Before the Queenstown Lakes District Council

Under	the Resource Management Act 1991
In the matter of	a submission under clause 6, Schedule 1 of the Resource Management Act 1991 on Stage 3B of the Queenstown Lakes Proposed District Plan
	Wayfare Group Limited (#31024)
	Submitter

Statement of Evidence of Grant Meldrum

28 May 2021

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Introduction

1. My name is Grant David Meldrum

2. I am a self-employed civil engineer based in Queenstown

3. I hold a bachelor's degree in Engineering from the University of Canterbury, have worked in the fields of civil, geotechnical and structural engineering for 38 years. This work has included land assessments, slope stability and geotechnical investigations, hydraulic design for waterways and flood protection works, design of structures in vulnerable locations, with much of this work associated with the Queenstown Lakes area where I have been resident for the last 24 years. I am a Chartered Member of Engineering New Zealand and maintain membership in special interest groups of Engineering New Zealand (Engineering General Practitioners Group, Structural Engineers Society and New Zealand Society for Earthquake Engineering).

4. In preparing this evidence I have reviewed:

   The following reports relevant to my area of expertise, including:

   i. Otago Alluvial Fans: High Hazard Fan Investigation – Otago Regional Council, July 2011
   ii. Walter Peak Farm Demonstration Building – Debris Flow Hazard Assessment – Golder Associates, July 2018; (**Golder Report**)
   iii. Patch Site Plan, Walter Peak Farm – Patch, 28 May 2021
   iv. Otago Regional Council GIS, Natural Hazard Register – accessed 27 May 2021
   v. The evidence of Mr Bond in respect of QLDC Proposed District Plan (PDP) Topic 19 (Walter Peak)

5. I have appended the Golder Report to my Evidence as **Appendix 1**. I also attach screenshots showing the Golder Report Zones superimposed on the ORC hazard maps for alluvial fans, giving a fuller picture of the natural hazard risks for the property as **Appendix 2**.

6. I have read the Code of Conduct for Expert Witnesses in the Environment Court Practice Note. This evidence has been prepared in accordance with it and I agree to comply with it. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

Scope of Evidence

7. I have been asked by Wayfare Limited to prepare evidence in relation to Natural Hazards and their potential impact on their property at the Walter Peak High Country Farm.

8. This includes:

    Review of reports and information listed above

    Opinion as to areas of Low Natural Hazard Risk

    Opinion as to areas of greater than Low Natural Hazard Risk.

Executive Summary

9. The property at Walter Peak High Country Farm is at the base of mountain slopes that have a history of debris-flow during high intensity rainfall events.

10. There have been natural hazard mitigation works undertaken following recent events (and on the basis of expert recommendations provided) that appear to be providing an adequate level of protection to the property.

11. Areas where future debris-flows may affect the property have been identified in the Golder Associates report (v above).

12. I agree with the findings of the Golder Report and based on this, the areas that are at higher risk from Natural Hazards are those areas upstream from the protection works – denoted Zones A and C in the Golder Report.

13. Areas to the north of the Mt Nicholas – Beach Bay Road, with the exception of Zone C, are considered to be at low risk of future debris-flow adversely affecting developments.

14. Liquefaction hazard is identified on the ORC Natural Hazard Database in the area immediately surrounding the beach and encompassing the farm demonstration building, homestead, Ardmore house and Middle house.

15. It is my opinion that the natural hazard risk from liquefaction is low and mitigation measures can be considered at the time of building consent application as allowed in the New Zealand building code.

Review of Reports listed in 4 above

16. The key / most relevant natural hazard risk to the Walter Peak site is hazards associated with active alluvial fans and known debris flow channels and risks from liquefaction. My evidence and review of relevant material has therefore focussed on these particular risks.

17. My evidence is within my area of expertise. I have previously provided verbal advice to the property manager at Walter Peak following the November 1999 debris flow. This consisted of advice on initial protection work to clear the debris flow material and provide enhancements to the bunds on site. I have also been involved with slope stability and debris flow analyses for clients with the Queenstown area. I therefore feel that I am qualified to provide evidence on this matter.

18. The various reports I have listed above assess the risk of debris-flow, effectiveness of current remedial measures and recommendations for upgrades or additions to these measures for Walter Peak.

19. The source of debris flow is the steep channels to the south of the property. Alluvial fan deposition, including debris-flows, from these slopes has been the major topography forming process in recent times and there have been such debris-flows within the last 25 years.

20. The slopes above Walter Peak High Country Farm will provide further debris-flows in the future. These will be sourced from the main drainage channels on the side of the hill. The areas of deposition and existing protection measures will be the primary inputs to identifying areas where future activities can be contemplated.

21. The Golder Report provides a detailed assessment of the current risks to various parts of the property, as well as existing protecting structures on the site (generally in the form of berms and treed areas).

22. It is my opinion that the Golder report is a suitable assessment on which to base recommendations for future uses on the property.

23. Liquefaction hazard is identified on the ORC Natural Hazard Database in the area immediately surrounding the beach and encompassing the farm demonstration building, homestead, Ardmore House and Middle House.

24. The area identified is within the domain B is defined as “may possibly cause land damage from liquefaction” and should be considered a “liquefaction awareness zone”. These are at the lower end of natural hazard risk.

25. Construction of buildings on land that may be subject to liquefaction damage is covered within the New Zealand building code verification method B1/VM4. Any necessary mitigation will be able to be addressed at the time of building consent applications.

Areas at low natural hazard risk

26. I agree that the areas identified by the Golder Report as zones D and E are at low risk of being affected by debris-flow. It is my opinion that the Golder report is a suitable assessment on which to base potential future development within various parts of the property.

27. Zone A and C are at a higher risk from effects of debris-flows as they are on the upstream side of protection works.

28. Zone B is primarily occupied by the tourism operations at the site. These areas are only populated by a small number of persons outside business hours. Debris flow risk will only occur during periods of extreme rainfall and should these occur during business hours it is considered that management systems can remove patrons and staff in a timely manner and before potential debris flow risk is heightened.

29. It is my opinion that the areas to the north of Mount Nicholas – Beach Bay Road excluding the area within Zone C from the Golder report are at low risk of debris-flow natural hazard. This includes the areas of alluvial fan and the hill between Beach Bay and the main lake to the north.

30. Liquefaction hazard is identified on the ORC Natural Hazard Database in the area immediately surrounding the beach and encompassing the farm demonstration building, homestead, Ardmore House and Middle House.

31. The area identified is within the domain B is defined as "may possibly cause land damage from liquefaction" and should be considered a "liquefaction awareness zone". These are at the lower end of natural hazard risk.

32. Construction of buildings on land that may be subject to liquefaction damage is covered within the New Zealand building code verification method B1/VM4. Any necessary mitigation will be able to be addressed at the time of building consent applications

Areas at greater than low natural hazard risk

33. The areas designated Zones A and C in the Golder report are part of the area of active management of debris-flows. These areas are at moderate to high risk of Natural Hazard (depending on the nature and scale of any new building or structure) and should not have buildings or structures used for living purposes.

34. Structures of an ancillary nature (Level 1 buildings as defined in the Building Act) would be suitable on these areas.

35. The above opinions are given on the basis that the existing protection structures are maintained and any future debris that is intercepted by these structures is removed as soon as reasonably practicable following the debris-flow event.

Grant David Meldrum

Dated this 28th day of May 2021

Appendix 1 – Golder Report

REPORT

Walter Peak High Country Farm

Debris Flow Hazard Assessment

Submitted to:

Real Journeys Limited | Downer New Zealand Limited

14 Captain Roberts Road
Te Anau 9600
New Zealand

Submitted by:

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Record of Issue

Company	Client Contact	Version	Date Issued	Method of Delivery
Real Journeys Limited	Chris Fleck	Rev 0	16 July 2018	Email
Downer New Zealand Limited	David Hutchison	Rev 0	16 July 2018	Email

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APPENDICES

1.0 INTRODUCTION

Real Journeys Limited owns Walter Peak High Country Farm (WPHCF), which is located on the western shores of Lake Wakatipu about 14 km southwest of Queenstown (Figure 1). WPHCF is operated as a tourist venture where visitors are brought across Lake Wakatipu by the TSS Earnslaw and disembark at a wharf adjacent to the former homestead of Walter Peak Station. Real Journeys plans to increase visitor numbers to about 2500 visitors every day as part of a current development plan for WPHCF.

Debris flows affected WPHCF about twenty years ago causing minor infrastructure damage and Real Journeys wish to ensure that visitors and staff are not exposed to an unacceptably high safety risk from debris flows. Real Journeys engaged Golder Associates (NZ) Limited (Golder) through Golder's contract with Downer New Zealand Limited (Downer) to review previous evaluations of debris flow risk and advise on the appropriate measures to manage the risk to Real Journeys' personnel and visitors. It is envisaged that development of risk management measures will be completed as part of a subsequent project stage. This report presents the findings of our assessment.

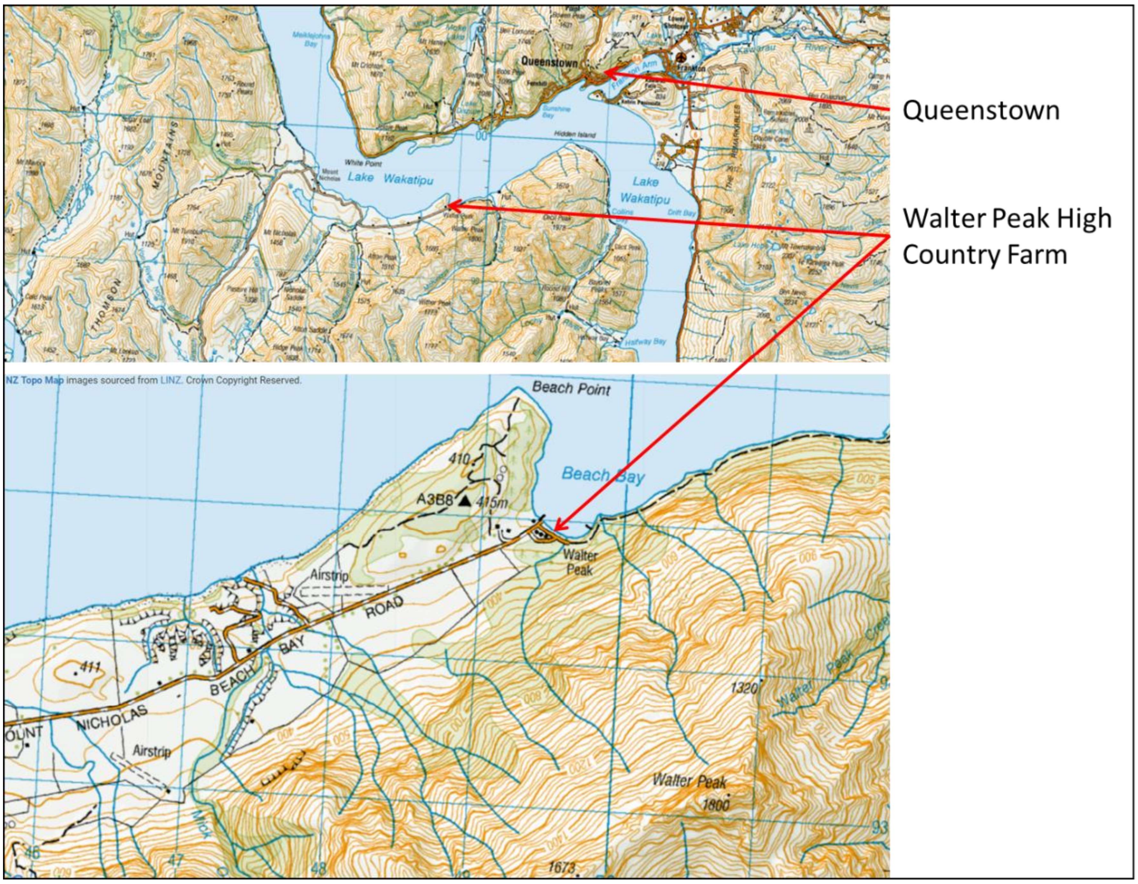


Figure 1: Locality map of Walter Peak High Country Farm (after NZ Topo Map).

2.0 DESCRIPTION OF THE SITE AND REAL JOURNEYS OPERATION

TSS Earnslaw operates daily and Real Journeys aims to have peak daily visitor numbers to WPHCF of 2500. Currently, the maximum number of visitors on site at any time is approximately 1000. The layout of tourist activities at the site is shown in Figure 2, with most activity occurring within an area of about 250 m by 100 m, highlighted in blue.

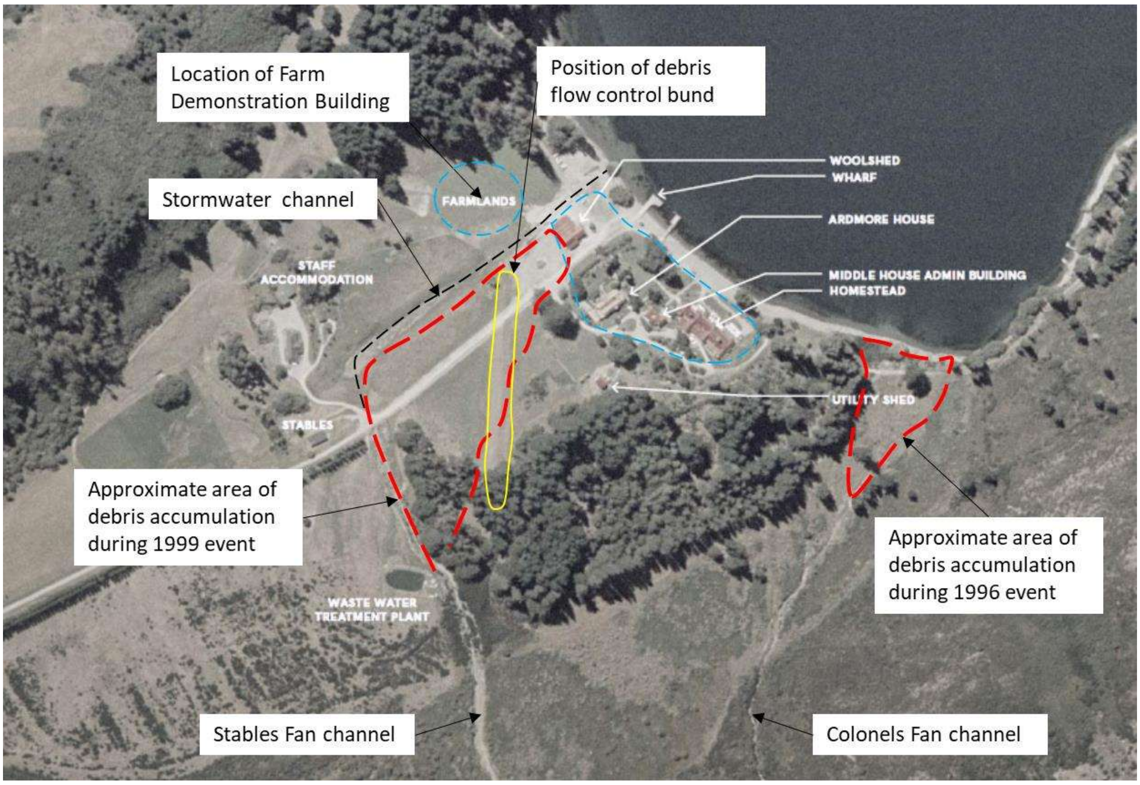


Figure 2: Existing layout of WPHCF facilities including debris flow channels, debris accumulation areas. Areas delineated in blue area the main areas of congregation. Image after Beca 2017.

The main areas of visitor congregation on site include the Farm Demonstration Building where about 200 visitors can observe shearing and other high country farming activities and a restaurant seating about 200 within the old homestead building (Figure 2). In addition, about 50 staff occupy various administration buildings, including the old woolshed and, as part of the development plan, will also live in the proposed staff village.

The ground surface typically grades towards Beach Bay at up to about 1V:10H. A natural watercourse flows towards Beach Bay between the old woolshed and the Farm Demonstration Building and this watercourse carries most stormwater flows (Figure 2).

2.1 Geology and Fan Geomorphology

Walter Peak is the name of a mountain located immediately south of WPHCF, rising to 1800 m above sea level (asl), some 1500 m above Lake Wakatipu. The dominant bedrock type at Walter Peak is schist of the Caples Terrane, which comprises mainly metamorphosed volcaniclastic sandstone and mudstone and has a layered or 'foliated' fabric (Turnbull, 2000, Figure 3). At Walter Peak, the foliation strikes approximately normal to the slope and dips at about 10° to 30° to the southwest, a configuration that is neutral for slope instability, being neither adversely nor favourably oriented. Schist is exposed near to the top of Walter Peak above about 1400 m asl and in the steep slopes between about 500 m and 1000 m asl.

Above 1000 m asl there is a veneer of glacial till of last glacial age (approximately 10,000 to 20,000 years old, Barrell 2011) on the slope (Figure 4). The till appears to comprise well-graded, bouldery gravels within a silty sand matrix and extend about 1000 m upslope. It appears that the source areas for the debris flows during 1996 to 2002 are located near to the contact between the glacial deposits and the underlying rock.

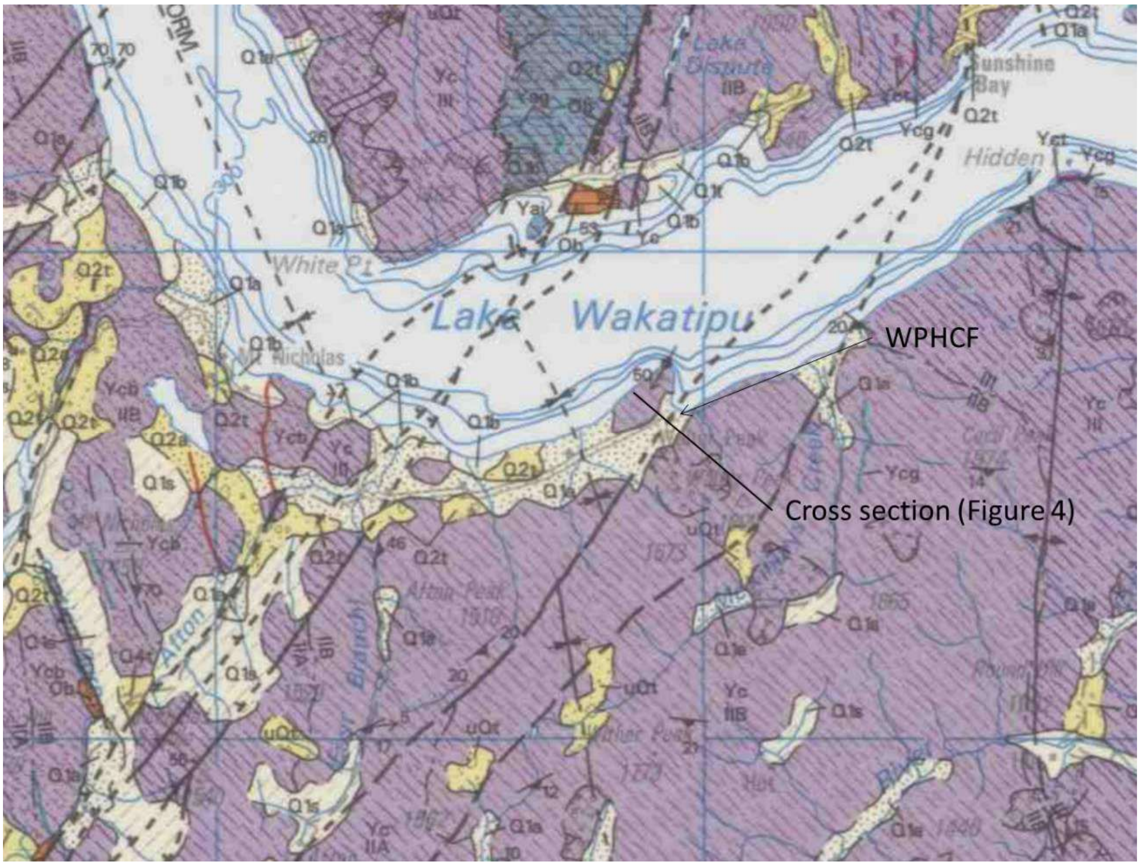


Figure 3: Geological map of the Walter Peak area with location of WPHCF arrowed (after Turnbull 2000).

A geotechnical investigation for the proposed staff village utilities area and car park (Figure 5) was undertaken by Geosolve (2018) and included trial pits at 25 locations to depths of up to about 4 m. The trial pits provide useful information to characterise the shallow geology at WPHCF. Geosolve infer from the subsurface investigations that the site is underlain by lake sediments over which lie alluvial fans that build out from the lower slopes of Walter Peak. We interpret that the lake sediments were deposited 5,000 - 10,000 years ago, following the end of the last glacial advance, and when Lake Wakatipu was significantly larger that it is today. The fan alluvium observed by Geosolve included schist boulders up to about 800 mm in largest dimension and buried soil horizons suggesting that deposition of alluvium occurs episodically as debris flow deposits up to about 2 m in thickness. The absence of fan alluvium for areas north of Mt Nicholas Beach Bay Road (Figure 1) suggests that no debris flows have reached that site during the last 5000 to 10,000 years.

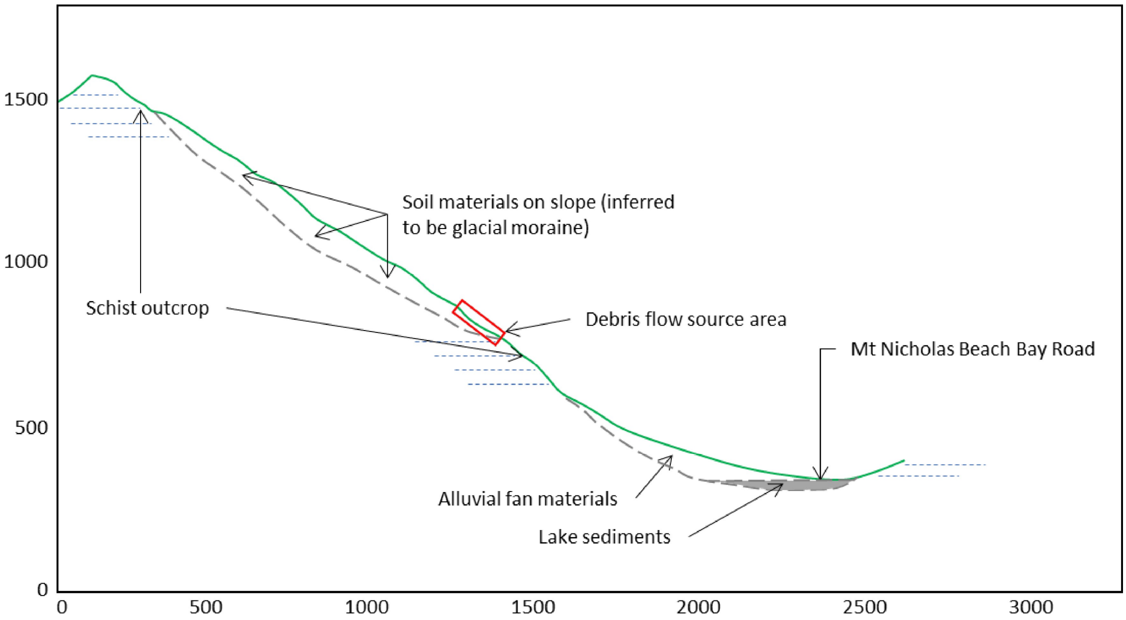


Figure 4: Schematic geological cross section (location shown in Figure 3).

2.2 Groundwater

Observations from a helicopter flight over the slopes of Walter Peak indicate that seepage occurs near the base/lowest-elevation of the glacial deposits perched mid-slope where the bedrock daylights. This suggests that a local groundwater system is present within the glacial materials. Such a groundwater system has a large catchment as the slope extends at least 1 km above the seepage line. Saturation of the glacial deposits is inferred to promote slope instability that can initiate debris flows.

3.0 DEBRIS FLOW HAZARD AT WALTER PEAK

3.1 History of Debris Flows Affecting Walter Peak

This assessment of the historical behaviour of the slopes above WPHCF is based on discussions on site with Mr Tony McQuilkin, who was manager of the site for several decades prior to 2015. Walter Peak Station was settled in the 1860s and the site of the WPHCF has been constantly occupied since that time. Historical documents refer to rockfall and debris flows periodically affecting the site (Bayley, 2015 and Baker, date unknown).

A debris flow affected the Colonel's Fan channel in 1996 following of a period of heavy rain (Figure 2). This debris flow affected the area south of the homestead with debris reaching the lake (refer to photograph A1 in Appendix A). No damage occurred to the homestead and there were no injuries. Following this debris flow, Mr McQuilkin used an excavator to clear debris and construct a series of bunds to direct debris in future events away from the homestead.

The Stables Fan debris flow (Figure 2) in 1999 was witnessed by Mr McQuilkin who was manager of the facility at the time (Photographs A2, A3 and A4 in Appendix A). This debris flow event deposited in the order of 10,000 m^3 of debris over an area with a maximum deposited thickness of 2 to 3 m of bouldery gravels in and around the WPHCF site. The Stables Fan debris flow occurred following a period of prolonged rainfall during November 1999. NIWA records indicate that 243 mm of rainfall occurred in Queenstown between the 15 November and 18 November 1999, while the average monthly rainfall for November in Queenstown is 63 mm. Mr McQuilkin remembered high flows in the various catchments above WPHCF and the rapid deposition of the debris over a period of a few minutes. Levees of debris adjacent to the channel suggests that the debris was transported as a debris flow but was finally deposited on the flat lower slopes of the fan as bedload (suspended sediments in water) carried by the flood flows. No damage to the key buildings on the site occurred and there were no injuries. A tractor and outbuildings, including the stables, were inundated and partially buried.

Heavy rainfall in 2002 generated a further small debris flow on the Colonel's Fan, which was contained within the existing channel and berms. The triggering rainfall event was approximately 100 mm in 24 hours that occurred during September 2002.

3.2 Physical Protection Works in Place

Earthworks structures in the form of channels and bunds have been constructed by the facility operators since the 1996 debris flows to protect buildings that are occupied by staff and visitors.

Following the 1999 debris flow on the Stables Fan, debris was reshaped to form a 200 m long bund, 2-3 m high, between the main channel of the stables stream and the Old Woolshed and Ardmore House (Figure 2). This bund directs flows into the main surface water channel between the Old Woolshed and the Farm Demonstration Building. In addition, the main channels of the Stables and Colonel's Fans (Figure 2) were cleared of debris to increase the flow capacity and the excavated material placed on the down slope side of the channel as a bund. The stream that runs between the Woolshed and the Farm Demonstration Building and carries storm water from Stables Fan into Beach Bay has been armoured with boulders and is fenced to exclude the public.

4.0 DEBRIS FLOW RISK ANALYSIS

We have completed a qualitative risk assessment of the life risk to visitors and staff at WPHCF from debris flows using a methodology commonly used in geotechnical practice (AGS 2000). In broad terms, the risk can be divided into the risk to physical structures (buildings and infrastructure) and to people, described as the loss of life risk. This study addresses only the loss of life risk, which can be defined as the product of several factors:

- The probability of a debris flow occurring (see Section 4.1 of this report).
- The probability that the debris flow impacts a site where people may be present (see Section 4.3 of this report).
- The probability that a person or persons are present when the debris low occurs (see Section 4.3 of this report).
- The vulnerability of the person or persons to impact by the debris flow (see Section 4.2 of this report).

While we have not conducted a quantitative risk assessment for this project, the above framework is useful for describing the lives risk for the operations at WPHCF and is appropriate given the uncertainties in return period and scale of debris flows.

Each of the above factors will be described in the following sections and assessed for zones with similar risk within the site (Figure 5). This assessment recognises that the debris flow risk to staff and visitors varies around the site.

Figure 5: Plan of WPHCF showing key elements of the site development and five zones inferred to have similar lives risk levels. Base image after Beca (2017).

4.1 Debris Flow Likelihood Assessment

Historical debris flows described in Section 3.1 occurred during periods of heavy and prolonged rainfall. Prolonged rainfall promotes slope instability within the debris flow source areas and surface flows aid in transport of the sediment.

Earthquake shaking is less likely than rainfall to be the primary trigger of a debris flow. At Walter Peak, strong shaking with a peak ground acceleration of about 0.4 g is predicted to occur with an average recurrence interval of about 500 years. At ground shaking of this intensity, some slope instability, such as rockfall and some local slumping of steep soil slopes, is expected to occur. Debris flows are unlikely to occur as an immediate impact of an earthquake because the likelihood that an earthquake coincides with a period of heavy rainfall is low. However, the likelihood of debris flows increases following an earthquake if the earthquake causes significant slope instability because of the increase in loose or weakened material in the source area.

Based on the historical record, we estimate that the return period for debris flows on the fans affecting WPHCF is in the range of approximately 30 to 50 years. McSavenney (2002) infers that an increased probability of debris flows occurred at WPHCF following the 1999 debris flow events. However, no significant debris flows have been recorded at the site since 2002.

There is little evidence for the range of potential debris flow sizes that could affect the site, other than the records of the debris flows described in Section 3.1. However, the distribution of fan materials found in geotechnical investigations by Geosolve (2018) suggests some limits to the size of individual debris flows. A potential thickness per event of up to about 2-3 m has been recorded and there is an absence of fan materials at the northern margin of the valley floor (Zone D in Figure 5). We are not aware of similar records from around the main buildings at WPHCF. However, it is possible that debris flow deposits do not extend into that area (Zone B in Figure 5). Although we have found no evidence of debris flows larger than the 1999 event, it is possible that larger debris flows could affect the site. We anticipate that smaller debris flows are relatively more frequent than larger events, but currently have no data to evaluate this. It is possible that small debris flows occur but are not observed by site staff because no damage is done.

4.2 Potential Effects of Debris Flow

Debris flows can be a highly destructive hazard that have caused many fatalities around the world including several in New Zealand. The hazard is due to the high velocity and flow rate of the debris flow and the ability to transport large boulders, trees and other objects that can have high impact energy. Rapidly inundating pulses of debris can be a severe hazard to infrastructure and to people within the channel carrying the debris flow.

People in the path of a debris flow or the resultant rapid aggradation pulse can be potentially wounded or killed. People are most vulnerable when they are physically trapped and unable to get away from the debris. Defensive structures such as bunds can prevent people from escaping the path of a debris flow or aggradation pulse. Fences, buildings and vehicles can make people more vulnerable to escape from debris flows. Buildings offer some protection from the debris flows and rapid alluvial aggradation where the sediment accumulation occurs relatively slowly and comprises relatively fine grained material including sands and gravels. Where the debris flow contains coarse boulder material, including other large debris such as wood, buildings will typically offer less protection. The occupied buildings at WPHCF are currently at the periphery of the fans and offer some protection from the rapid alluvial aggradation that has been observed at the site. Vehicles can provide some protection from flooding, but not from debris flows and rapid aggradation which can bury vehicles including the occupants.

No evaluation has yet been made of the extent of protection offered by the various buildings at the WPHCF site.

4.3 Population at Risk and Spatial Distribution of People

The current expansion proposal by Real Journeys plans for 2500 visitors per day at WPHCF, concentrated during approximately 8 hours each day. Up to 50 Real Journeys staff will also be accommodated on site. We have divided the site into five zones (Zone A to Zone E Figure 5), partly on the basis of anticipated population at risk.

- Zone A is the area of the Colonel's Fan affected by debris flows in 1996 and 1999. It is separated from the homestead by various bunds and channels constructed to contain surface water flows and debris flows. Zone A is fenced from access by visitors and is rarely occupied by staff.
- Zone B is the most densely populated part of the site including the wharf where visitors disembark, the homestead, restaurant facilities, Middle House Admin Building, Ardmore House, the Woolshed and associated gardens. The western margin of Zone B is defined by the bund constructed following the 1999 debris flow and the northern margin of Zone B is the edge of the stream channel that carries surface flows into Beach Bay. The maximum number of visitors present in Zone B at any time is approximately 1000 and out of business hours Zone B is unoccupied. During periods of heavy rainfall, visitors are expected to be indoors.
- Zone C comprises the area west of the bund and includes the stream that carries surface flows on Stables Fan and carried debris flows in 1999 and 2002. Zone C includes a proposed car park, animal pens, stables and the stream between the Woolshed and Farm Demonstration Building. Visitors have access to this area but are not expected to be present in high numbers, particularly in periods of heavy rain. Staff are present in Zone C for maintenance and in transit between the Staff Village and the rest of the operation. The expected population within Zone C is typically up to ten people during day time and is unoccupied out of business hours.
- Zone D is the area north of Mt Nicholas Beach Bay Road to be occupied by the proposed Staff Village. Up to 50 staff will live in several buildings. Zone D is located on the furthest part of the Stables Fan from the source area. Subsurface investigations completed by Geosolve (2018) indicate an absence of fan materials, suggesting that debris flows have not significantly affected this area in the past. It is anticipated that the maximum number of staff (about 50) will be present at night, but that some staff will be present during day time.
- Zone E is the area north of the stream including the Farm Demonstration Building and the hill slopes to the north. This area is sufficiently elevated above the stream to have a low likelihood of being affected by debris flows. Up to approximately 100 visitors occupy the farm demonstration building during the day and Zone E is not occupied out of business hours.

4.4 Summary of Debris Flow Life Risk to Real Journeys Staff and Visitors to WPHCF

A summary of debris flow risk affecting Real Journeys staff and visitors to WPHCF is presented below:

- Debris flows of the type and size that have been observed at WPHCF have the potential to cause death or injury. Debris flows larger than those that have been observed at WPHCF are possible, but there is considered to be insufficient information to quantify the life risk of those events.
- Debris flows occur in response to unusually prolonged heavy rainfall and are as such rare events. Periods of prolonged heavy rainfall are therefore indicators of heightened likelihood of debris flows and can be used as a trigger for additional vigilance and risk mitigating actions. Snow melt in spring may also be a time of increased risk.
- Some areas of the site (Zones A and C) are more likely to be affected by debris flows due to the proximity of debris flow channels, bunds and the local effect of site topography.
- The distribution of visitors around the site increases the life risk in those areas with the highest population density, in particular the area around restaurant facilities (Zone A) and the Farm Demonstration Building (Zone E). For debris flows similar to the observed events, these buildings are located in distal areas of the debris fans where the likelihood of damaging debris flow impact is relatively low. In addition, the buildings where visitors and staff congregate offer some protection against the type of debris flows that have been observed at WPHCF. However, the level of protection afforded by each building and how this might help to mitigate the life risk from debris flows has not been assessed.
- Existing protection works in the form of bunds and enhanced channels are judged to offer significant mitigation against debris flows affecting the areas of highest population density. However, these structures will tend to increase the effect of debris flows in the areas within which the debris flows are contained. Those areas tend to have low population density, but there is potential for individuals to be engulfed by a debris flow if they are in the area at the time.
- Maintenance of the network of defensive structures will be required to maintain the current level of protection. In addition, a review of the design and configuration of defensive measures may indicate potential enhancements under the ALARP (*As Low As Reasonably Practicable*) principle.
- We have not completed a quantified risk assessment but judge that the risk to the lives of staff and visitors from debris flows can be adequately mitigated by relatively minor earthworks, including maintenance of the existing network of mitigation structures and a management plan that includes routine monitoring and actions to implement during higher risk periods of prolonged or heavy rainfall.
- Debris flow hazard is likely to be elevated following strong earthquake shaking at the site and this would warrant additional inspection of the potential source areas to assess the subsequent hazard.

5.0 CONCLUSIONS

- A significant risk to the lives of staff and visitors is present at WPHCF from debris flows. This has been highlighted by recorded debris that occurred in 1996, 1999 and 2002. No injuries or deaths have occurred as a result of these debris flows, but a stables and tractor were damaged by inundation by the debris in 1999.
- The exposure to debris flow hazard varies around the site as population density is concentrated in buildings in the relatively low hazard locations within the site, such as the restaurant and farm demonstration building. However, a part of the site (Zone C) is located between a defensive bund and the active channel of Stables Fan and has a relatively high debris flow risk despite the low population density. This is because deposition of material will concentrate in this area and the fences, bunds and channels may hinder escape.
- We believe that debris flow risk to staff and visitors can be maintained at acceptably low levels by implementing a management plan that includes maintenance and potentially augmentation of the current defensive structures on site, monitoring of the potential debris flow source areas and changes to channel forms, development of an action plan for Real Journeys staff for periods of heightened risk and in the event of debris flows affecting the site.

6.0 RECOMMMENDATIONS

1) A detailed review of the existing defensive measures is recommended to allow an evaluation of the likely effectiveness of these structures at protecting the most vulnerable parts of the operation. This review should include an assessment of the carrying capacity of the channels and effective height of the bunds with a view to identifying deficiencies that need to be addressed.
2) A site walkover of the potential source areas for debris flows should be completed by an engineering geologist to identify any evidence for increased slope failure activity that could indicate an elevated likelihood for debris flows. This inspection will also serve as a benchmark for future monitoring of source areas that could follow periods of unusually heavy rain, earthquakes or observations of debris flows affecting the site.
3) Complete an assessment of the structural integrity of buildings on site and the level of protection from debris flows afforded to occupants.
4) A debris flow management plan should be developed to inform site staff about the debris flow hazard, when debris flows are most likely, what observations might signal an increased debris flow hazard and what actions should be taken to mitigate the risk to staff and visitors. The plan will also define monitoring and maintenance activities that could be carried out to help mitigate the debris flow risk. Consideration of practical early warning systems that could assist in guiding the activities on site during periods of heightened debris flow risk should be considered.

7.0 LIMITATIONS

Your attention is drawn to the document, "Report Limitations", as attached (Appendix B). The statements presented in that document are intended to advise you of what your realistic expectations of this report should be, and to present you with recommendations on how to minimise the risks to which this report relates which are associated with this project. The document is not intended to exclude or otherwise limit the obligations necessarily imposed by law on Golder Associates (NZ) Limited, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

8.0 REFERENCES

AGS (2000) LANDSLIDE RISK MANAGEMENT CONCEPTS AND GUIDELINES, Australian Geomechanics Society, subcommittee on landslide risk management

Barrell, D.J.A. (2011) Quaternary Glaciers of New Zealand. In J. Ehlers, P.L. Gibbard and P.D. Hughes, editors: Developments in Quaternary Science, Vol. 15, Amsterdam, The Netherlands, 2011, pp. 1047-1064.

Bayley, B, (2015) The Colonel's House at Walter Peak Station. The Queenstown Courier, Issue Number 93, Queenstown and District Historical Society.

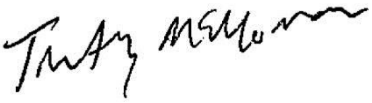
Beca (2017) Walter Peak Masterplan Revision E dated February 2017.

Geosolve (2018) Geotechnical Report, Walter Peak Farm, Queenstown: Unpublished consultants report 170657, dated April 2018.

McSaveney, M (2002) Assessment of debris-flow mitigation measures at Walter Peak, Queenstown. Prepared for Convelle Enterprises Ltd.

Turnbull, I. M. (compiler) 2000. Geology of the Wakatipu area. IGNS 1:250 000 geological map 18.

Golder Associates (NZ) Limited



Tim McMorran
Associate | Principal Engineering Geologist

APPENDIX A

Photographs of Debris Flows at Walter Peak High Country Farm

Photograph A1: Debris flow channels from 1996 debris flows showing source areas in the upper part of the image and two prominent channels (Colonel's Fan on the left and Stables Fan on the right. Note that little debris affected the buildings.

Photograph A2: Effects of the 1999 debris flow. Note additional debris affecting the Colonel's Fan and significant debris deposited to the right of the buildings on the Stable's Fan. (Photograph courtesy of Real Journeys.)

Photograph A3: Deposition of boulder gravel on the Stables Fan following the 1999 debris flow. The building is the old stables that was inundated by about 1.5 m and was subsequently abandoned.

Photograph A4: Debris inundating the area west of the woolshed (foreground) in 1999. Note the main stormwater channel on the right of the image. (Courtesy of Real Journeys).

APPENDIX B

Report Limitations

Report Limitations

This Report/Document has been provided by Golder Associates (NZ) Limited ("Golder") subject to the following limitations:

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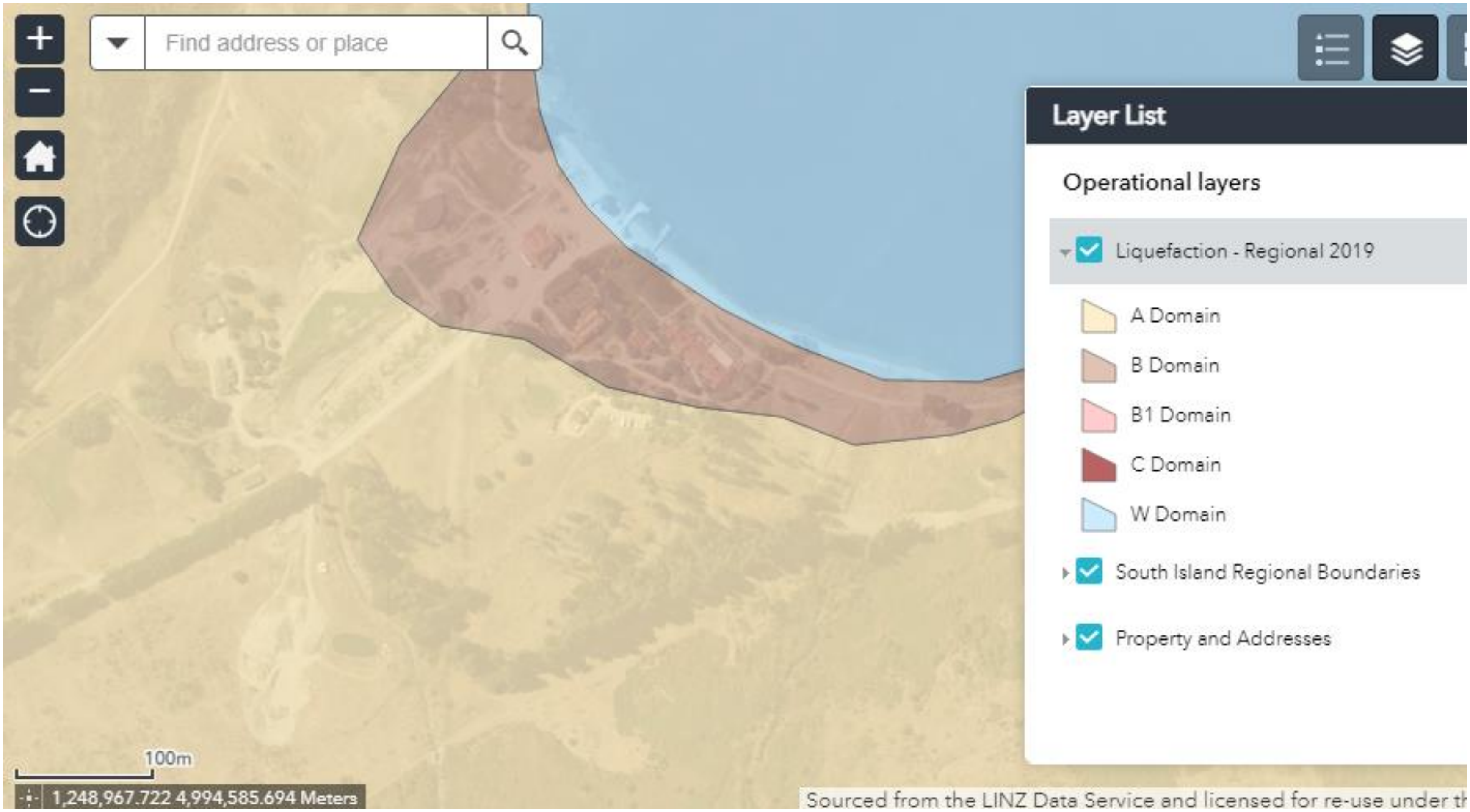
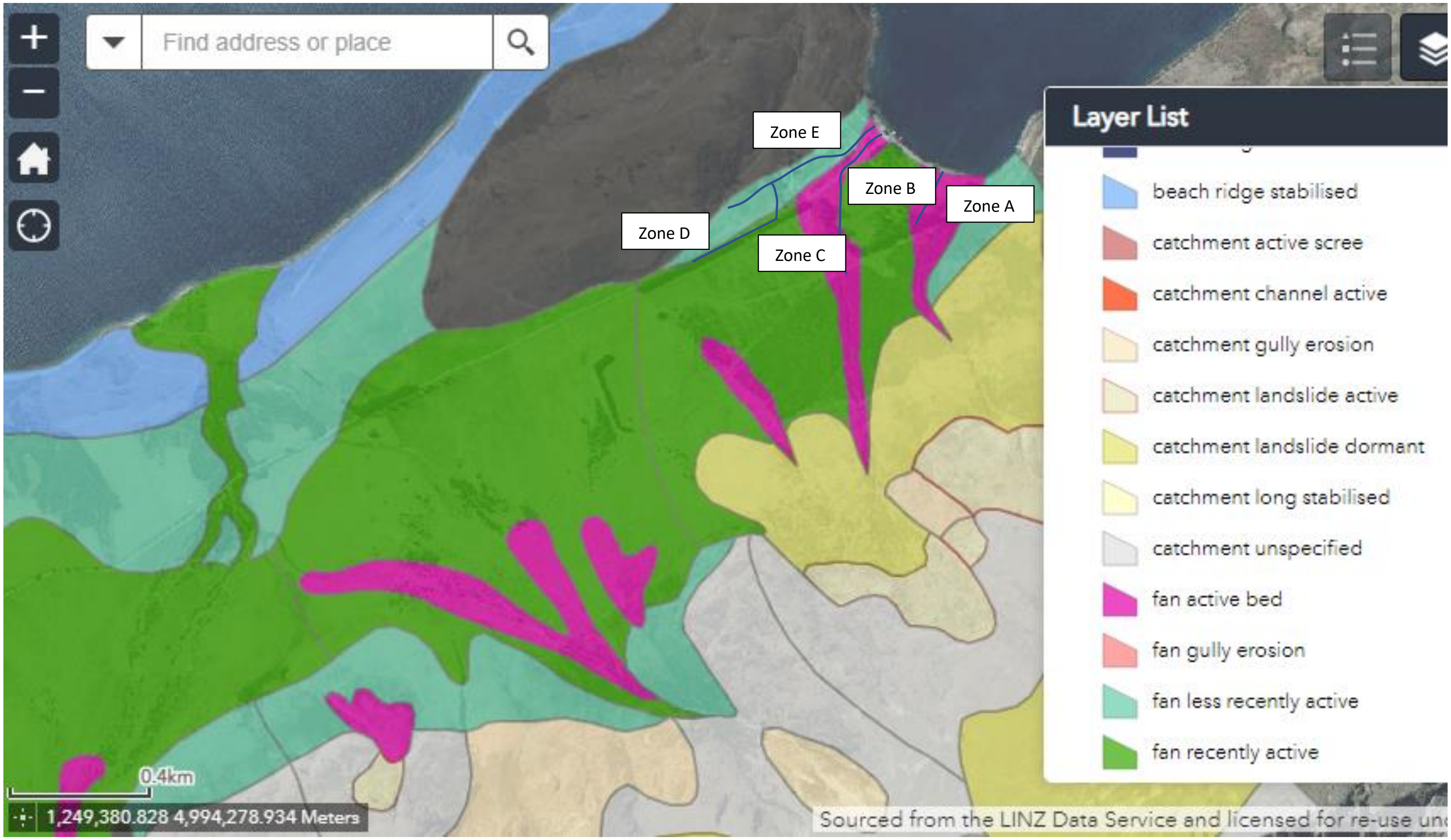
Appendix 2 – Hazards map overlay

Figure from Golder Associates Debris Flow report



Liquefaction Zones – Domain A Unlikely to have liquefaction damage, Domain B May have liquefaction damage



Golder report Zones superimposed on ORC hazard map for alluvial fans