee Glenroy Risk Zoning Plan (Centre)

Figure No.: Appendix B, Figure 3b
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Oaks Living Limited
Waitiri Development, Gibbston Valley
Geotechnical Assessment
Mānia - Glenlee Glenroy Risk Zoning Plan (South)

Figure No.: Appendix B, Figure 3c
Revision: 0

Annotated mitigation options are indicative and subject to detailed assessment.

Crest instability in soil on road cut 6-8 m high.

Locally low-lying area below uncertified dam - flooding risk.
Possible localised liquefaction.

10-15 m high rock slope with ~15m soil slope above.

Challenging construction likely on terraced vineyard terrain.

Alluvial fan/flooding.

Moderate slope beyond boundary and localised shallow gully heads may require consideration.

Gibbston Highway

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Waitiri Development, Gibbston Valley
Geotechnical Assessment
Karapuken - Drystone Risk Zoning Plan

Figure No.: Appendix B, Figure 4
Revision: 0

Annotated mitigation options are indicative and subject to detailed assessment.

Kawarau River ~50m down. GeoSolve ref. 190624 completed rock mapping of this face and concluded foliation measurements were favourable.

Orange slope zone.

Existing structures and possible 1980s mining area

Crest setbacks

Kawarau River

Existing pond and potential flooding zone.

Possible 1980s mining area

Low height rock bluff exposures may be addressed with scaling and spot bolting.

Gibbston Highway

Stream 10-15 m down. Orange zones adjacent stream bank crests may be mitigated with palisade piling.

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Scale (at A3): 1:3,000
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Oaks Living Limited

Waitiri Development, Gibbston Valley
Geotechnical Assessment
Taiheke - Riverside Risk Zoning Plan

Figure No.: Appendix B, Figure 5
Revision: 0

Annotated mitigation options are indicative and subject to detailed assessment.

Flows from existing pipework in hills above have caused significant erosion and possible avulsion, leading to saturation of this area.
Mitigation options could be assessment of existing infrastructure and design of diversion
ORC landslides mapped in this area.

Historic mining tailings within gully

Significant erosion and possible avulsed cahnnel

Debris Fan

Crest setbacks from crest of 40-50 m high ridge.

Potential zone affected by flooding.
Minor mitigation anticipated.

Possible rockfall zone with a likely minimal runout distance.
Mitigation options could include scaling, localised rock bolting or protection bund.

Yellow zone possible localised moderately steep slopes and shallow overland flowpaths.
Mitigation options - foundation piling and subsoil drainage.

Crest setbacks from crest of 40-50 m high ridge.

Historic mining tailings within gully

Existing pond flooding risk.

Outcrops

Orange and red crest setbacks.
Palisade wall option.

Existing pond flooding risk.

Existing pond flooding risk.

Kawarau River

Gibbston Highway

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Oaks Living Limited
Waitiri Development, Gibbston Valley
Geotechnical Assessment
Kūrae - Waitiri Risk Zoning Plan (North)

Figure No.: Appendix B, Figure 6a
Revision: 0

Annotated mitigation options are indicative and subject to detailed assessment.

Existing pond flooding risk.

Rockfall risk area. Possible mitigation could include protection bund design.

Possible shallow seepage initiating slumping upslope. Existing pond flooding risk downslope. Drainage and earthworks (e.g., removal of slip material) may be an option.

Possible rockfall risk/debris area (obscured by vegetation). Schist debris runout area.

~80-90 m from crest to SH6

Orange and red crest setbacks and shallow overland flow. Palisade wall option/drainage.

1m3 boulder

Outcrops

Gibbston Highway

Kawarau River

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Oaks Living Limited
Waitiri Development, Gibbston Valley
Geotechnical Assessment
Kūrae - Waitiri Risk Zoning Plan (South)

Figure No.: Appendix B, Figure 6b
Revision: 0



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