Geotechnical Report and Stability Assessment

Albert Town Landslides

Report prepared for:

Otago Regional Council

Report prepared by:

GeoSolve Ltd

Distribution:

Otago Regional Council

GeoSolve Limited (File)

9 December 2014

GeoSolve Ref: 140722

ACENZ
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1 Introduction

This report presents the results of geotechnical investigations carried out by GeoSolve Ltd (GSL) for the Otago Regional Council (ORC) to assess slope stability conditions and provide geotechnical inputs for the study area up- and down-stream of the Albert Town Bridge.

The investigations were carried out in accordance with GSL's proposal dated 2 December 2014, which outlines the scope of work and conditions of engagement.

Documents provided by ORC to GSL to inform this project included site inspection and briefing notes, and records of concerns and opinions expressed by local residents.

2 Site Description

The study area is located in Albert Town which is situated approximately 5.2 km northeast of central Wanaka, as shown in Figure 1 below.

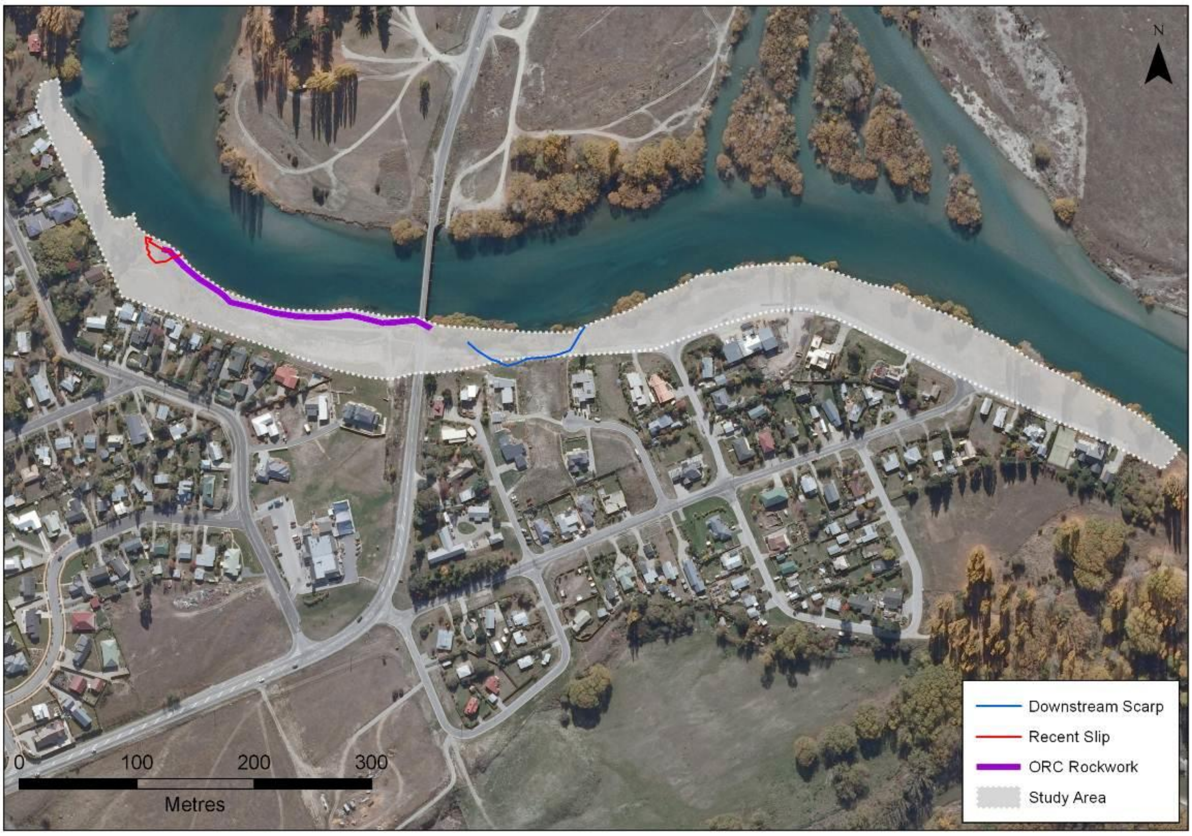


Figure 1: Site Location Plan (courtesy of Otago Regional Council)

The investigation covered the entire study area identified in Figure 1, with specific attention to the two identified instabilities 250 m upstream and 80 m downstream from Albert Town Bridge. The investigated areas can be accessed via a walking track off Albert Town – Lake Hawea Road. The track runs along the stream bank through the affected zones, with several residential lots located above.

3 Geotechnical Appraisal and Conditions

An engineering geological site appraisal has been undertaken. GSL visited the subject property on 3 December 2014 and undertook a detailed geotechnical site inspection. The site inspection was followed up with an intensive review of existing data and reports, including:

- Assessments undertaken by Geoconsulting Ltd for ORC (2014) and QLDC (2013)
- Technical comment from local resident and civil engineer Ben Mitchell (2014) (email correspondence with ORC)
- Albert Town Landslide Flood Level Mitigation Report including Slope Stability Assessment - Opus (2003)
- Bathymetric survey data 2003 – 2014 (TL Survey Services)
- Engineering Geology Project: Landslides Associated with the Hawea Advance Outwash Gravels and the post Albert Town Lake Silts in the Upper Clutha - Andrew Klahn 37687508
- Data, information and analysis held on GeoSolve files

The opinions expressed in this report are based upon ground investigation data obtained at discrete locations and historical information held within the GeoSolve database. The nature and continuity of subsoil conditions away from the investigation locations is inferred and cannot be guaranteed.

Key GeoSolve personnel involved have been:

Graham Salt BSc, BE, ME, PhD, CPeng, InTPE, FIPENZ - Lead Technical Specialist

Graham is a geotechnical Engineer with over 30 years' experience in pavements, engineering geology, geohydrology and geotechnical engineering. His main areas of interest are pavement design and structural evaluations, slope stability including seismic assessment, de-watering, materials, foundations, laboratory and field testing, design/ construction/ quality control of earth and rockfill embankments, reservoir engineering, numerical methods and software development. Much of his work has been in the upper Clutha River area, in association with hydroelectric power proposals. Graham's full CV can be found here: http://www.geosolve.co.nz/images/staff_CVs/CV%20GAS.pdf

Graeme Halliday BSc (Geology and Chemistry) - Senior Engineering Geologist

Graeme has a degree in geology and chemistry from the University of Auckland, and 40 years' experience as an engineering geologist in the lower South Island. He worked on the Manapouri and Clyde Dam projects, including landslide stabilisation work around the Clyde reservoir, one of the largest projects of its type in the world. He subsequently carried out landslide hazard mapping for the Queenstown Lakes District, and worked on many slope stability problems including the major 1999 Frankton Landslide at Queenstown, the 2000 collapse of the Nevis Bluff, and coastal landslide mapping at Moeraki. He has attended a number of international conferences where he presented papers on landslide topics. Following the Christchurch earthquakes, he worked for the Earthquake Commission (EQC) on stability issues in the Port Hills.

3.1 Geological Setting

The Clutha River in the Albert Town urban area is flanked by outwash gravel terraces from the last glaciation (Hawea Advance), which ended about 15,000 years ago. The river subsequently down-cut, entrenching into the outwash gravels and underlying glacial lake silts and Tertiary sediments.

This process resulted in landslides on the riverbanks as the river undercut the weak riverbank sediments (see Figure 2, Appendix A). A number of these landslides are currently active, and move in response to toe erosion during flood events. Others are inferred to be dormant.

The active Cardrona Fault is inferred to trend in schist bedrock beneath Albert Town, but there are no active scarps on the terrace surfaces and the position of the fault is not well constrained. The average return period for earthquakes on the fault is estimated to be 7500 years, so the risk is considered low. The greatest seismic risk is from the Alpine Fault, with a 30% probability of a magnitude 8 earthquake in the next 50 years that would likely generate severe shaking.

3.2 Active Albert Town Landslides

A close geological examination of the right bank of the Clutha River within the study area as defined in the ORC briefing document, has identified only two currently active landslides (Figures 3 and 4, Appendix A). These are termed the Albert Town Upstream and Downstream Landslides.

The rapid landslide that moved in 2003 immediately upstream from the Albert Town Bridge (here termed the Benchmark Slide) has been removed, and the area stabilised by a rock buttress revetment. The protective rockwork appears to have been successful with no signs of further instability visible at this reach.

3.2.1 Albert Town Upstream Landslide

This is a small landslide about 30m wide in a steep terrace face that affects a section of the cycle track along the bank of the Clutha River, about 250m upstream of the Albert Town Bridge (see Appendix A, Fig. 3; and Appendix B, Fig. 5). It has undergone intermittent minor movements in recent years in response to flood events, including the development of a perimeter scarp up to 1.5 m high at the western margin, which produces an abrupt step in the cycle track.

There are several scarps within the landslide which is showing signs of retrogressing back up the slope. The toe is inferred to exit below river level in the deeply eroded thalweg of the river on the outside of the adjacent bend (Appendix B, Fig. 5). The rock revetment along the river bank terminates a few metres onto the landslide, and may be contributing to scouring of the river channel and bank in the landslide toe area immediately upstream owing to possible eddying action (see 3.2.1.1 below.

The landslide is developed largely in laminated lake silts, with outwash gravels lying above an old erosion surface in the upper landslide. A bedding plane-parallel translational sliding mechanism is inferred, due to the presence of weak clayey silt layers along the sub-horizontal bedding. The water table is inferred to generally rise away from the river with moderate gradient.

3.2.1.1 Likely Characteristics of Future Movement

With further flood induced toe erosion, this landslide is likely to continue to undergo minor movement manifested as intermittent creep, and retrogress further up the slope.

It is possible that a major retrogression towards the top of the steep terrace could be triggered by a major flood scour. The loss of support could possibly result in a relatively rapid movement event. However, owing to substantial side friction associated with the narrow width of the landslide, it is considered that velocities would likely be of the order of 1 metre/minute rather than the 1 metre/second inferred for the rapid 2003 event.

3.2.2 Albert Town Downstream Landslide

The feature (located as shown in Appendix A, Figure 4) is a long riverbank landslide that was studied in detail in an April 2009 University of Canterbury project by A. Klahn, guided by current GeoSolve staff. At that stage it was located entirely below the riverbank road, but in recent times it has retrogressed back to the road cut on the uphill side (Appendix B, Fig. 6). The displacements evident on the road surface are minor, ranging from about 20-150 mm. A small sinkhole about 100 mm diameter is present on one of the scarps.

Toe erosion by the river during flood events is again considered the reason for the movement.

This landslide is developed largely in laminated lake silts, with outwash gravels lying above (Appendix B Fig. 6). A translational mechanism similar to the upstream landslide is inferred. The water table is inferred to rise at a moderate gradient away from the river.

The upper scarp feature at the top of the road-cut near the axis of the slide (see Appendix A, Figure 4) is about 300 mm high, exhibits local tension cracking, and extends about 25 m across the width of the 9 Bridgewater Road property. It cannot be visually traced further upstream or downstream.

The upper scarp exposes silty gravels (inferred to be colluvium), with lake sediment silts visible at one location (see Appendix B, Figure 6) . The face of the cut below the scarp is silty gravel colluvium.

The owner of the property advises that the scarp first formed about 2-3 years ago, but has not noticed significant movement since. Local tension cracking indicates minor current movement.

It is unclear whether the scarp is due to deep seated retrogression of the slide (as shown on the left-most retrogressed failure surface in Appendix B, Figure 6) , or to shallow slumping on the 30 degree cut slope caused by local withdrawal of support at the toe.

3.2.2.1 Likely Characteristics of Future Movement

With continuing toe erosion during floods the landslide is likely to undergo further minor movements. Movement characteristics may depend on the subsurface configuration of the failure surface.

- If the failure surface is shallow, future movement on the 30 degree slope is unlikely to be rapid, and risk to track users and adjacent properties is considered low.
- If the failure surface is deep-seated, future movement rates could be significant because the slide is wide in relation to its length in the direction of movement (minimal lateral restraint or “3D effect”). There are some more favourable aspects, mainly the low average inclination of the landslide and the residual strength condition that is likely to now be developed on most of the potential failure surface (see Appendix B, Fig. 6).

4 Summary

Landslides induced by river erosion at Albert Town have become evident over the last two decades. The hazard arises primarily where saturated fine-grained interglacial lake sediments (rather than outwash gravels) border the river. Field assessment and mapping has been carried out to enable informed evaluation of the potential for rapid mobility and likelihood of damage to properties.

Qualitatively it is considered that the recently activated (or reactivated) landslides do present concerns, but this initial stability assessment suggests that the main issues will be long term stability from incremental retrogressive landsliding rather than immediate hazards, as the likelihood of large scale en-masse rapid movement is relatively low.

5 Conclusions and Recommendations

- The study area exhibits two active landslides, which are discussed in this report. No additional areas of instability have been identified within the study area.
- Beyond the study area, a number of active and inferred dormant landslides are known to exist in the wider Albert Town region (see Appendix A, Figure 2). These have been identified in the course of earlier hydroelectric investigations and are inferred to have similar mechanisms as the two instabilities within the study area.
- The upstream landslide is likely to continue to creep slightly and episodically, and regress up the slope with ongoing flood induced toe erosion. Velocities in case of failure would be expected to be in the order of 1 metre/minute.
- The downstream landslide is likely to experience continuing further minor movements. Even though the landslide may regress a short distance up the road, the risk of a major retrogression into the properties above the cut is considered low due to the relatively moderate slopes. For the same reason, the risk of rapid movement is considered low also.
- Overall, we consider that a significant long-term problem is presented by the two landslides within the study area, owing to on-going river bed degradation and bank undermining causing continued retrogression of the failure zones. However imminent rapid failure of either landslide is unlikely unless triggered by a major flood or earthquake.
- As arranged, GeoSolve will shortly present recommendations for a suitable surveillance program, contingency response measures, and concept mitigation options. Critical short-term arrangements will be in place for the Christmas / New Year holiday period in case of serious developments.
- Irrigation on the upper terrace is not considered to be a significant exacerbating factor, as the surficial outwash gravels are relatively free draining. The dominant failure driver is considered to be loss of toe support owing to river scour, rather than saturation of the terrace soils.
- The passage of pedestrian and cycle traffic onto the marked instabilities (Appendix A, Figures 3 & 4) and on the upper terrace (Figure 3) and elsewhere within the study area is not considered to apply sufficient loadings to be a significant exacerbating factor.
- Under present conditions, in the event of either landslide within the study area mobilising it is likely that ground movement would be sufficiently slow to provide warning and escape time for persons in the unstable areas. However following a major flood or earthquake, the hazard may be elevated with potential for a rapid landslide with little immediate warning.

6 Applicability

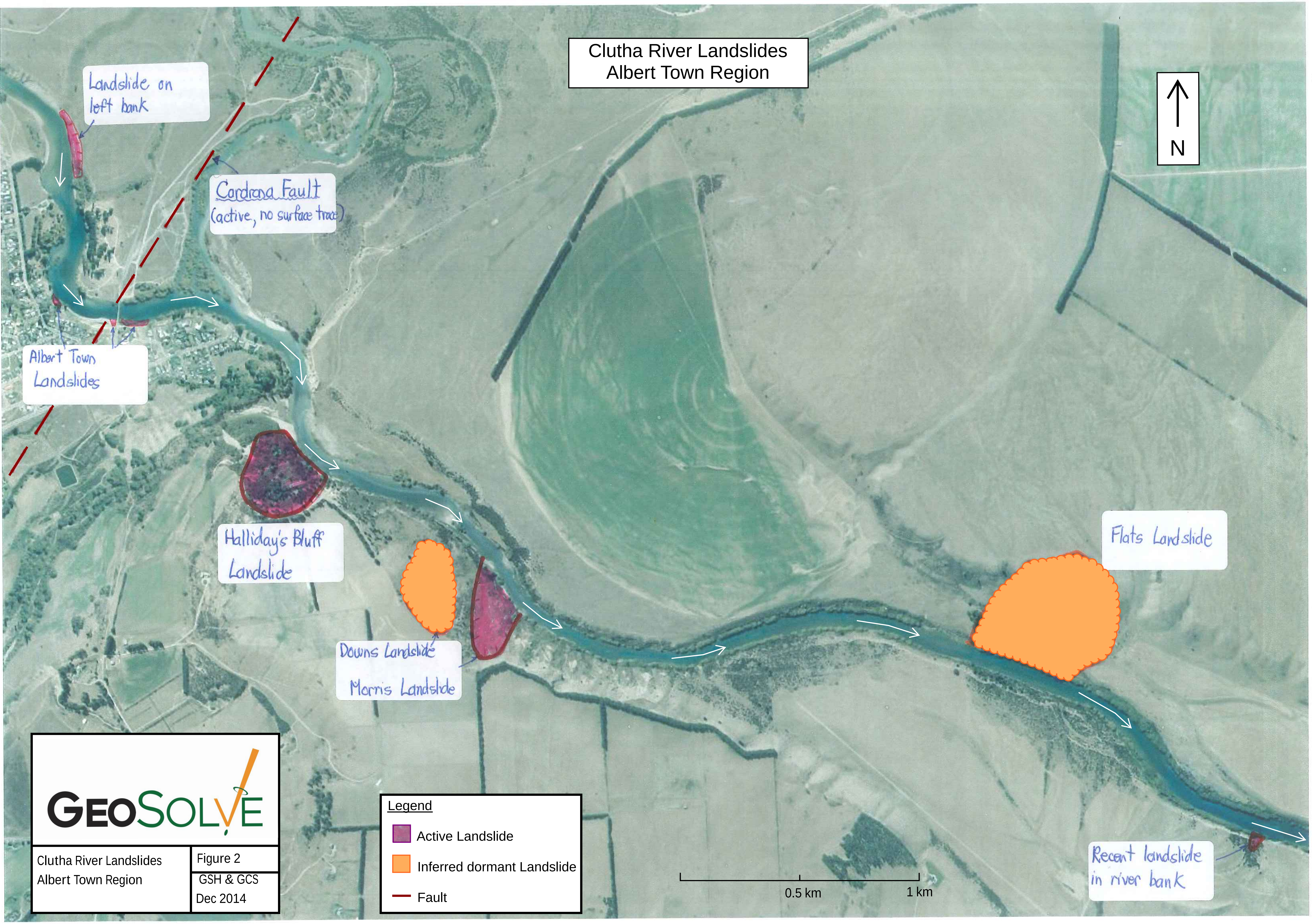
This report has been prepared for the benefit of Otago Regional Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Report prepared by:

Gina Schmitz Graduate Geotechnical Engineer	Hank Stocker Senior Engineer

Investigated for GeoSolve Ltd by:	Reviewed and Authorised for GeoSolve Ltd by:
Graeme Halliday Senior Engineering Geologist	Graham Salt Technical Director

Appendix A: Site Plans



Clutha River Landslides
Albert Town Region
N
Landslide on left bank
Cardrona Fault (active, no surface trace)
Albert Town Landslides
Halliday's Bluff Landslide
Downs Landslide
Morris Landslide
Flats Landslide
Recent landslide in river bank
Legend
Active Landslide
Inferred dormant Landslide
Fault
0.5 km
1 km
GEOSOLVE
Clutha River Landslides
Albert Town Region
Figure 2
GSH & GCS
Dec 2014

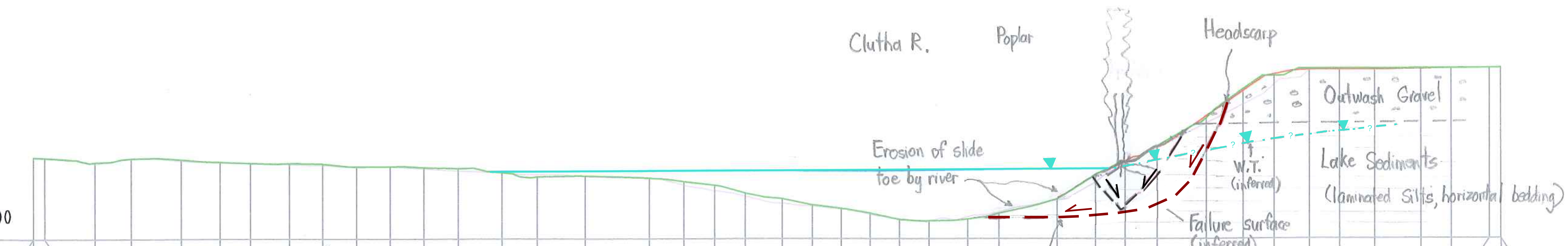
Albert Town Upstream Landslide

Albert Town Downstream Landslide

Appendix B: Cross Sections

Section AA'

A A'



Datum: 365.000

EXISTING SURFACE	376.39	376.30	375.68	376.20	376.03	375.68	375.54	375.51	375.42	375.03	375.05	374.91	374.80	374.24
2004 SURFACE														
DIFFERENCE														
OFFSETS	-177.30	-175.70	-168.70	-163.67	-156.75	-151.39	-147.15	-141.75	-137.13	-132.40	-127.73	-123.07	-118.29	-112.23

EXISTING SURFACE	373.63	373.72	373.44	372.92	372.43	371.32	370.54	369.69	369.20	368.54	367.64	367.45	367.69	368.50
2004 SURFACE														
DIFFERENCE														
OFFSETS	-107.30	-100.64	-91.69	-86.91	-82.69	-78.41	-73.27	-69.08	-65.05	-61.03	-56.97	-52.82	-47.47	-43.15

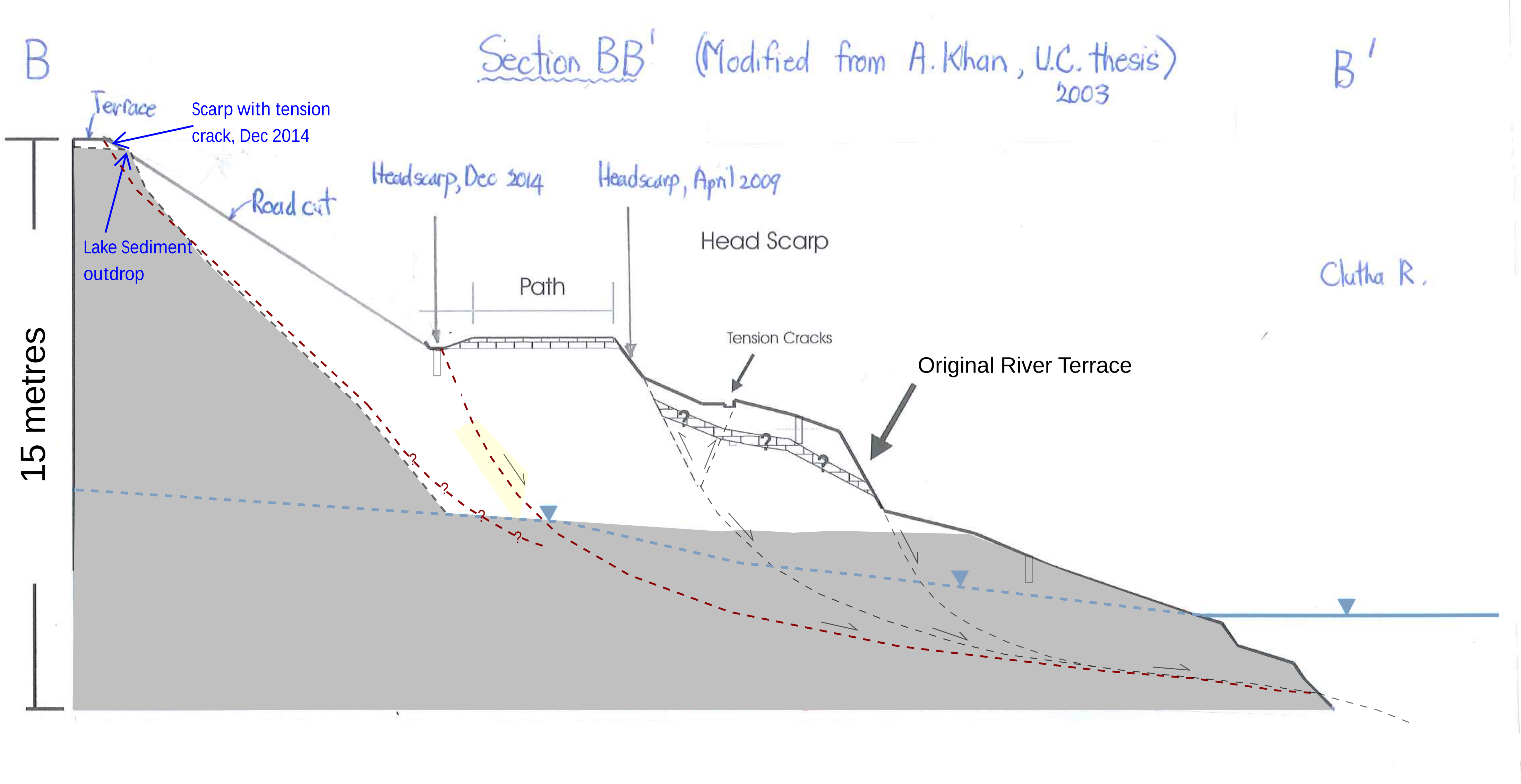
EXISTING SURFACE	370.53	373.91	375.74	377.90	381.77	385.77	387.59	388.58	388.61	388.59	388.60	388.61	388.63	388.67
2004 SURFACE		373.93	375.85	377.82	382.05	385.50	387.80	388.44	388.45	388.45	388.54	388.61		
DIFFERENCE		-0.01	-0.11	0.08	-0.28	0.26	-0.21	0.14	0.16	0.14	0.06	0.00		
OFFSETS	-35.09	-29.72	-25.58	-21.09	-14.24	-9.18	-4.90	0.00	4.19	9.08	15.53	19.75	25.08	26.68

CH: 90.000

Horizontal/ Vertical Scale:
1 : 1000 (A4)

GEOSOLVE

Albert Town Upstream Landslide Cross Section A - A'	Figure 5 GSH and GCS Dec 2014



Legend

Lake Silts	Water Table
Pavement	Inferred Water Table
Colluvium	Possible Failure Surface
Retrogressed Failure Surface	

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Albert Town Downstream Landslide Cross Section B - B'	Figure 6
	GSH and GCS Dec 2014