Preliminary Geotechnical Assessment

Ladies Mile Masterplan Area, Queenstown

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Candor3

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GEOTECHNICAL WATER RESOURCES PAVEMENTS

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1 Introduction

1.1 General

This report presents the results of a preliminary geotechnical inspection and desk top study carried out by GeoSolve Ltd to enable comment on the subsurface conditions and expected geotechnical issues for the Ladies Mile masterplan area.

Photograph 1a – Site photo taken on the hills east of the site, looking south across the masterplan area.

This assessment has been completed for Candor3 in accordance with the GeoSolve Ltd short form agreement dated 21 August 2020, which outlines the scope of work and conditions of engagement.

The opinions and conclusions presented in this report are based on the following sources of information:

- A walkover inspection and mapping of the site by an engineering geologist;
- A review of historic information currently held on the Geosolve database for sites in the local area;
- A review of the Queenstown Lakes District Council and Otago Regional Council natural hazard register maps, and;
- A review of the published geological map, 'Institute of Geological & Nuclear Sciences Ltd, Geology of the Wakatipu, 1:25,0000 Geological Map 18'.

2 Site Description

2.1 General

The Ladies Mile masterplan area of focus is approximately 160 Ha in size, and is located between Shotover River and Lake Hayes, as shown in Figure 1 below. State Highway 6 (Frankton-Ladies Mile Highway) runs in an east-west direction through the site.

Figure 1 – Site location plan. The Ladies Mile Masterplan Area of Focus is marked in red ***(map sourced from maps.qldc.govt.nz/qldcviewer).***

The site area is largely undeveloped and comprises farmland, associated farming infrastructure, council infrastructure, roading networks, scattered residential dwellings and associated outbuildings. There is sporadic vegetation across the study area.

The site is bounded by Shotover River to the west, Slope Hill to the north, Lake Hayes to the east and the existing Lake Hayes Estate, Queenstown County Club and Shotover Country residential areas to the south.

2.2 Topography and Surface Drainage

2.2.1 General

An overview plan showing site boundaries and 5 m topographic contours is attached in Figure 1, Appendix A. Detailed plans of the development area showing 1 m topographic contours are attached in Figures 2-7, Appendix A.

For the purposes of this report we have separated the masterplan area into the following topographic areas; sub-horizontal terrace, northern hillslopes, southern terrace slope, eastern slopes and western slopes and terraces, as shown in Figure 1, Appendix A and explained below.

2.2.2 Sub-horizontal terrace

The majority of Ladies Mile masterplan area is situated on a sub-horizontal terrace, with an altitude of approximately 352-366 m above sea level and gradient of < 1° towards the east-northeast. Immediately beyond the southern boundary, the ground falls moderately to steeply (20-35°) to the south and southwest, approximately 7-18 m down a historic river terrace.

Surface drainage is generally expected to flow from the sub-horizontal terrace in a south, east and west direction and drain to more permeable layers beneath the site. It is expected that groundwater flows track towards Lake Hayes and the Kawarau River at the eastern end of the site and Shotover River at the western end of the site.

Local culverts and drainage ditches/paths are present around the property boundaries in association with the adjacent road network.

2.2.3 Northern hillslopes

The area located along the toe of the northern hillslopes, along the northern perimeter of the masterplan area, is generally gently sloping to the south (approximately 2-5°). Immediately beyond the northern boundary, the ground rises and steepens up towards Slope Hill, with slopes of 15-35° locally. Subvertical schist bluffs also exist in isolated locations north of the masterplan area.

Well-incised gullies are formed in the hillslopes north of the site. Surface drainage generally flows in a southerly direction. Cut-off drains are present at the toe of the northern hillslopes, which divert water to retention ponds present in the locations shown on the attached Figures 3 & 5, Appendix A. From the retention ponds water generally drains to more permeable subsoil layers, and groundwater flows are expected to track towards Lake Hayes. Overland flows beyond base of the slopes were generally not observed.

2.2.4 Eastern slopes

The eastern part of the masterplan area is gently to moderately sloping (approximately 5-30°) to the east, towards Lake Hayes.

Large, well-incised gullies are present in the central part of this area, running in a west to east direction. The gullies are approximately 8-10 m deep with gully sides sloping approximately 30-45°. The gullies have significant topsoil development, aged vegetation and are understood to be generally dry year-round. It is inferred that these gullies are relic overland flow paths and have been abandoned following historic changes in overland flow paths.

Surface drainage is expected to flow in an easterly direction, towards Lake Hayes, but generally drains to more permeable layers below the site. Groundwater flows are expected to track towards Lake Hayes.

The site steepens and connects to the northern hillslopes, in the northern part of the site.

2.2.5 Western slopes and terraces

The topography of the western part of the masterplan area has an overall fall to the west, towards the Shotover River. The area comprises sub-horizontal benches separated by terraces sloping at approximately 20-30°. State Highway 6 runs east-west through the site, with cut slopes of up to approximately 15 m high formed for the road. All surface drainage and groundwater flows are expected to flow in a westerly direction, towards Shotover River.

3 Geotechnical Investigations

An engineering geologist from GeoSolve Ltd conducted site inspections between 12 & 14 October 2020 to identify prominent geological features and natural hazards. The sites which GeoSolve had access to for the mapping are shown in Figure 8, Appendix A.

A review of a number of historic geotechnical investigations held on the GeoSolve database, within and surrounding the masterplan area of focus, has been carried out for the preparation of this report. The investigation locations used to infer the likely site stratigraphy are described in Table 1 below.

Table 1: Investigation locations used to infer the likely site stratigraphy

Location	Investigations
Sub-horizontal terrace	7 test pits to depths of up to 3.3 m, 24 Scala penetrometer tests to depths of up to 1.9 m and 2 heavy dynamic probe tests to depths of up to 10.9 m. 4 sonic boreholes to 8 m depth and mapping of soil exposures.
	Geological mapping of the site, including soil exposures.
	30 test pits to depths of up to 4.3 m, 22 heavy dynamic probe tests to depths of up to 15 m and 3 sonic boreholes to 15 m depth with standard penetration testing.
Northern hillslopes	1 sonic borehole to 8 m depth and mapping of soil exposures.
	6 test pits to depths of up to 2 m with associated Scala penetrometers.
Eastern slopes	1 cone penetrometer test to 15 m depth. 4 test pits up to 3 m depth.
Western slopes and terraces	29 test pits to depths of up to 4.6 m with associated Scala penetrometer tests, 3 soakage tests, 5 sonic boreholes to depths of between 10 and 15 m and installation of 2 piezometers within the sonic boreholes to monitor groundwater levels.
	8 test pits to depths of up to 3.6 m with associated Scala penetrometers.
Entire site	Deep ORC well and bore data available on the ORC database.

No site-specific intrusive investigations have been completed for this report and on that basis all opinions, conclusions and recommendations that are presented in this report are preliminary in nature. The geotechnical conditions will need to be confirmed by site specific and building specific investigations and engineering assessment during the resource consent and detailed design phase.

4 Subsurface Conditions

4.1 Geological Setting

The site is located in the Wakatipu basin, a feature formed largely by glacial advances. The last advance occurred about 15,000 years ago, scouring the schist bedrock in the Lake Hayes area and depositing glacial till. On ice retreat, Lake Wakatipu initially formed at a high level (Frankton Flats - Queenstown Airport level). In the site area, sediments from the Shotover River built a large delta into the lake and silty sediments accumulated in the lakebed.

Headward erosion by the Kawarau River eventually intersected the lake and gradually lowered it to the current level. Lake Hayes, behind the delta barrier, was lowered by Hayes Creek, which cut a deep gully through the deltaic sediments in the site area. Downcutting slowed when the creek intersected a buried schist ridge, now evident in the Hayes Creek bed.

Active fault traces were not observed at the site or in the immediate vicinity, and the closest major active fault is the Nevis-Cardrona Fault system. However, significant seismic risk exists in this region from potentially strong ground shaking, associated with the rupture of the Alpine Fault, located 80 km northwest of Queenstown along the west coast of the South Island. There is a high probability that an earthquake with an expected magnitude of over M8 will occur along the Alpine Fault in the next 50 years.

4.2 Inferred Stratigraphy

No intrusive investigations have been completed for the purposes of this report; however, examination of local soil and rock exposures, and information contained on the Geosolve database has been used to infer the stratigraphy beneath the site.The GNS geological map of the site is shown in Figure 2 below.

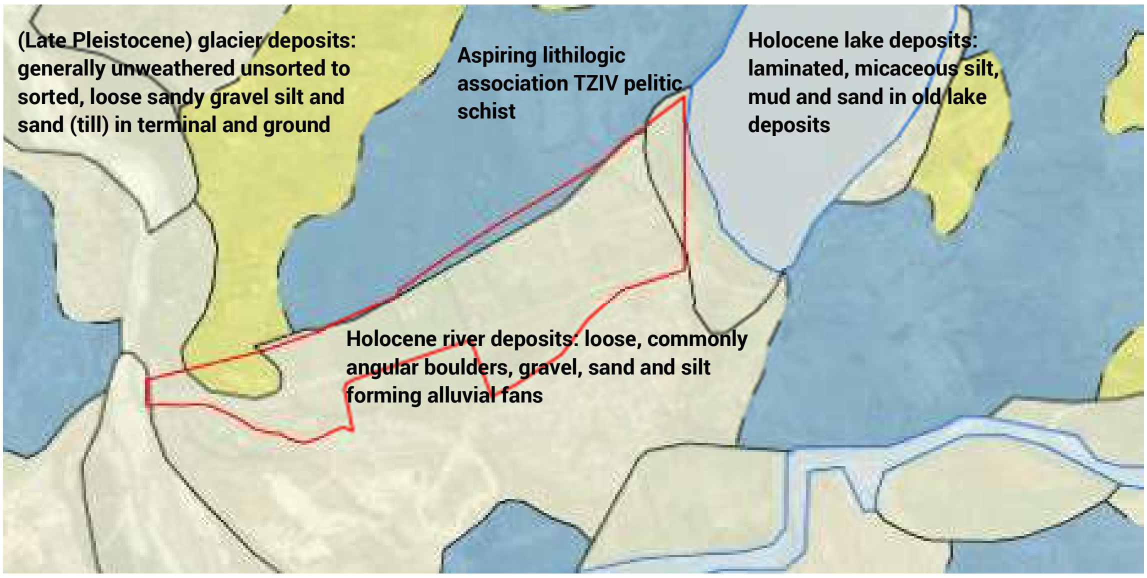


Figure 2: GNS geological map of the site (source https://data.gns.cri.nz/geology/). Site outline is marked in red.

The inferred subsurface conditions beneath the various parts of the site are summarised in Table 2 below.

Table 2: Inferred stratigraphy beneath the masterplan area.

Area	Expected subsurface conditions
Sub-horizontal terrace (majority of the site)	• **Topsoil**, overlying; • Approximately 0.1 to 1.0 m of **loess silt**, overlying; • Localised **alluvial silt**, overlying; • A significant thickness of (10-70+ m) of interbedded **deltaic/alluvial sand, gravel and silt** deposits with varying fractions of each constituent material.
Toe of northern hillslopes (localised areas only)	• **Topsoil**, overlying; • **Alluvial fan** depositional material, overlying; • **Alluvial silt**, overlying; • **Deltaic/alluvial silt, sand and gravel**, overlying; • **Schist bedrock** at depth.
Eastern slopes	• **Topsoil**, overlying; • Localised **alluvial fan** depositional material, overlying; • **Alluvial silt**, overlying; • **Deltaic/alluvial silt, sand and gravel**.
Western terraces and slopes (south-western area)	• **Topsoil**, overlying; • Localised **colluvium** (within sloping areas only), overlying; • **Loess silt**, overlying; • Up to approximately 1 m of localised **floodplain deposits**, overlying; • **Deltaic/alluvial sand, gravel and silt** deposits with varying fractions of each constituent material.
Western terraces and slopes (north-western area)	• **Topsoil**, overlying; • Localised **colluvium** (within sloping areas only), overlying; • **Loess silt**, overlying; • **Alluvial silt**, overlying; • **Deltaic/alluvial sand, silt and gravel**, overlying;

	• **Schist bedrock**.

Uncontrolled fill is expected to be sporadically present and variable in composition. There is expected to be many areas of shallow uncontrolled fill across the site associated with existing building, roads, landscaping mounds and general earthworks construction. Inferred areas of uncontrolled fill are shown on Figures 2-7, Appendix A.

An area of encapsulated **contaminated fill** is present within the eastern part of the masterplan area, in the location shown in Figure 7, Appendix A. The contaminated fill is approximately 3.0 m deep was placed in 2015 as part of the Threepwood residential development. Further comment is provided in Section 6.5 below.

Surficial **schist bedrock** was not observed within the masterplan area; however, schist bedrock was observed immediately north of the masterplan area in the locations shown on Figures 2 to 7, Appendix A.

4.3 Groundwater

The regional groundwater level is expected to lie at depth beneath the majority of the site area. Otago Regional Council (ORC) well data from the site indicates the regional groundwater table is at depths of approximately 39-51 m below the sub-horizontal terrace ground level, which covers the majority of the site area.

The groundwater level can reduce to 10-20 m depth at the east and west extremities of the site as the relative height reduces adjacent to the Shotover River and Lake Hayes. Seepage associated with overland flow paths is possible in the north of the site, close to the northern hillslopes.

5 Natural Hazards

The QLDC hazard map for the site is attached in Figure 9, Appendix A.

5.1 Seismic

A severe seismic risk is present in the region as discussed in Section 4.1 and appropriate allowance should be made for seismic loading during detailed design of future proposed buildings, foundations, retaining and associated earthworks.

5.2 Liquefaction

The majority of the site is identified on the Queenstown Lakes District Council (QLDC) natural hazard maps as being 'possibly susceptible' to liquefaction (Opus, 2002), with the eastern part identified as being 'susceptible' to liquefaction (Opus, 2002) and the north-western part not being mapped as being subject to a liquefaction risk. Our assessment indicates there is low liquefaction risk for the area mapped as 'possibly susceptible' to liquefaction (Opus, 2002) due to the significant depth to the regional groundwater table (approximately 39-51 m). No further investigations are considered necessary with respect to liquefaction in this area.

If development is proposed on the western shores of Lake Hayes, within the area mapped as 'susceptible' to liquefaction (Opus, 2002), further assessment will be required to quantify the liquefaction and lateral spreading risk, specific foundation design may be required.

The western masterplan area close to the Shotover River may also need further consideration.

5.3 Slope Stability

5.3.1 Northern hillslopes

The northern hillslopes are identified on the QLDC Hazard Maps as a landslide area 'susceptible to shallow debris flows' (Opus, 2002. Hazards Register Part II Stage 2 Risk Management Study). This hazard area is not mapped to extend onto the site, and apart from localised gully erosion upstream of the alluvial fans, no deep seated, recent or active instability of the soil slopes were observed on the hillslopes from the study area during the site walkover inspection. Further details regarding the alluvial fan hazard are discussed in Section 5.5.

Toe of slope stability

Toe of slope displacements have the potential to affect residential development located at the toe of the northern hillslopes. However, due to the geological model comprising surficial silt soils overlying schist bedrock, the risk of toe displacements affecting residential development is expected to be low. Further analysis should be undertaken at resource consent and detailed design stage. If subsequent detailed analysis reveals any significant hazard, this is expected to be readily avoided or mitigated by standard planning or engineering measures, such as suitable setback distances from the toe of the slope.

Historic landslide feature

A small historic landslide feature was observed above the north-eastern end of the hillslopes, in the location shown in Figure 7, Appendix A. Subvertical schist bedrock forms the scarps. This schist debris landslide is inferred to be slowly creeping in response to heavy rainfall and seismic events.

5.3.2 Southern terrace slope

A terrace slope varying between approximately 7-18 m high and sloping approximately 20-35° to the south and southwest, is present along the southern boundary of the masterplan area.

No deep seated or large-scale instability has been identified; however, stability of the slope will need to be assessed for foundation design purposes. Detailed slope stability assessments should be carried out at the resource consent and detailed design stage to determine appropriate building setbacks and any specific foundation requirements close to the crest of the slope.

Previous slope stability assessments completed by GeoSolve for sites along of the same terrace slope have shown setbacks for standard foundations have varied between 5 and 20 m from the slope crest. Engineered foundations with building specific design have achieved a setback of around 3.5-5 m from the slope crest.

5.3.3 Existing landslide feature, north-western area

The QLDC hazard maps show a landslide area in the north-western part of the masterplan area, see Figure 9, Appendix A. The landslide is identified as 'non verified.' The source of the landslide is noted as the IGNS QMAP 1:50,000 compilation sheets. This map and the accompanying overview report 'Surficial geology of the Wakatipu Basin, Central Otago, New Zealand, reference 94/39,1994' have been reviewed. An excerpt from the map showing the site location is provided below in Figure 3.

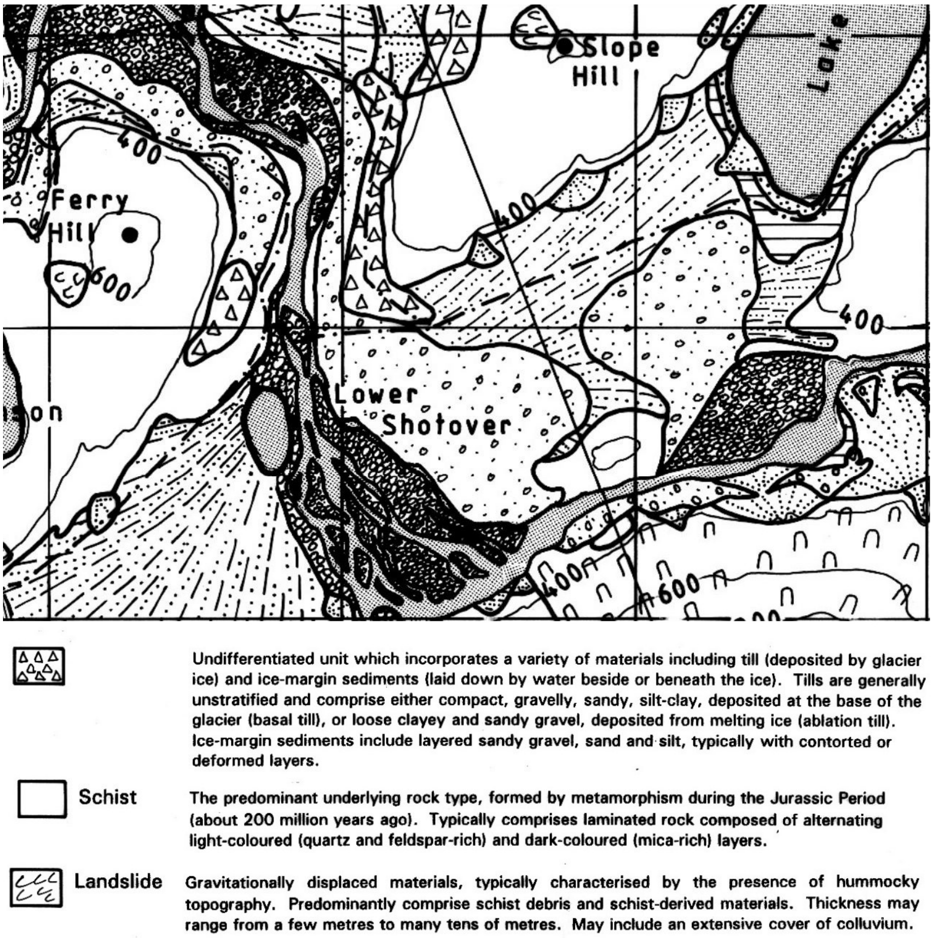


Figure 3: Excerpt from IGNS Map Surficial Geology of the Wakatipu Basin, October 1994

From Figure 3 above it can be seen that there is no landslide feature shown. The site area is shown to be underlain by glacial deposits in lower areas and schist bedrock in upper areas.

A walkover inspection has also been completed and the following comments are provided.

- The lower area of the landslide is characterised by historic river terrace and terrace riser landforms typical of those found around this area of the Shotover River.
- Schist bedrock, dipping west-southwest at 25°, was observed in the lower landslide area. This is characteristic of in-situ schist and untypical of a landslide.
- The upper areas are gently sloping and do not show the typical landforms expected of a landslide.
- In general, there are no distinctive landslide features present in the area.

Based on the above assessment it is considered likely that the landslide feature shown on the QLDC data results from an error whilst compiling the hazard maps.

However, GeoSolve does not have any subsurface investigations from within the mapped landslide area, and shallow test pits can be completed to verify the above opinion.

5.3.4 Sub-Horizontal Terrace, Western slopes and terraces & Eastern Slopes

Terrace slopes and eastern gullies

No deep seated or large-scale instability has been identified; however, stability of the slopes will need to be assessed for foundation design purposes. Detailed slope stability assessments should be carried out at the detailed design stage to determine appropriate building setbacks and any specific foundation requirements close to the crest of the slopes.

State Highway 6 excavation

The excavations for State Highway 6 are up to approximately 15 m high at a slope angle of approximately 30-35°. Deltaic sand and gravel are exposed in the excavations.

Shallow surface erosion was observed during the site walkover inspection, however no deep seated or large-scale instability has been identified. Stability of the slopes will need to be assessed at the detailed design stage.

5.4 Rock Fall

As discussed in Section 4.2, surficial schist bedrock was not observed within the masterplan area, however surficial schist bedrock is present immediately north of the masterplan area, in the locations shown on the attached Figures 2-7, Appendix A.

Small scale rock fall associated with localised weathering and gradual fretting of the rock bluffs beyond the northern boundary of the masterplan area was observed during the site mapping.

The risk of rockfall within the overall masterplan area is considered to be low, however if development is proposed in close proximity to the northern hillslopes, further mapping and review should be completed to confirm the risk and whether any mitigation is required.

Standard mitigation options such as allowing a suitable setback avoidance distance from slopes, rockfall bunds or bolting in situ rock outcrops is expected to be readily achievable.

5.5 Alluvial Fans

Northern Hillslopes

The QLDC hazard maps identify three alluvial fans along the northern hillslopes, as shown in Figure 9, Appendix A. These alluvial fans are all mapped as active, debris-dominated (GNS, 2005, regional scale mapping). Geomorphological mapping carried out by GeoSolve identified another four alluvial fans along the northern hillslopes, in the locations shown in Figures 2-3, 5 and 7, Appendix A. The alluvial fans along the toe of the northern hillslopes have been numbered 1-7 on the attached site plans, each alluvial fan is described in detail in Table 3 below.

Table 3: Alluvial fans along toe of northern hillslopes

Alluvial Fan #	QLDC hazard maps description	Site observations
1	N/A	Small-scale depositional feature from upslope overland flow paths/ephemeral streams. Well-established topsoil horizon, very low potential to mobilise debris within the channel, limited access feature inferred.
2	N/A	Small-scale depositional feature from upslope overland flow paths/ephemeral streams. Well-established topsoil horizon, very low potential to mobilise debris within the channel limited access feature inferred.
3	Active, debris dominated (GNS, 2005, regional scale mapping)	Well-established topsoil horizon, only minor flow in channel at time of site inspection, schist bedrock is exposed in gully above alluvial fan, large trees growing in channel, minor flow within gully appears to soak to ground near base of the slope, low potential to mobilise debris within the channel, floodwater dominated. North-eastward draining cut-off drain formed which diverts flow to pond. Diversion channel will need to be maintained/formalised to preserve potential flood-mitigation to the site if further development is proposed.
4	N/A	Well-established topsoil horizon, only minor flow in channel at time of site inspection (limited access, feature inferred), schist bedrock is exposed in gully above alluvial fan, large trees growing in channel, small ephemeral streams in gully drain to relatively permeable ground prior to reaching site boundary. North-eastward draining cut-off drain formed which diverts flow away from alluvial fan surface. Diversion channel will need to be maintained to preserve potential flood-mitigation to the site. Low potential to mobilise debris within the channel, floodwater dominated.
5	N/A	Well-established topsoil horizon, only minor seepage observed, schist bedrock exposed in gully above alluvial fan, large trees growing in channel. Flow from this feature appears to soak to ground.
6	Active, debris dominated (GNS, 2005, regional scale mapping)	Well-established topsoil horizon, only minor seepage observed, schist bedrock exposed in gully above alluvial fan, large trees growing in channel, water drains to holding pond within the alluvial fan, low potential to mobilise debris within the channel, floodwater dominated.

7	Active, debris dominated (GNS, 2005, regional scale mapping)	Rock exposed in gully above alluvial fan. Mitigation measures in place: channel lined with cobbles and boulders, diversion channel leads flow to the east with the outflow adjacent to Lake Hayes, through a culvert beneath the road. Overland flow is inferred to managed by the civil works undertaken for the Threepwood residential development.

From the available information and our site inspection and interpretations, we conclude that the risk from alluvial fan activity from the northern hillslopes is low. If subsequent detailed investigations reveal any significant hazard, this is expected to affect small areas only, and if necessary can be readily avoided or mitigated by standard planning or engineering measures, such as raised floor levels, flow attenuation (as conducted at Alluvial Fan feature 7) or constructing buildings outside the affected area. Sheet flood flow should be considered from these features as part of any future proposed development.

Eastern Slopes

The QLDC hazard maps identify an alluvial fan 'active, floodwater-dominated' within the eastern part of the site, on the slopes above Lake Hayes as shown in Figure 9, Appendix A.

The catchment for this feature comprises two large incised gully features. It is understood that no other flow source areas contribute to these gullies. It is inferred that these gullies are relic overland flow paths and have been abandoned following historic changes in overland flow.

The alluvial fan source area was observed to have very low potential to mobilise debris within the channel and was dry at the time of our site inspection.

From the available information and our site inspection and interpretations, we conclude that the risk from alluvial fan activity in this location is low. If subsequent detailed investigations reveal any significant hazard, this is expected to affect small areas only, and if necessary, can be readily avoided or mitigated by standard planning or engineering measures, such as raised floor levels or constructing buildings outside the affected area.

It should be noted that a stormwater detention basin constructed as part of Threepwood residential development is located adjacent to the northern drainage channel. If the capacity of the basin is exceeded in a large rainfall event overland flow could be diverted into this drainage channel.

5.6 Flooding

Shotover River

A flooding-rainfall risk from the Shotover River is identified on the QLDC hazard database along the western perimeter of the site, partially extending into the lower slopes. If development is proposed within this area, further assessment is required to determine flood-mitigation measures, such as minimum floor levels.

Lake Hayes

No flooding risk along the western shore of Lake Hayes is mapped on the QLDC hazards database. However, if development is proposed in close proximity to Lake Hayes it is recommended that a flooding assessment is carried out to determine minimum floor levels.

5.7 Historic Quarrying Activity

An anecdotal area of historic lime quarrying is present within the eastern slopes of the subject site, as shown in Figure 7. This area is localised however, any fill material associated with this activity could be subject to settlement following a major regional earthquake event. Any foundations proposed within this area will require specific engineering design and assessment at detailed design stage.

6 Preliminary Engineering Considerations

6.1 General

The recommendations and opinions contained in this report are based upon historical ground investigation data obtained at discrete locations which is held on the GeoSolve database. No specific intrusive investigations have been undertaken by GeoSolve for this assessment and therefore all conclusions and recommendations within this report should be considered preliminary and are to be confirmed by further investigation.

6.2 Slope Stability

Toe of slope stability adjacent to the northern hillside and crest stability adjacent to incised gullies and terrace slopes will need to be considered as part of any future development.

An isolated existing schist debris landslide is located in the northern eastern corner of the masterplan area, as shown in Figure 7, and is inferred to be slowly creeping in response to high rainfall and seismic events.

Detailed slope stability assessments of the site, particularly for areas affected by existing slope instability, should be carried out upon completion of further investigations to determine any specific mitigation requirements.

Several remedial options, or combination of options, are available to address any identified slope stability issue and include;

- Extending pile foundations for affected buildings down to key into underlying competent rock (suitable along toe of northern hillslopes only where depth to rock is shallow);
- Construction of a dense, granular geogrid raft beneath affected buildings and/or a geogrid reinforced slope crest;
- Building strengthening to accommodate expected displacements;
- Construction of an in-ground wall along the crest of the slopes;
- Increase building setbacks from sloping areas.

6.3 Rock fall

Bluffs and relatively steep slopes are present immediately beyond the northern boundary of the site. There is some natural weathering and minor fretting of the rock faces observed, but these are unlikely to impact on the site. Our preliminary analysis indicates the risk of rock fall is low, however if development is proposed in close proximity to the northern hillslopes, further mapping and review should be completed to confirm whether any mitigation is required.

6.4 Alluvial Fan

Our preliminary analysis indicates the risk of alluvial fan activity from the northern hillslopes and eastern slopes is low. If subsequent detailed investigations reveal any significant hazard, this is expected to be minor and affecting small areas only, and if necessary can be readily avoided or mitigated by standard planning or engineering measures, such as raised floor levels or constructing buildings outside the affected area.

6.5 Uncontrolled Contaminated Fill Material

As discussed in Section 4.2 above, approximately 3.0 m of contaminated fill is present within the eastern part of the masterplan area, see Figure 7, Appendix A.

This area is not suitable for development in its current state. If the area is to be developed, all contaminated fill will have to be removed from site and engineered fill will be required to re-establish site levels.

6.6 Foundations

6.6.1 General

During the earthworks operations all topsoil, organic matter, uncontrolled fill and other unsuitable materials should be removed from the construction areas in accordance with the recommendations of NZS 4431:1989.

Loess Silt, Sandy Silt and Silty Sand Deposits - Shallow foundations can be constructed across the site, however reduced foundation bearing capacities are likely if bearing on the near-surface silt, sandy silt and silty sand deposits. These soil materials typically provide low ultimate bearing capacities of approximately 120 to 180kPa as identified in historic geotechnical investigations within the masterplan area, assuming NZS3604 type footings, and are typically subject to loss of strength due to weather and trafficking during construction. Specific engineering assessment and foundation design and undercutting and replacement with granular engineered fill is generally undertaken to improve the foundation bearing capacity in these soil types. A reduced bearing capacity in comparison to NZS 3604 "good ground" is available in these soil types.

Deltaic Sand and Gravel - Increased foundation bearing is expected to be available on sand and gravel soil materials. These soil materials observe some variability. NZS 3604 "good ground" is expected to be present in some areas; however, lower ultimate bearing capacities of 180-270 kPa, assuming NZS3604 type foundations, is possible.

The ground is unlikely to consistently meet the minimum requirements for 'good ground' (i.e. >5 blows per 100 mm) in accordance with NZS3604:2011 within the upper soils.

Typical shallow foundation e.g. strip, pad and waffle slabs will be suitable provided they take into account local bearing capacity variations and are proportioned accordingly. Where weaker soils are present beneath foundation footprints undercutting and replacement with engineered fill compacted in accordance with NZS4431 is also expected to provide a feasible option.

Extending footings, or pile foundations, down to bear on the underlying deltaic sand and gravel, which will provide improved bearing, may be an alternative solution and may be required for larger buildings.

Site specific and building specific investigations to confirm bearing capacity should be provided as per the QLDC guidelines as part of the resource consent and detailed design stage.

Specific investigation and assessment should be completed to determine a cost-effective foundation solution for any proposed development, at the resource/building consent and detailed design stage.

Buildings located close to the crest and toe of the existing slopes may require specific engineering design by a suitably qualified and experienced structural engineer.

6.6.2 Multi-storey buildings

Multi-storey buildings are expected to be feasible at the site provided that foundations are extended down to bear on the alluvial sand and gravel deposits. Building-specific confirmation of bearing capacity should be carried out at the detailed design stage.

If required, ground improvement is expected to be readily achievable by placing engineered fill beneath foundation areas to increase foundation bearing capacity.

It should be noted that the preliminary engineering considerations for the alluvial fan and rockfall risk, Section 6.4 and 6.3 respectively, are applicable to single and multi-storey residential building developments.

6.7 Groundwater Issues

The water table is expected to lie at depth beneath the site and any proposed excavations. Dewatering or other groundwater-related construction issues are unlikely to be required.

6.8 Surface Runoff and Drainage

Stormwater management will need to be adressed as part of future development.

The overall drainage pattern within the site is expected to flow from Slope Hill to the base of the northern hillslopes, where water soaks to ground. Groundwater flows are expected to track towards Lake Hayes and the Kawarau River at the eastern end of the site and Shotover River at the western end of the site.

6.9 Stormwater Soakage

On-site stormwater soakage disposal is expected to be readily achievable within the site.

The subsurface conditions vary between loose to medium dense silt, sand and gravel compositions.

Historic soakage testing carried out by GeoSolve within the masterplan area have returned soakage values ranging from 1x10-4 to 2x10-6 m/s.

Specific soakage testing will be required in future areas of soakage disposal.

7 Future Geotechnical Site Investigations

Further geotechnical site investigation is required to confirm the geological model and provide geotechnical parameters for resource and building consent application and detailed design. Further investigations should comprise:

- A test pit investigation to determine ground conditions at shallow depths;
- Undertake a detailed slope stability assessment of the slope along the southern site boundary, to determine any specific mitigation requirements;
- Development of the geological model. Geological cross section model – several cross sections extending through the site;
- Heavy dynamic probe (DPH), cone penetrometer (CPT) or bore hole testing for multi-storey buildings;
- Review of proposed earthworks and foundation options;
- Geotechnical assessment and reporting suitable for resource and building consent.

If development is proposed along the northern site boundary, the following is recommended:

- Undertake a rockfall assessment to determine any mitigation requirements in the northern area of the site.
- Undertake an alluvial fan assessment (inferred to be floodwater dominated) to determine any mitigation requirements in the northern area of the site.

If development is proposed along the eastern site boundary (along the western shores of Lake Hayes) the following is recommended:

- Heavy dynamic probe (DPH) or cone penetrometer (CPT) to quantify the liquefaction and lateral spreading risk;
- Flooding analysis of Lake Hayes to determine minimum floor levels.

If development is proposed along the western site boundary (along Shotover River) the following is recommended:

- Flooding analysis of Shotover River to determine minimum floor levels.

8 Conclusions and Recommendations

- This report has been based on historic data on the GeoSolve database. The existing geotechnical information is limited to discrete areas within the masterplan area.
- Preliminary assessment indicates that future development at the site is feasible from a geotechnical perspective provided further investigation and assessment is undertaken. No geotechnical issues were identified which cannot be addressed by standard engineering assessment and construction practices. Specific geotechnical design input will be required for retaining design, slope stability, rock fall, alluvial fan, liquefaction risk, foundations and construction methodology.
- The inferred site stratigraphy for the various areas of the site is presented in Table 2.
- In general, the surface geology is not consistent and for shallow foundations bearing capacity will vary. Preliminary assessment indicates suitably proportioned foundations or undercut and replacement with engineered fill will provide suitable options.
- Extending footings or pile foundations down to bear on a competent layer at depth (alluvial sand and gravel) is expected to be a feasible option, depending on detailed design and assessment.
- Our assessment indicates there is low liquefaction risk for the area mapped as 'possibly susceptible' to liquefaction (Opus, 2002) due to the significant depth to the regional groundwater table (approximately 39-51 m). No further investigations are considered necessary with respect to liquefaction in this area.
- If development is proposed on the western shores of Lake Hayes, within the area mapped as 'susceptible' to liquefaction (Opus, 2002), further assessment will be required to quantify the liquefaction and lateral spreading risk.
- There is a region-wide seismic risk at the site, which should be addressed in all future engineering design.
- Further site investigation and assessment is required. The assessment should confirm the preliminary recommendations in this report and provide detailed engineering recommendations as appropriate.

9 Applicability

This report has been prepared for the benefit of Candor3 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.

Yours faithfully,

…………………………………….

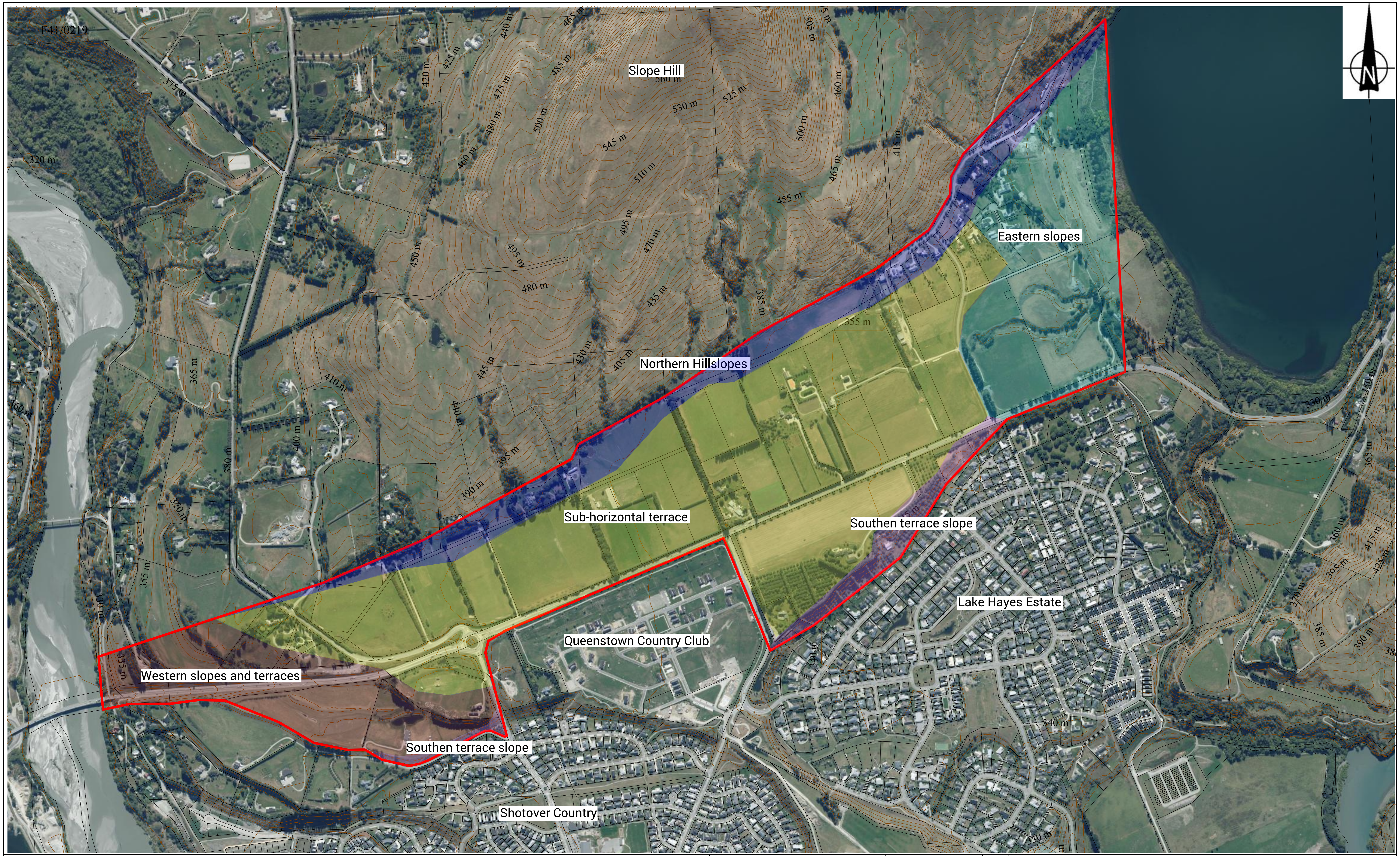
Simon Reeves
Engineering Geologist

Reviewed for GeoSolve Ltd by:

…………………………………….

Fraser Wilson
Senior Engineering Geologist

Appendix A: Overview Plan, Site Plans, QLDC Hazard Maps



Key

Ladies Mile Masterplan Area of Focus

5 m contour interval
LiDAR data from QLDC Open Maps

Scale 1:10 000
0 100 200 300 400 500 (m)

CADFILE:	Sketch 1.xar	DRAWN	MBS	10/2020
SCALE (AT A3 SIZE):	AS SHOWN	DRAFTING CHECKED	SR	10/2020
PROJECT No:	200353	APPROVED	FAW	10/2020

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WATER RESOURCES
PAVEMENTS

Candor3
Ladies Mile Masterplan
Ladies Mile, Queenstown
Overview Plan

FIG No: FIGURE 1

REV. 1

Key

- Ladies Mile Masterplan Area of Focus
- Expected areas of uncontrolled fill
- Top of slope
- Schist bedrock
- Overland flow path
- ORC wells

CADFILE:	Sketch 1.xar	DRAWN	MBS	10/2020
SCALE (AT A3 SIZE):	AS SHOWN	DRAFTING CHECKED	SR	10/2020
PROJECT No:	200353	APPROVED	FAW	10/2020

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Ladies Mile Masterplan
Ladies Mile, Queenstown
Site Plan

FIG No: FIGURE 2

REV. 1

Key

Top of slope	Soil outcrop	ORC wells
Expected areas of uncontrolled fill	Overland flow path	
Schist bedrock	Dip/dip direction	

1 m countour interval
LiDAR data from QLDC Open Maps

CADFILE:	Sketch 1.xar	DRAWN	MBS	10/2020
SCALE (AT A3 SIZE):	AS SHOWN	DRAFTING CHECKED	SR	10/2020
PROJECT No:	200353	APPROVED	FAW	10/2020

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Candor3
Ladies Mile RFP
Ladies Mile, Queenstown
Site Plan

FIG No: FIGURE 3
REV. 1

Key

- Top of slope
- Expected areas of uncontrolled fill
- Soil outcrop
- Overland flow path
- ORC wells

1 m countour interval
LiDAR data from QLDC Open Maps

CADFILE:	Sketch 1.xar	DRAWN	MBS	10/2020
SCALE (AT A3 SIZE):	AS SHOWN	DRAFTING CHECKED	SR	10/2020
PROJECT No:	200353	APPROVED	FAW	10/2020

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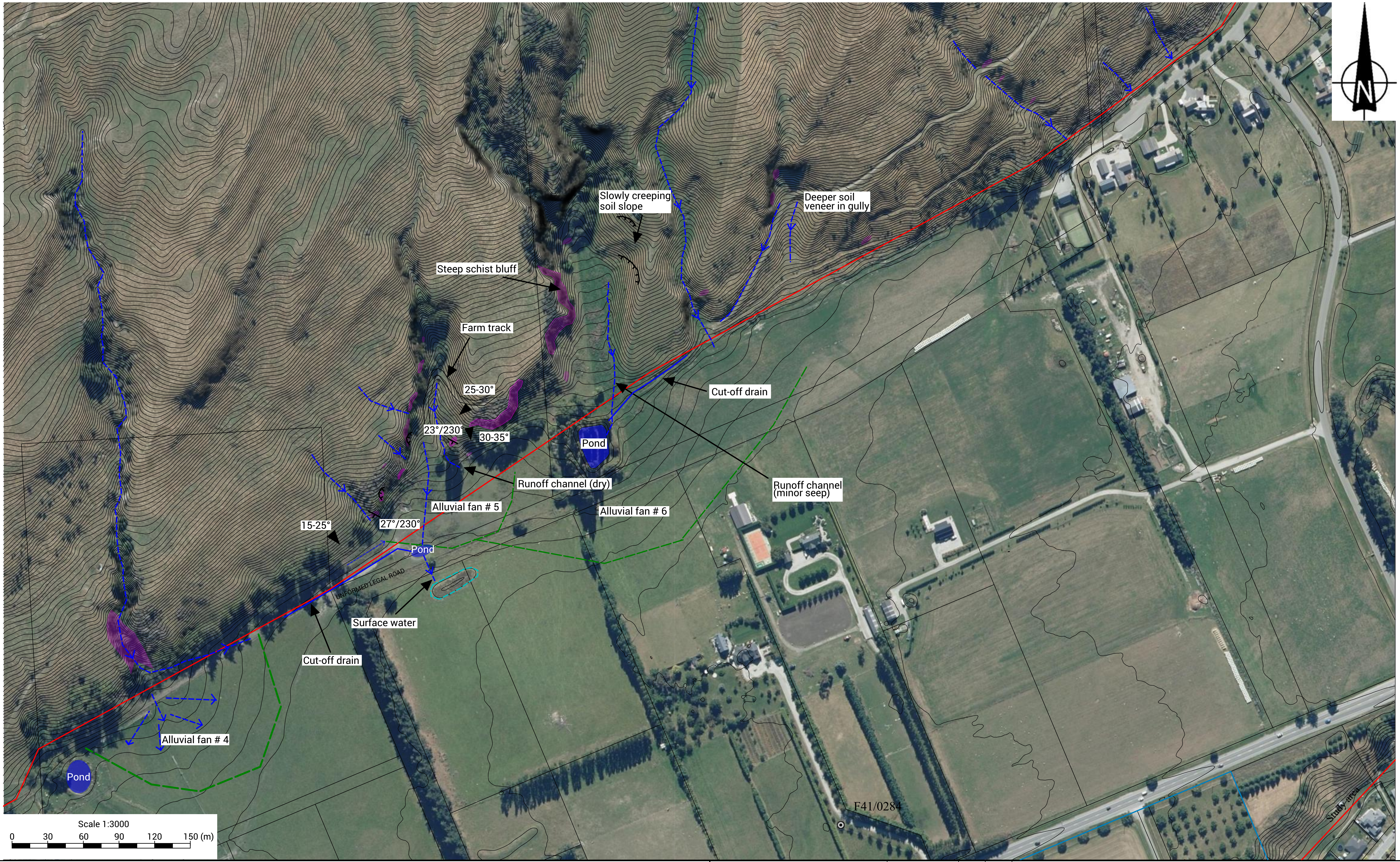
Ladies Mile RFP
Ladies Mile, Queenstown
Site Plan

FIG No: FIGURE 4

REV. 1



Key

Top of slope		Soil outcrop		ORC wells	
Expected areas of uncontrolled fill		Overland flow path		1 m countour interval	
Schist bedrock		Dip/dip direction		LiDAR data from QLDC Open Maps	

CADFILE:	Sketch 1.xar	DRAWN	MBS	10/2020
SCALE (AT A3 SIZE):	AS SHOWN	DRAFTING CHECKED	SR	10/2020
PROJECT No:	200353	APPROVED	FAW	10/2020

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Candor3
Ladies Mile RFP
Ladies Mile, Queenstown
Site Plan

FIG No: FIGURE 5
REV. 1

Key

- Top of slope
- Expected areas of uncontrolled fill
- Schist bedrock
- Soil outcrop
- Overland flow path
- Dip/dip direction
- ORC wells

1 m countour interval
LiDAR data from QLDC Open Maps

CADFILE:	Sketch 1.xar	DRAWN	MBS	10/2020
SCALE (AT A3 SIZE):	AS SHOWN	DRAFTING CHECKED	SR	10/2020
PROJECT No:	200353	APPROVED	FAW	10/2020

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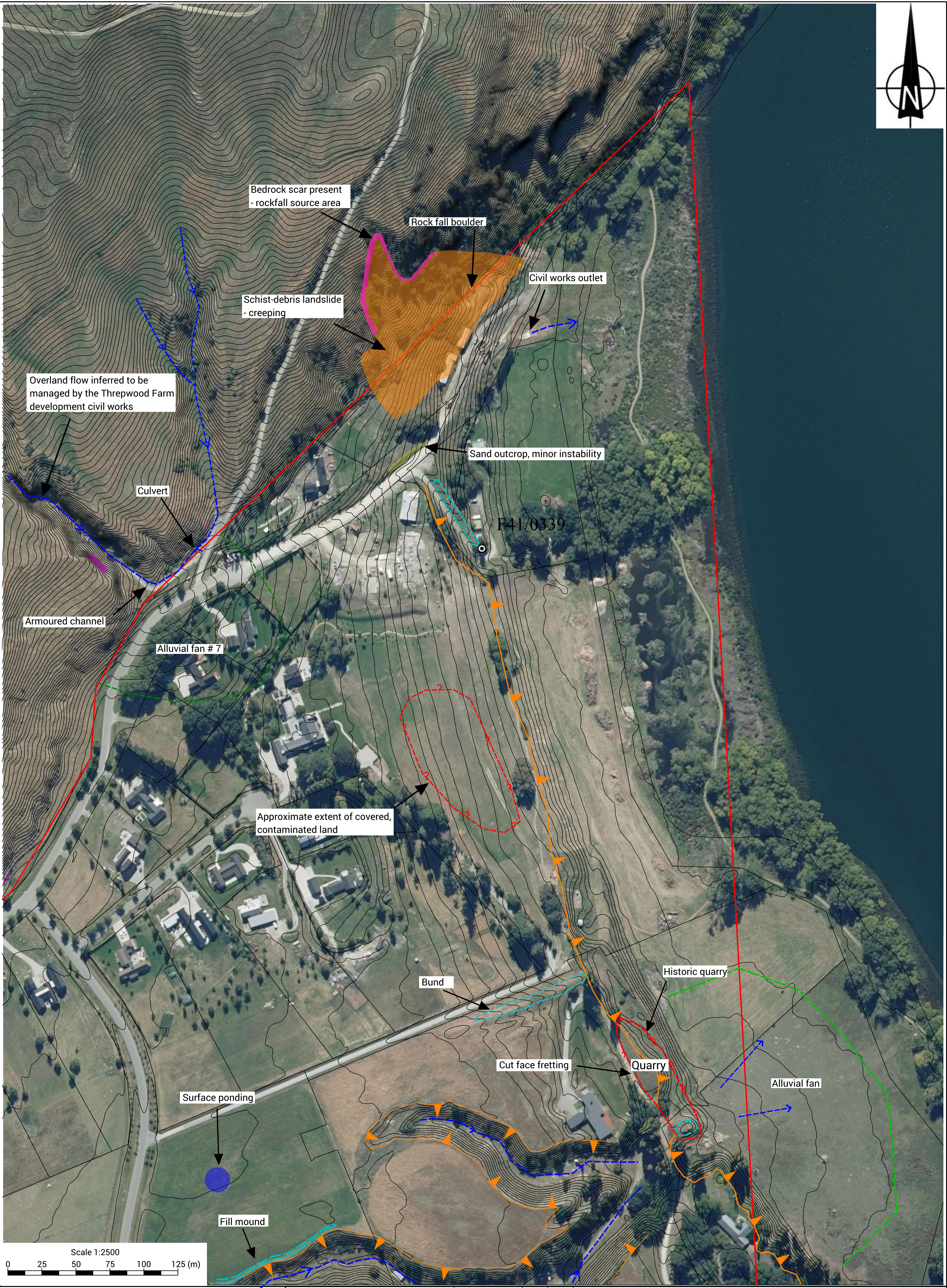
PAVEMENTS

Candor3
Ladies Mile RFP
Ladies Mile, Queenstown
Site Plan

FIG No: FIGURE 6

REV. 1



Key

- Top of slope
- Expected areas of uncontrolled fill
- Schist bedrock

CADFILE:	Sketch 1.xar	DRAWN	MBS 10/2020
SCALE (AT A3 SIZE):	AS SHOWN	DRAFTING CHECKED	SR 10/2020
PROJECT No:	200353	APPROVED	FAW 10/2020

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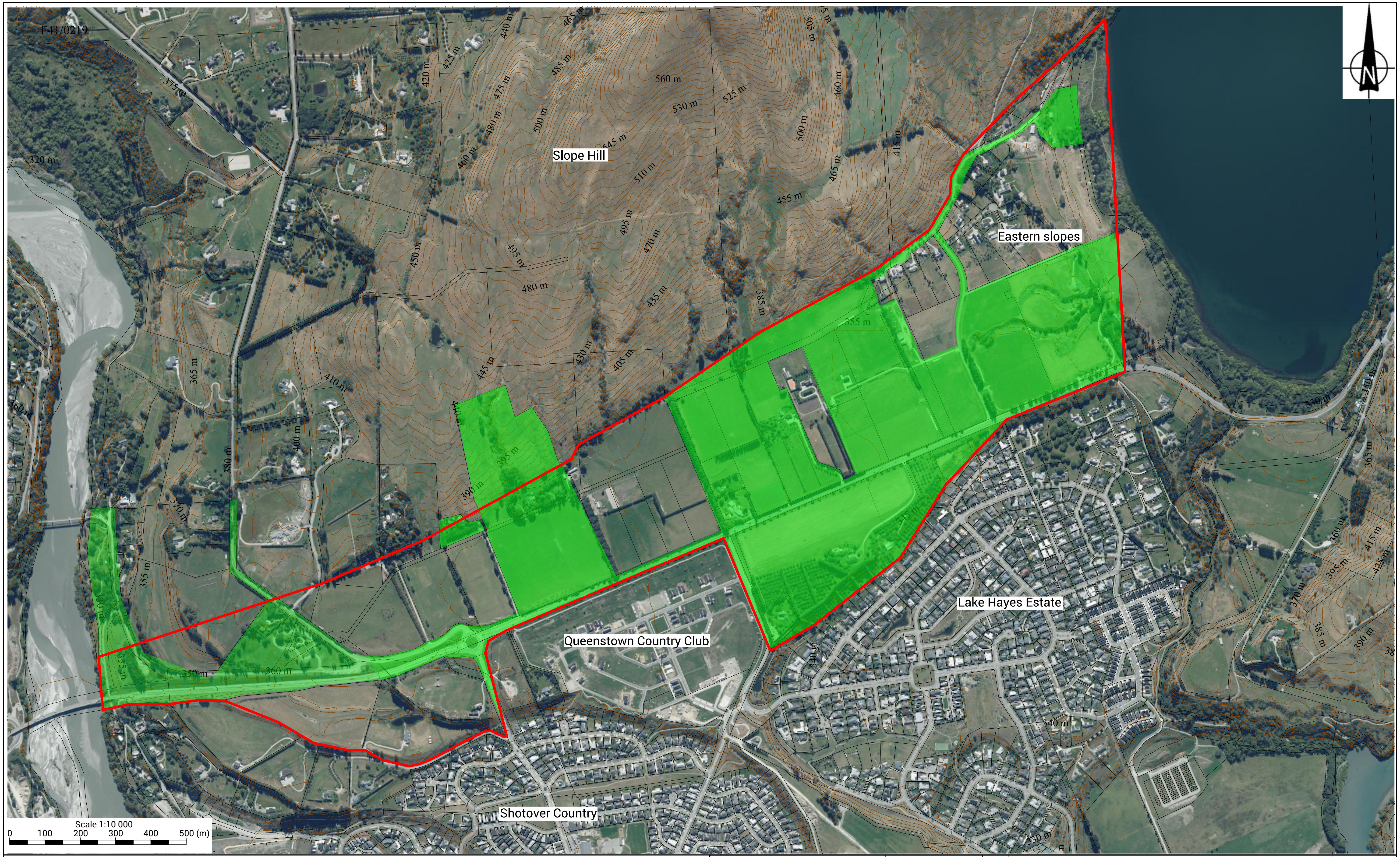
Ladies Mile RFP
Ladies Mile, Queenstown
Site Plan

FIG No: FIGURE 7

REV. 1



Key

Ladies Mile Masterplan Area of Focus

Areas where GeoSolve had access

5 m contour interval
LiDAR data from QLDC Open Maps

CADFILE:	Sketch 1.xar	DRAWN	MBS	10/2020
SCALE (AT A3 SIZE):	AS SHOWN	DRAFTING CHECKED	SR	10/2020
PROJECT No:	200353	APPROVED	FAW	10/2020

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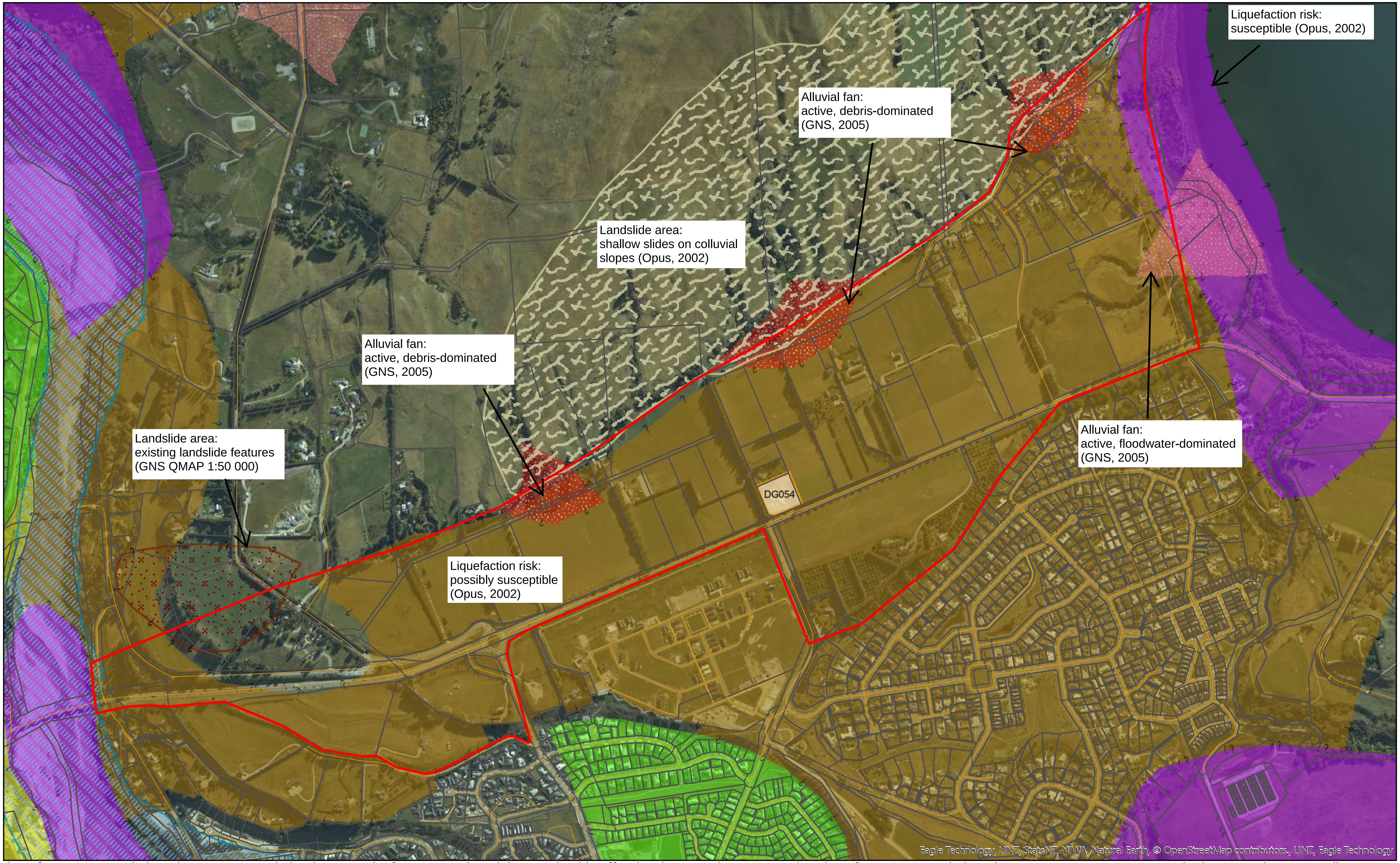
Ladies Mile Masterplan
Ladies Mile, Queenstown
Access Plan

FIG No: FIGURE 8

REV. 1

QLDC Natural Hazards Map



QUEENSTOWN LAKES DISTRICT COUNCIL

0 0.5 1 2 km

Scale: 1:9,028

Figure 9

N