

#### **4.4 S4 – WILLOW CREEK**

##### **Background**

The Willow Creek site is located on the east side of Highway 2:08, approximately 4.7 km north of the bridge over the Oldman River.

The landslide at this site is occurring in the west slope of the Willow Creek valley, which is located to the east of Highway 2. The landslide is located along the outside of a bend in the creek channel. It appears that movement of the landslide is triggered by creek erosion along the toe of the slope at the west bank of the creek which in turn leads to rotational failures within the landslide mass in the lower and middle portions of the west valley slope. The backscarps of these failures form a near-vertical bluff of exposed soil along the crest of the west valley slope. Subsequent block toppling failures along this bluff have led to retrogression of the slope crest near the fenceline. This retrogression appears to typically occur in increments in the order of 1 to 2 m at a time, rather than at a more gradual, steady pace. The valley slope is approximately 15 to 20 m high and the minimum offset of the crest of the valley slope from the east edge of the highway has reduced from 25 m in July 2003 to approximately 18 m as of December 2005.

This site has been monitored by AIT and consultant personnel since 1993. A number of SI's and piezometers were installed in 1994 and were read at various times up to the spring of 2003. During that time the SI's did not measure any significant movement. The SI's are not well-suited to provide early warning of crest retrogression for this type of landsliding given that the retrogression occurs as a result of block toppling failures along the existing crest rather than lateral movement along weak soil/bedrock layers underlying the slope. Therefore, the SI's are no longer being read on a regular basis and the current monitoring strategy for this site is based on surveys of the slope crest position and visual observations of the slope condition.

In the spring of 2007, AIT requested that AMEC prepare a repair design for this site based on recommendations from the previous annual inspections that stream bank protection measures be used to mitigate the root cause of the landsliding. The annual inspection documented in the following subsections was performed in parallel with this design work.

##### **Site Assessment**

The site assessment was performed on June 20, 2007. The weather at the time of the site assessment was sunny and clear. The inspection covered the area between the northbound lanes of Highway 2 and along the slope crest, as well as a traverse down to the creek bank below the central portion of the landslide.

### **Observations**

The following points summarize the observations made during the site assessment. Please also refer to Appendix S4 for a site plan and annotated photographs illustrating key observations.

- The overall condition of the landslide is the same as observed in the previous annual inspections. Ongoing erosion along the west creek bank at the toe of the slope continues to trigger landslide movement and westwards retrogression of the slope crest towards the northbound lanes of Highway 2.
- At the time of the inspection, an approximately 50 to 60 m segment of the slope crest had retrogressed westwards across the fenceline and towards the northbound lanes of Highway 2. Photos S4-1 and S4-2 show the position of the slope crest relative to the fenceline. Overall, it appeared that the slope crest had retrogressed slightly (e.g. 1 to 2 m in places) in the past year and not by the larger increments noted between the June 2005 rains and the 2006 inspection.
- The minimum offset of the slope crest from the edge of the pavement was in the order of 15 to 18 m at the time of the inspection.
- There did not appear to have been significant changes in the position or condition of the toe of the central portion of the landslide, as opposed to observations during the 2006 inspection that the toe position appeared to have thrust out approximately 10 to 15 m further into the creek channel in the previous year. The creek level at the time of each annual inspection varies from year to year (depending on the timing of the inspection relative to spring runoff), therefore observations of the landslide toe geometry relative to the edge of the creek are somewhat qualitative.
- As noted in previous inspections, the surface of the colluvium in the landslide area had a “flowed” appearance, however there did not appear to be active groundwater discharge at the time of the inspection. It is judged that the flowed appearance is largely due to slope wash from rain storms saturating the exposed silt/clay soils and causing them to flow down the slope face.

### **Assessment and Risk Level**

The overall assessment of the landslide conditions and the risk to the highway at this site remains as follows:

- The slope crest will continue to retrogress westwards towards the highway in response to ongoing landslide movement in the middle and lower portions of the west valley slope. It would likely take some time, possibly years, before the slope crest retrogression would directly undermine the northbound lanes of the highway. However, prior to that point a guardrail along the east shoulder of the road will be required due to the proximity of the slope crest to the road.

- As outlined in the Background section, the slope crest retrogression towards the highway occurs in response to landslide movement in the middle and lower portions of the west valley slope. This landslide movement is caused by creek erosion along west creek bank/toe of the west valley slope. There is a lag time between landslide movement on the middle and lower slopes and the subsequent increment of crest retrogression towards the highway. Therefore, if mitigative measures are implemented to reduce the landslide movement caused by creek erosion at the toe of the slope, the crest retrogression should also be reduced but not immediately (unless the crest is stabilized by other means).
- It is also possible that changes to the erosion conditions at the toe of the slope resulting from hydrological changes to Willow Creek (i.e. channel shifting upstream or downstream of the site, long-term flow volumes and patterns) may affect the rate of retrogression towards the highway. This is not considered to be very likely, based on the hydrotechnical assessment of the creek channel as part of the ongoing repair design.

Therefore, AMEC recommends the following Risk Level factors for this site:

- Probability Factor of 9 because the landslide is active and westward crest retrogression towards the highway will continue.
- Consequence Factor of 2 for the present location of the landslide relative to the northbound lanes of the highway.

Therefore, the current recommended Risk Level for this site is equal to 18, which is the same as recommended following the 2005 and 2006 assessments. Note that without any repair measures to prevent further landslide movement, the Consequence Factor will increase over time and the Risk Level will increase correspondingly.

### **Discussion and Recommendations**

At the time of writing, the repair design is expected to be completed in the late summer of 2007, with tendering of the work planned for the fall of 2007 and target construction period in the first and second quarters of 2008.

Aside from implementation of the repair (creek bank protection, bioengineering measures for the slope face, and soil nails to stabilize the oversteepened slope crest), AMEC recommends that the annual inspections of this site be continued in order to confirm the effectiveness of the repair measures. The annual inspections will need to include:

- Visual inspection of the stream bank protection measures after future spring peak flows.

- Visual inspection of the bioengineering/erosion protection measures on the slope face in the landslide area.
- Visual inspection of the slope crest, including measurements of the slope crest position relative to a series of reference pins to be installed adjacent to the slope crest. This will provide a repeatable reference measurement to check for future retrogression of the slope crest towards the highway.