11.6. November 2017 Roxburgh Debris flow

Prepared for:	Technical Committee
Activity:	Safety & Hazards - Natural Hazards
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1. Précis

Flooding caused by the 26 November 2017 intense thunderstorm in the Roxburgh Township area resulted in extensive sedimentation in the Township. The purpose of this report is to present the observations and preliminary assessments made after the event and associated flooding. The report also describes the alluvial fan hazards for this area.

The pre-existing debris flow hazard for Roxburgh has been known for at least four decades. Damaging debris flows and floods triggered by very intense rainfall events occurred in the past, with documented events in 1938 and 1978. One of the creeks (Black Jacks Creek) also experienced an event in 2015.

Further investigations and assessments are in-progress to understand the implications of the November 2017 event on the alluvial fan characteristics and associated hazards and to establish the need for monitoring and any further mitigation measures. Some initial findings and conclusions are presented in this report.

Staff of ORC and CODC are working together to determine the most appropriate way of updating and informing the Roxburgh community about this work.

It is recommended that this report is received and noted.

2. Event description

The area around Roxburgh Township experienced thunderstorms on the afternoon of 26 November 2017 accompanied by very intense and localised precipitation. Metservice had issued a thunderstorm watch for Central Otago earlier that afternoon predicting rainfall intensities of 25 to 40mm per hour (Figure 1).

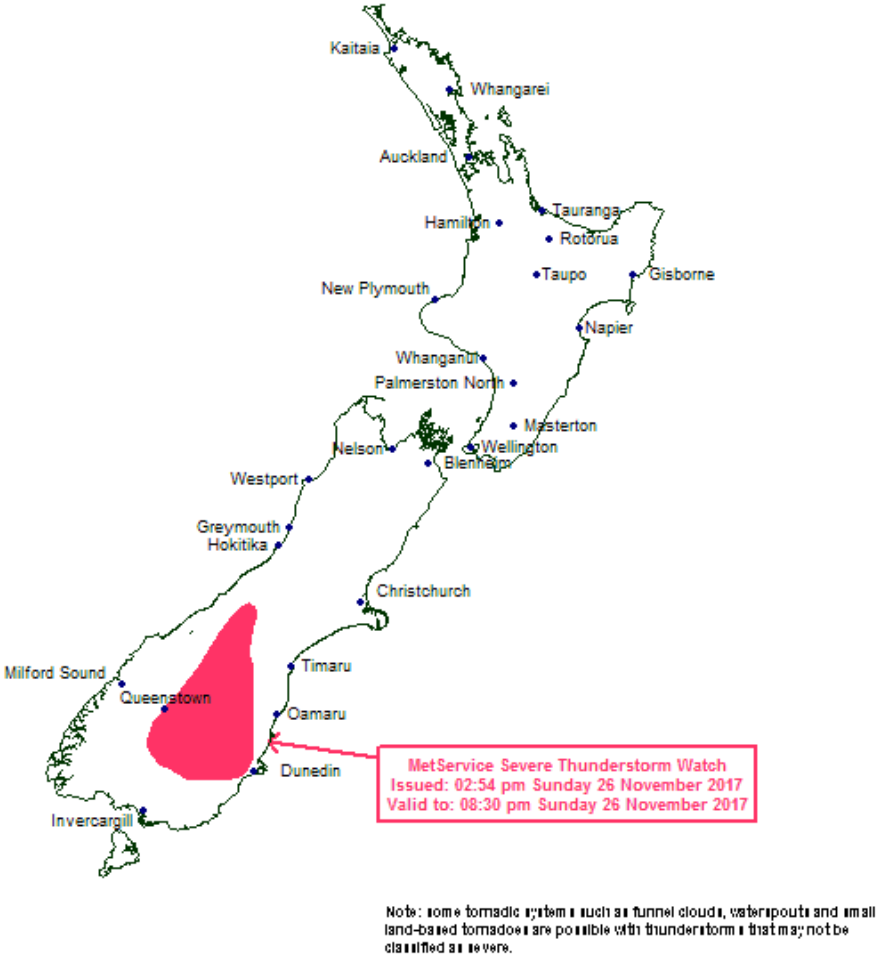

Figure 1. Forecast thunderstorm area from the Metservice Severe Thunderstorm Watch issued at 02:56 pm Sunday 26 Nov 2017.

A preliminary assessment of the intensity of the rain event indicates that the thunderstorms produced short duration, high intensity rainfall bursts (>40mm/h) located above the Roxburgh Township and in the Teviot/Millers Flat (Tima Burn) area.

Creeks draining the steep hillsides west of Roxburgh Township (Figure 2) mobilised substantial volumes of sediment (possibly as debris flows or hyperconcentrated flows) and deposited some of this material across alluvial fans and into the Clutha River (Figure 3). Observations made by Otago Regional Council (ORC) staff on 27 November 2017 indicate that rapid sediment aggradation filled some channels beyond capacity, causing flows to spread and avulse across the channels' alluvial fans.

The most severe out of channel sedimentation occurred on the alluvial fans of Reservoir Creek, which flows through northern Roxburgh and of Black Jacks Creek 3km south of the township. Un-named creeks near the golf course in southern Roxburgh, and just north of Roxburgh Township were also impacted (Figure 2).

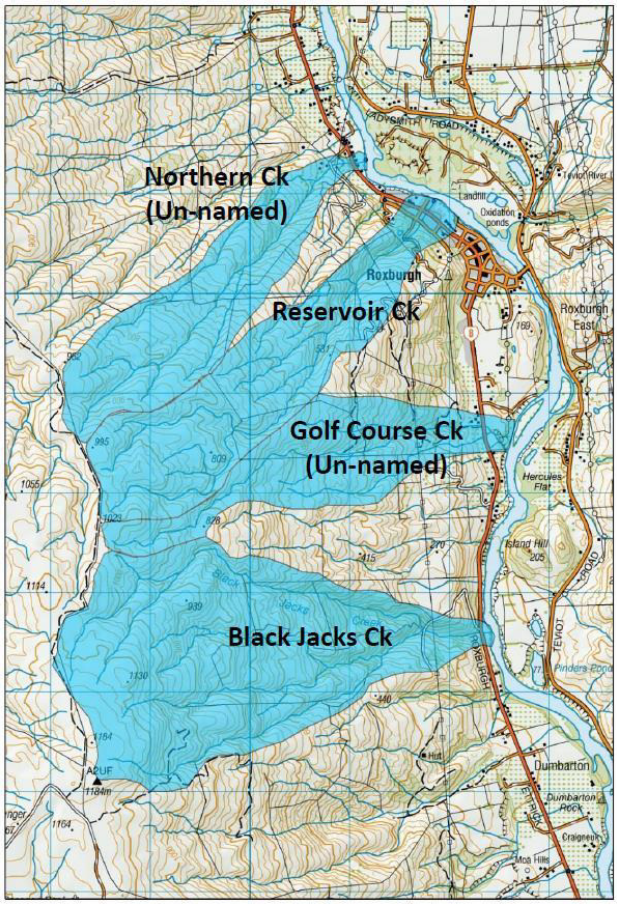

Figure 2. **Location of catchments where substantial alluvial fan sedimentation occurred on 26 November 2017.**

Figure 3. **View up Reservoir Creek showing sediment and debris deposited at the confluence with the Clutha River – Photo taken by ORC staff on 27 November 2017. Excavator has cleared part of the channel in the middle of the view. Width of debris at river edge is approximately 70 m. The Clutha River flows from right to left.**

In the upper catchments, many small landslips and bank failures were observed adjacent to the channels (Figure 4). Observations suggest that sediment laden flows travelled down the channels, stripping vegetation from the channel banks, and mobilising bed sediment. Significant quantities of sediment, ranging from silt to large boulders (over 1m diameter), were deposited across alluvial fans, including in northern Roxburgh Township (on roads, streets, properties, school grounds) (Figure 5).

The debris deposited in the Clutha River at Reservoir Creek and Black Jacks Creek have created deposition lobes which extend tens of meters into the river. These lobes potentially reduce channel capacity, and could induce bank erosion by changing river flow patterns (Figure 5).

Figure 4. **Example of small landslips and bank failures in the upper reaches of Black Jacks Creek – Photo taken by ORC staff on 27 November 2017.**

Figure 5. **Sediment deposition in Roxburgh Township and in the Clutha River from Reservoir Creek – Photo taken by ORC staff on 27 November 2017. The sediment lobe from Reservoir Creek protruding into the Clutha River is visible in top right of image. Note the finer sediment deposited on SH8 in the centre of the image.**

The event did not cause fatalities but some properties were severely affected and disruptions to some infrastructure was significant: SH8 was blocked for several days north and south of Roxburgh. Access to other streets in the township was also blocked due to debris deposition. Water and wastewater pipes were damaged during the event. The power and communication networks were also affected in the area.

A number of households were evacuated on Sunday evening until the water levels has receded. Some houses suffered partial inundations (water and fine sediment). The grounds of the Roxburgh area school were damaged by flooding resulting in the closure of the school for a few days. It was fortunate that the event happened on a day that the school was not in use.

3. Previous work on alluvial fans

The pre-existing debris flow hazard for Roxburgh has been known for at least four decades. Damaging debris flows and floods triggered by very intense rainfall events occurred in the past, with documented events in 1938 and 1978. One of the creeks (Black Jacks Creek) also experienced an event in 2015[1]. Information on these hazards is available to the public through the Otago Natural Hazards Database[2].

In 2006, the ORC initiated a general review of the hazards associated with alluvial fans in the region, which was undertaken by Opus International Consultants Limited and GNS Science. The review resulted in a report (Opus 2009) describing the nature and formation of alluvial fans, the type of hazards that they pose to land use and human activity, and how such hazards may be mitigated. More than 2000 alluvial fans, equating to 6% of the total land area of the Otago region have been mapped.

Following this regional compilation, in 2008 ORC engaged GNS Science to map and assess a selection of fans in greater detail, including fans in the Roxburgh area (GNS 2009.). A subsequent 2011 ORC report reviewed high hazard alluvial fans, including Reservoir Creek in Roxburgh (ORC 2011).

4. Alluvial fans in the Roxburgh Township area

All catchments in the Roxburgh area with alluvial fan activity on 26 November 2017 were previously identified as having active and recently active alluvial fans (e.g., Figure 6).

As noted above damaging debris flows and floods triggered by very intense rainfall events occurred in the past, with documented events in 1938, 1978 and (at Black Jacks Creek) 2015.

[1] Coastal Otago Flood Event: 3 June 2015, Otago Regional Council, October 2015, p53.

[2] https://www.orc.govt.nz/managing-our-environment/natural-hazards/otago-natural-hazards-database

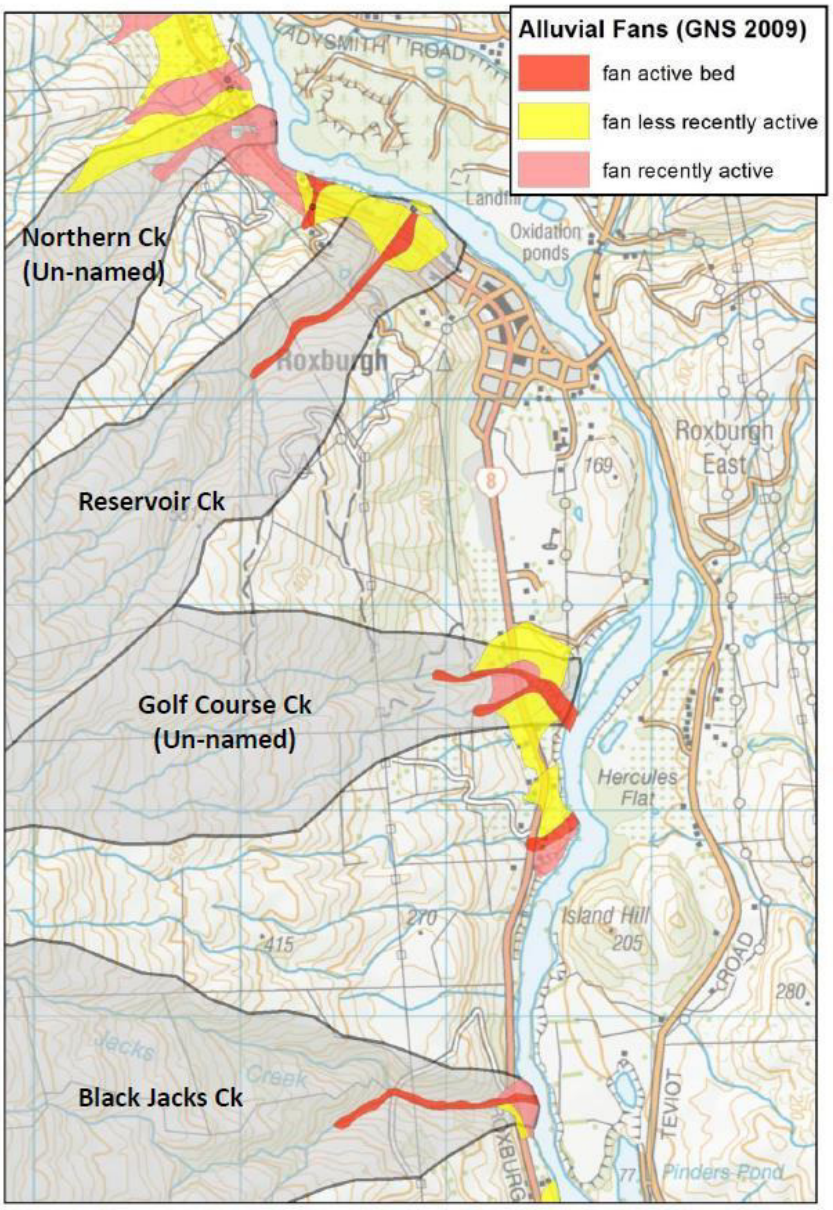

Figure 6. **Mapped alluvial fan landforms near Roxburgh Township (GNS 2009).**

4.1. Reservoir Creek

Reservoir Creek is a 3.5 km2 catchment which runs through northern Roxburgh. Reservoir Creek alluvial fan was specifically described in the 2011 ORC report (ORC, 2011, Appendix A). This fan has been modified extensively by urban development and is bisected by State Highway 8 (SH8) (Figure 7).

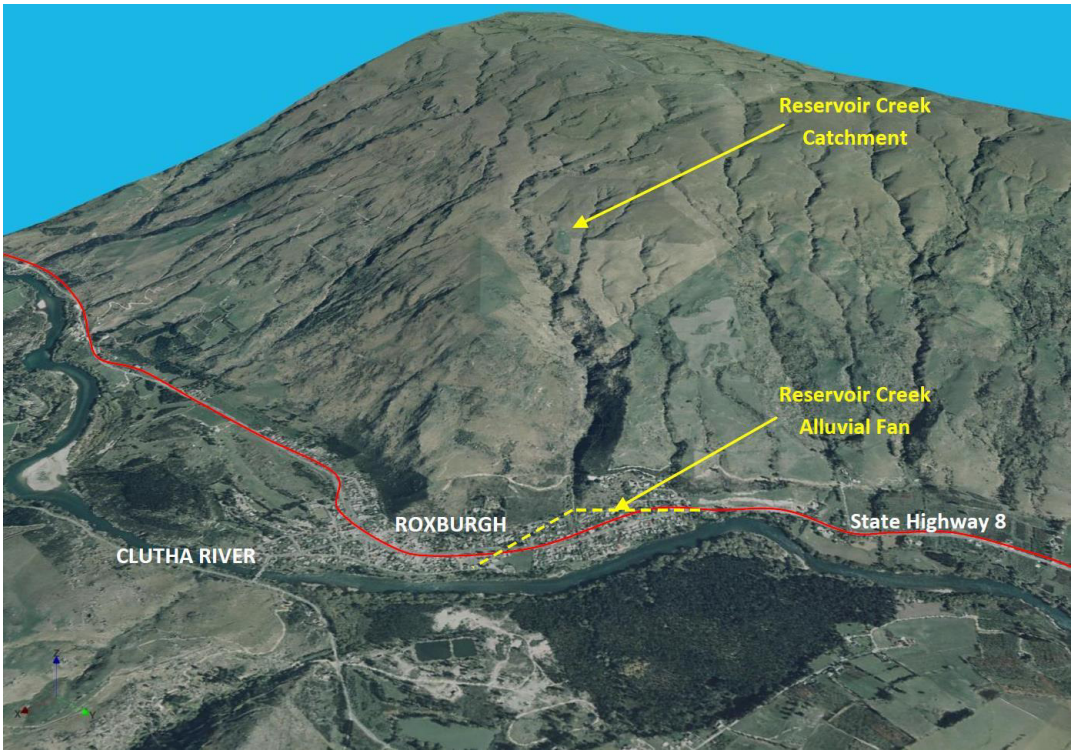

Figure 7. **Image showing the Reservoir Creek alluvial fan with respect to the surrounding environment (from ORC, 2011).**

The fan has been subject to recurrent debris flow events in the past. In October 1978, debris flows overwhelmed the channel and affected residential properties on the surface of the fan above and below SH8 (Figure 8).

Figure 8. **Sedimentation on the Reservoir Creek fan surface. Top left photo is looking downstream and top right photo is looking upstream (16 October 1978). Bottom photo is showing silt deposited on SH8 (15 October 1978) (OCB photos).**

Following this 1978 event, in the early 1980's, the Otago Catchment Board (OCB) has excavated the channel and constructed a concrete lined channel in the downstream section of Reservoir Creek (from where it exits the valley). The channel structure is designed to rapidly convey floodwaters and debris across the alluvial fan and into the Clutha River (Figure 9). The concrete channel is 200 m long, 3 m wide at its base, 9 m wide at the top, and 2 m deep.

Figure 9. Concrete lined channel in the downstream section of Reservoir Creek (2009, ORC staff photo).

On 26 November 2017, out of channel sedimentation occurred across the alluvial fan of Reservoir Creek. In the early stages of the event, the concrete lined channel contained most of the debris within the channel as designed, and deposited it in the Clutha River. Eventually the concrete channel backed up with sediment, and resulted in silt and water exiting the channel. Silt-laden floodwater escaped the channel near the top of the fan, and flowed downslope into nearby properties including the Roxburgh Area School (Figure 3 and Figure 5).

The concrete channel was filled with sediment, a volume of 2400 cubic meters. At the outlet of the channel at the Clutha River, a 70 m wide and 35 m long visible lobe of sediment accumulated, with an estimated volume of a further 5000 cubic meters. An unknown volume of sediment also accumulated on the river bed, and additional sediment likely bypassed the lobe deposit and was swept downstream. Boulders up to 1 m in diameter were visible in the lobe deposit. The Reservoir Creek sediment deposited in the bed of the Clutha River created a new rapid with standing waves in excess of 1 m in amplitude.

4.2. Black Jacks Creek

The 6.5 km2 Black Jacks Creek catchment is located 3km south of the Roxburgh Township (Figure 2). This catchment is not urbanised but SH8 crosses the relatively small alluvial fan. Black Jacks Creek runs under the highway through a concrete box culvert before discharging into the Clutha River.

There are no flood mitigation structures on Black Jacks Creek and debris can readily block the culvert under SH8 sending floodwaters and debris across the highway.

Like Reservoir Creek, the fan has been subject to recurrent debris flow events in the past. In October 1978, a debris flow overwhelmed the channel and large amounts of debris were deposited on SH8 (Figure 10). An event also occurred in 2015 closing SH1 for two days (Figure 11)[3].

Figure 10. Sedimentation on the lower reach of Black Jacks Creek – 15 October 1978. Left photo is looking upstream to the culvert under SH8 and the right photo is looking along SH8 towards Roxburgh Township (OCB photos).

Figure 11 Flooding at Black Jacks Creek at SH8, 3 June 2015.

[3] op cit.

Figure 12. Sedimentation on the lower reach of Black Jacks Creek – 27 November 2017 (ORC staff photo). Width of view along the riverbank is 150 m.

A significant volume of sediment also needed to be removed from SH8 and from the fan surface (Figure 12) to re-establish the channel. The Black Jacks Creek alluvial fan is comparatively small, but the 120 m long and 50-100 m wide central area of the fan was covered by sediment averaging ~0.5 m in thickness, including a 70 m length of SH 8. The channel also required excavation to re-establish a flow path. These two components suggest approximately 6000 cubic meters of sediment was deposited in the lower channel and on the fan surface. Black Jacks Creek did not build a substantial lobe out into the Clutha River (compared to Reservoir Creek), but an unknown volume of sediment bypassed the alluvial fan and was deposited in the River. The sediment on the fan surface ranged from fine silt, through to boulders in excess of 1 m in diameter.

4.3. Other creeks

Two other catchments in the Roxburgh Township area experienced notable flooding and sedimentation during the 26 November event.

Golf Course Creek (informal name) blocked the culvert crossing SH8, and a large volume of coarse sediment (small boulders) was deposited upstream of and across the highway, inundating adjacent paddocks. Floodwaters carried fine sediment across the broader alluvial fan, with significant sediment deposited across the rugby grounds (Figure 13).

Figure 13. **Sedimentation in the lower reaches of an unnamed creek, here referred to as Golf Course Creek– 27 November 2017 (ORC staff photos). In the left image, boulders inundated a paddock upstream of the highway. The right photo shows finer sediment (silt to small gravels) deposited across the rugby field.**

An un-named creek immediately to the north of Roxburgh (Figure 2) also had debris deposited across its alluvial fan, which blocked SH8 and resulted in sediment deposited against structures (Figure 14).

Figure 14. **Sediment deposited across the alluvial fan of a creek north of Roxburgh (27 November 2017, ORC staff photo).**

In the Teviot/Millers Flat area (Tima Burn) south of the Roxburgh Township (Clutha River left/eastern bank, opposite Roxburgh), the intense rainfall generated damaging flash flooding and sediment laden water, but no debris flows were documented.

5. Investigations and assessments following the event

After the 26 November rainfall event, ORC staff undertook several site visits to document the event and assist with clean-up operations. Following the site visits more in-depth assessments and associated data collection have been commissioned.

In order to quantify the extent of sedimentation that occurred in the Clutha River, a bathymetric survey of the Clutha River in the vicinity of Roxburgh Township (5km long approximately) was undertaken in early December 2017. Post-event aerial photography was also captured in late December 2017 so it can be compared with pre-event photos to assist in estimating the volumes of sediments mobilised in affected catchments. This data set will also assist in identifying debris supply and deposition areas.

In response to the sediment deposition into the Clutha River, Damwatch Engineering was engaged by ORC to undertake a preliminary assessment of the significance of the sediment deposition lobes in the Clutha River and of the resulting potential increase of the flood and bank erosion hazards (Damwatch Engineering, 2017). Their report is attached.

The assessment involved a site visit by Damwatch Engineering and computational hydraulic modelling of river flows past the sediment deposition sites to estimate changes in water levels for flows of different magnitudes and increases in flow velocities. This assessment utilised the bathymetric survey data described above.

The main conclusions of the Damwatch Engineering assessment are:

1. "*The sediment lobes deposited by Reservoir Creek and Black Jacks Creek [...] are the only ones that have significantly affected the water level profile along the river at these locations*";
2. The existing flood hazard has "*increased slightly due to slightly elevated flood levels. The extent of these elevated flood levels will rapidly diminish within several hundred meters upstream of each sediment deposition area due to the steep slope of the Clutha River*";
3. "*There are a number of houses located along the section of Tweed Street which runs parallel with the Clutha River which will be exposed to a slightly increased flood hazard*" when flows exceed 3350m^3/s (approximate magnitude of the December 1995 flood);
4. "*The sediment deposition areas in the Clutha River at the Reservoir Creek and Black Jacks Creek confluences has also caused the existing bank erosion hazard along the opposite left bank to be increased slightly due to increased flow velocities. However, the increased flood flow velocities are not excessive and tend to approach an upper limit of 3.4-3.6m/s. The river banks are protected by willow trees at both locations*";
5. "*The lateral slope of the sediment deposits will enhance erosion of sediment material by flood flows. While the largest boulders may not be moved by flood flows, erosion of sediment material around them will tend to undermine them and cause them to roll down the slope and deposit on the river bed*";
6. "*The gradual erosion of the sediment deposits by flood flows over time will cause the slightly increased flood and bank erosion hazards to slowly trend back to the pre 26 November 2017 levels*".

Damwatch Engineering also recommended to capture more bathymetric data to confirm some assumptions made during their preliminary assessment and to assist the monitoring of the gradual attrition of the Reservoir Creek deposition area due to erosion by continual flood events. This additional work is being arranged and will allow more thorough assessment of the matters described in conclusions 2 and 3 above.

GNS Science was engaged by ORC to assess the debris supply and mobility in the upper catchments and the likelihood and consequence of localised avulsion and breakout should further flooding occur. An assessment of the potentially increased likelihood of further sediment-laden floods will also be provided. GNS Science was also asked to include recommendations on any works and monitoring that should be put in place to reduce the short-term risk of future debris flooding. These assessments by GNS Science are in-progress and conclusions and recommendations are expected by the end of January 2018.

ORC is also taking advice on the feasibility and benefits of the installation of a monitoring network on notable landslides adjacent to the creeks which have the potential to block the creek and initiate further debris flows.

In the longer term and based on the assessments described above, the natural hazards risk for the Roxburgh Township area will be re-assessed. The re-assessment will use NZS9401:2008 (Managing Flood Risk - A Process Standard), have regard to the notified Regional Policy Statement and incorporate present understanding of future climate change. This action is consistent with Council discussion in respect of the Rangitaiki River April 2017 flood event[4]. It is planned to collaborate with Central Otago District Council (CODC) during this assessment.

Part of this assessment will be the determination of target or design channel geometries (longitudinal profiles, cross-sections) for the four major creeks. This will require assessment of sediment storage and conveyance characteristics between the top of each catchment and the Clutha River and decisions on how these are best managed. This information will enable river maintenance requirements and responsibilities to be more clearly defined.

Staff of ORC and CODC are working together to determine the most appropriate way of updating and informing the Roxburgh community about this work.

6. Conclusion

The debris flows and flooding caused by the 26 November 2017 intense thunderstorm in the Roxburgh Township area resulted in extensive sedimentation across alluvial fan surfaces associated with some of the catchments draining the steep hillsides west of the Township.

Damaging debris flows and floods triggered by very intense rainfall events have occurred in the past. The alluvial fan characteristics and associated hazards were described in several reports commissioned by the ORC from 2006.

[4] Rangitaiki River Scheme Review – April 2017 Flood Event, Report to Technical Committee, 6 October 2017.

Further investigations and assessments are in-progress to understand the implications of the November 2017 event on the alluvial fan characteristics and associated hazards and to establish the need for monitoring and mitigation measures.

In the longer term and based on the assessments described above, the natural hazards risk for the Roxburgh Township area will be re-assessed.

7. Recommendation

a) *This report is received and noted.*

Endorsed by: Gavin Palmer
Director Engineering, Hazards & Science

References

Barrell D.J.A..; Cox, S.C.; Greene, S.; Townsend, D.B. 2009: Otago Alluvial Fans Project: Supplementary maps and information on fans in selected areas of Otago. *GNS Science Consultancy Report* 2009/052. Prepared for Otago Regional Council. 19 pages, 3 tables and 3 appendices

Grindley, J.; Cox, S.C.; Turnbull, I.M. 2009: Otago Alluvial Fans Project. Opus International Consultants Limited, *Report no. 1205 – Version 2*, *Reference 6CWM03.58*, prepared for Otago Regional Council. 64 pages, 2 appendices

Otago Regional Council 2011: Otago Alluvial Fans: High Hazard Fan Investigation. Otago Regional Council *ISBN: 978-0-478-37649-4*. 96 pages, 1 appendix

Webby G: Roxburgh – Preliminary Assessment of Flood and Erosion Hazards in Clutha River. *DAMWATCH Engineering Letter 22 December 2017.* 24 pages, 1 appendix

Attachments

1. Appendix A **[11.6.1]**
2. Glossary **[11.6.2]**
3. 2017-12-22 preliminary assessment of flood and erosion hazards in Clutha River at Roxburgh **[11.6.3]**