SECTION A – FILE REVIEW

Site Location

- This site is located along Highway 41:03, approximately 3 km south of Elkwater, AB and within Cypress Hills Provincial Park.
- UTM coordinates: Easting 553613, Northing 5499027 (NAD 83, Zone 12U)
- SE-18-8-2 W4M
- NTS mapsheet 72 E/9

There are two areas, referred to as "Area A" and "Area B", at this site that are being damaged by landslide movement. The relative positions of Area A and Area B, as well as their location relative to the town of Elkwater, AB, are shown on the airphoto figure in the report on the March 2007 call-out site inspection, a copy of which is included in Section F of this binder.

Chronological Background

Table A1 provides a chronological background for this site.

Site Geology, Hydrogeologic And Geomorphologic Setting

A review of airphotos of the site and published geological references for the site area was performed as part of the March 2007 call-out site inspection work. In summary:

- The highway is constructed across the lower portion of the east valley slope of a north-draining, unnamed creek valley incised into the north slope bordering the Cypress Hills Plateau to the south. The highway is approximately 10 to 15 m in elevation above the creek at the base of the valley and roughly parallels the creek channel. As shown on the airphoto figure in Section F of this binder, the southern segment of the highway at this site is oriented northwest/southeast and the northern segment is oriented roughly north/south.

- The valley slope around Area A is approximately 50 to 60 m high with an overall crest-to-toe slope angle of approximately 12 to 13°. The slope angle for the upper half of the slope is around 16° and the slope angle for the lower half of the slope (i.e. the sideslope across the highway alignment) is around 8°. The slope above the highway has distinct slump topography extending all the way up to the crest of the valley slope (roughly 225 m horizontal and 50 m vertical to the upslope of the highway right-of-way). The cross-section of the valley slope in Section F of this binder shows at least four large slump blocks visible in the slope profile. A very approximate sketch of circular failure surfaces below the visible slump block tops shows that the depth of landslide movement could be in the order of 10 to 20 m.

- The airphotos show widespread slumping on the slopes below the Cypress Hills Plateau at the site and in adjacent areas. This is consistent with the published surficial geology information that notes that the northern slope below the Cypress Hills Plateau, including the area around the site, has numerous and widespread landsliding with movement

surface along shaly and bentonitic beds in the underlying bedrock as well as the observations of slump block profiles in the areas around and upslope of the highway.

- The surficial geology maps for this area show that this site was not covered by ice during the most recent glaciation. This means that there are no glacial soil deposits in the area and the surficial deposits on the slopes are landslide debris derived from the underlying bedrock.

- The generalized geological profile around the site area is listed below (from top to bottom). The approximate geological profile at the site is also sketched onto the slope cross-section included in Section F of this binder.

- Cypress Hills Loess – an unglaciated, unconsolidated sand, silt and clay deposit varying in thickness between approximately 0.3 and 2.4 m. This material is essentially the oxidized cap of the underlying Cypress Hills Formation bedrock.

- Cypress Hills Formation – a Tertiary Period bedrock deposit consisting of conglomerate and sandstone with some thin bentonitic beds. The published geological information states that the thickness of the Cypress Hills Formation varies between approximately 8 and 15 m, which would mean that the contact between the Cypress Hills Formation and the underlying Ravenscrag Formation would daylight in the upper third of the valley slope at this site. However, as shown in Photos 14 and 15 in Appendix B, debris from the conglomerate beds in the Cypress Hills Formation was observed in the middle and lower portions of the slope around and just above the highway. This suggests that the Cypress Hills Formation/Ravenscrag Formation contact may actually be in the middle or even lower portions of the slope at this site.

- Ravenscrag Formation – thinly bedded, Tertiary Period bedrock deposit consisting of fine grained sandstone, clays (presumably derived from clay shale), some bentonite and coal beds. Photo 13 shows an exposure of weathered Ravenscrag Formation visible in one of the cut slopes along the upslope side of the road. The published geological information states that the thickness of the Ravenscrag Formation is greater than 30 m in this area, therefore the elevation of the base of the Ravenscrag Formation should be around or below the base of the valley slope at this site.

- Frenchman Formation – an Upper Cretaceous Period bedrock deposit of medium grained sandstone with rare coaly beds. The thickness of the Frenchman Formation is greater than 30 m in this area. It may underlie the lower portion of the valley slope in this area, depending on the thickness of the overlying Ravenscrag Formation.

Description Of Past Site Problems and Description Of Past Investigations and Description Of Mitigative Measures Implemented

There has been a long history of landslide damage to the highway at this site, dating back to at least the early 1970's.

The landslide movement is likely occurring along the bentonitic clay and clay shale beds in the Ravenscrag Formation bedrock that underlies the valley slope. The landsliding is naturally occurring and almost certainly pre-dates the construction of the highway. The landsliding was originally caused by the downcutting of the creek valley which removed the lateral support from the lower portions of the valley slope. The apparent high groundwater levels in the valley slope (as evidenced by the seepage into the upslope road ditch and the standpipe data from AIT's files) are also likely driving the landslide movement. In addition, the construction of the highway across the lower portion of the slope would have placed additional load on the lower portions of the unstable slope and slightly increased the driving force for the landslide movement.

The landslide damage to the highway has been mitigated to date with frequent overlays and patching of the road surface. It does not appear that any single episode of landslide movement has caused a temporary road closure in the past, however significant amounts of maintenance have been required.

AT performed a series of limited site investigations, instrument installations and monitoring and limited mitigation measures at various times during the 1970's, 1980's and 1990's. Some of the records from this work were found and reviewed after the March 2007 call-out site inspection, and have been summarized in Table A1 on the next page and in Section 3.3 of the AMEC October 2007 report. A copy of this report is attached in Section E of this binder – please refer to it for further details.

Table A1 – S26 – Highway 41:03, South Of Elkwater, AB
Chronological Background

Date	Description
Early 1971	Borehole drilling and site assessment by AT with respect to placing a buttress along the toe of the slope to stabilize the highway alignment. It was determined that a sufficiently-sized buttress could become impractical and that the best path forward would be to continue to treat the landslide damage to the highway as a maintenance issue.
1971 and 1972	AT files make reference to grade and drainage improvements to the highway in these years.
May 1973	Memo in AT files notes that the road was resurfaced once in 1972 and twice in 1973 as of the end of May 1973. A total of between 18 and 24 inches of settlement was estimated to have occurred since the 1971/1972 grading and drainage improvements.
July 1973	A July 1973 memo documented a site inspection and described the situation at the site as a "severe maintenance problem". A further investigation to characterize the landslide conditions and determine a repair if possible was recommended.
August 1973	A series of 23 auger boreholes were drilled along and adjacent to the road through Area A.
1985	Installation of three SI's and three standpipe piezometers within Area A during April 1985. By the end of May 1985, two of the SI's had sheared off between 4 and 6 m depth due to landslide movement. The third SI showed possible landslide movement around 9 to 10 m depth as of August 1985, with no further data in the file after that date.
1986	AT's records include a note to file that further landslide movement was occurring in Area A as of April 1986. Additional borehole drilling, standpipe installations and readings were performed later in 1986. Three test pits were excavated in July 1986, followed by recommendations to install trench drains to depths of approximately 2 m. It is not clear if these drains were subsequently installed.
1993	Site photos in AT's files that show tension cracking in the road surface in Area A that is similar to that observed during the March 2007 site inspection.
1998	November 1998 memo in AT's files that notes that the settlement of the road surface has been ongoing for years. A series of patches and overlays had been placed to regrade the road surface and the guardrail was raised in the fall of 1998.
March 2007	Call-out site inspection by AMEC. Continued landslide damage was noted in Area A, along with relatively lesser damage in Area B. Recommended Risk Level of 52 for Area A. Recommended a geotechnical site investigation to confirm the depth of landslide movement and assess the applicability of various measures to lower the groundwater levels in the landslide mass and attempt to reduce the rate and magnitude of future landslide damage to Area A.
June 2007	Site inspection by AT and AMEC personnel. No significant changes since the March 2007 inspection. Recommended Risk Level of 52 unchanged.

Late May/ early June 2008	Geotechnical borehole drilling and instrument installations in Area A. Five standpipe piezometers, three slope inclinometers (SI's) and a trial installation of a Measurand ShapeAccelArray (SAA) cable adjacent to one of the SI's were completed. The SAA cable was connected to datalogging and communications equipment to enable remote access to continuous data from the instrument. A rainfall gauge, also with remote data access, was also installed at the site.
June 2008	Site inspection by AT and AMEC personnel. No significant change to the damage to the road surface in Area A. The recommended Risk Level for Area A was reduced from 52 to 36 because the lack of significant additional damage to the road surface since the 2007 inspection was judged to indicate that the rate of landslide movement (at least during 2007/2008) was less than previously estimated based solely on the 2007 site observations. The landslide movement in Area B appeared to be relatively more active over the previous year and a Risk Level of 52 was recommended.
June to September 2008	Instrument readings in Area A. No confirmed landslide movement in the SI's or the SAA cable between the initial readings in early June and the late September readings.
Late July 2008	Installation of a trench drain within the upslope highway ditch through Area B in order to attempt to reduce the significant and ongoing cracking and settlement of the road surface through Area B that had been occurring to date during 2008.
August 11, 2008	Call-out site inspection to Area B by AMEC and AT personnel. Significant landslide damage to the segment of highway in Area B was noted. Recommended Risk Level of 52 for Area B. Recommended a geotechnical site investigation to confirm the depth and mechanism of landslide movement and assess the applicability of options to stabilize and support the existing highway as well as scope out a potential upslope relocation of the highway through Area B.
September 2008	Geotechnical borehole drilling and instrument installations in Area B. Three SI's, two pneumatic piezometer and one magnet extensometer/settlement gauge were installed.
Late 2008	Follow-up readings of the instruments in Area B. No confirmed landslide movement between the initial readings in late September 2008 and the mid-November 2008 readings.