Report on 2017 monitoring of the Johnsons Landing landslide

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Monitoring of the potentially unstable area above the Johnsons Landing landslide continued in 2017. Three field visits were made in May, July, and October. Measurements were made by myself, with assistance from Katy Fraser (FLNRO) and a Johnson's Landing resident (Tony Holland). Reflectors along the headscarp were also surveyed in October 2017 by Sproulers' Enterprises Limited.

Slope displacement measurements

Eight measurement sites are located along the crack that bounds the top edge of the potentially unstable area. One of these (Site 1) is a line of 6 metal pins, with the top pin drilled into bedrock above the crack. The other sites consist of two or three wooden stakes driven into soil above and below the crack. The distance between the stakes is measured manually with a tape measure.

Table 1 summarizes the movement in 2017 compared to the movement in previous years, and the orthophoto below (Figure 1) shows the location of the sites.

The measurement results this year are difficult to interpret, particularly at Site 1. As mentioned above, Site 1 has 6 metal pins. Between October 2016 and May 2017 the distance between pin 1 and pin 2 increased by 1.25 m; however, the distance between pin 2 and pin 3 decreased by 77 cm and the distance between pin 4 and pin 5 decreased by 20 cm. Therefore, the crack at Site 1 appears to have widened 31 cm. All other measurements between pins remained the same within a few centimetres. Pin 2 is drilled into a large boulder. Therefore, it is possible that the boulder shifted in such a way that the distance between pins 1 and 2 increased and pins 2 and 3 decreased. It is also possible that the movement at this site is a result of the crack widening or shifting.

The crack at Site 4 widened by 17 cm and the crack at Site 7 widened by 8 cm. All other sites show no movement or very minor movement within measurement error as some stakes have become loose over the years. Sites 1 and 4 are the two sites that have shown small, but progressive, movement over the past 5 years.

Table 1. Summary of total annual movement (year beginning in October)

Site	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	Total movement 2012/2013 to 2017
1	0.64 m	0.15 m	0.07 m	0.06 m	0.31m	1.23
2	-0.47 m	-0.28	Missing stake			
3	Missing stake					
4	0.38 m	0.22 m	0.04 m	0.03 m	0.17 m	0.84
5	Installed fall 2013	0.03 m	0.01 m	0 m	0 m	0.04
6	Installed fall 2013	0.03 m	0 m	0.02 m	-0.02 m	0.03
7	Installed fall 2013	0.21 m	0.04 m	0 m	0.08 m	0.33
8	Installed fall 2013	0.05 m	0.07	0.12 m	-0.13 m	0.11

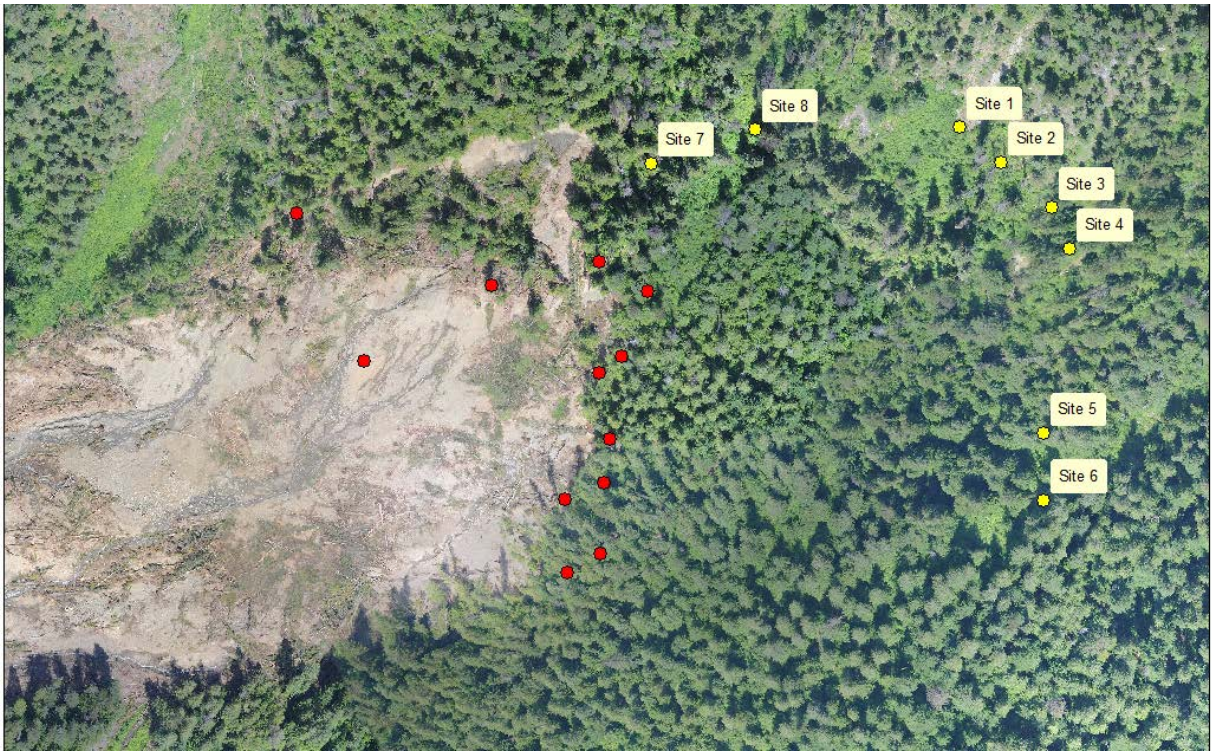

Figure 1. Measurement locations that are measured by hand are identified in yellow (with labels), and measurement sites surveyed by SEL from a base station are shown in red.

Weather record

The 2012 landslide is thought to have been triggered by high groundwater levels, caused by the exceptionally high rainfall in June 2012, as well as by above-average snowpack and late snowmelt. Gar Creek is groundwater-fed, and is known to respond slowly to snowmelt and rainfall, compared with other streams in the area.

Table 2 summarizes rainfall for the past five years in the April-June period, as recorded by the Powder Creek fire weather station. Rainfall was slightly below average over this period in 2017 (171 mm as compared to 200 mm average). The snowpack over the past five years at Upper Gray Creek Pass to the south is also summarized in the table. In 2017 the snowpack was not measured at Upper Gray Creek Pass on April 1, though it was measured on March 1 and June 1. The snow water equivalent for 2017 was estimated by interpolating between the March 1 and June 1 measurements and comparing the Gray Creek record with the Redfish snow pillow. The snowpack on April 1 is estimated to have been slightly above average at 109%.

Table 2. Weather and snow data from 2012-2016 near Johnson's Landing. No data was collected April 1 2017 at the Upper Gray Creek snow course; therefore, snowpack was estimated based on comparison with the March 1 and May 1 values and the Redfish snow pillow.

Rainfall at Powder Creek (mm)	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**Normal at Kaslo**
April	63	49	75	26	18	76	62
May	44	59	77	25	94	50	61
June	208	164	48	42	81	45	77
3-month sum	314	272	200	93	193	171	200
Upper Gray Creek Snowpack (% of Normal)	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**Upper Gray Creek April 1 SWE Normal 1981-2010 (mm)**
April 1	134%	100%	113%	83%	118%	109% (est.)	722

Survey of Reflectors at the Headscarp

A set of reflectors were installed on the rim of the headscarp in 2014 to provide a more sophisticated method of measuring movement of the slide in addition to the manual measurement of stakes. The reflectors have been measured once a year by Sproulers' Enterprises Limited (SEL) in 2014, 2015, 2016 and 2017.

The spatial and temporal pattern of movement does seem to indicate that there has been some minor westerly movement at the headscarp over the past four years. However, it is challenging to quantify the annual movement because of various sources of error inherent in the current surveying methods. I will be undertaking discussions with SEL next year on how to modify the survey methods to obtain more accurate results.

Other observations

No visible changes occurred at the landslide headscarp this year.

On March 27, 2017 residents reported that the night before they had heard a lot of noise coming from the creek at about 1130 pm. A flight over the landslide area revealed that a slide had occurred along the channel bank of Gar Creek about 350 m downslope from the main headscarp. The slide material likely partially blocked the creek, before releasing as a small debris flood that travelled down the channel depositing most of the debris upstream of the site of the former community water intake. Additional small failures at this site are probable in years to come.

It should be noted that monitoring the crack does not provide any real-time warning of imminent landslide hazard. Instead it provides useful information on the behaviour of the unstable area, which may help us better assess the landslide hazard in the future.

Conclusions and recommendations

Even though this spring was not particularly wet, increased movement at the upper tension crack was measured. Therefore, I recommend continuing to both manually measure the upper tension crack and survey the headscarp in 2018.