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PRELIMINARY GEOTECHNICAL ASSESSMENT
POTENTIAL TERRAIN HAZARDS (SLOPE STABILITY)
LOWER VIEWMOUNT ROAD AREA
SMITHERS BC

Submitted to:

Regional District of Bulkley-Nechako
PO Box 820
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Submitted by:

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EXECUTIVE SUMMARY

The Regional District of Bulkley-Nechako commissioned AMEC Earth & Environmental to undertake a preliminary geotechnical assessment of potential slope stability terrain hazards in the vicinity of Lower Viewmount Road, near Smithers BC. The study consisted of a desktop review of available mapping, geologic information, historical records and air photography. In addition, a two day field reconnaissance was carried out by AMEC geotechnical engineering staff in April of 2006. The study area comprised primarily residential properties located on or adjacent to the current and historic valley sidewall of the Bulkley River. Significant findings of the assessment are summarized as follows:

1. An active, deep-seated landslide feature is present on the outside bend of the Bulkley River where the river impinges directly on and actively erodes the toe of the valley sidewall slope. This landslide currently affects major portions of properties between and including 195 Lower Viewmount Road to 559 Lower Viewmount Road. Continued or renewed landslide movement and possible retrogression (enlargement) of the landslide is likely. Costs for investigation and implementation of practical long term stabilization measures for the landslide area are likely to be beyond the financial resources of any one property owner, and would likely exceed the combined property value of the potentially affected properties.

2. A house at 195 Lower Viewmount Road appears to have been inadvertently constructed across an active portion of the main scarp of the deep-seated landslide. The house has sustained significant structural distortion. There does not appear to be sufficient room remaining on the property which would provide a suitable and long term setback relocation area for the house. Continued movement of the ground under the house can be expected, driven by river erosion rates, precipitation patterns, and local land use activities.

3. Signs of active movement have also been noted along the main landslide scarp across the properties at 265 and 355 Lower Viewmount Road. Houses on these properties are close to but set back slightly from the observed/inferred upper crest of the landslide feature. To date, the house structures do not appear to have experienced significant landslide related ground movements and corresponding structural distress. However, the possibility of such distress cannot be ruled out in the future, in the event that further movement or expansion (retrogression) of the landslide occurs.

4. The location of the main scarp of the landslide is less distinct across Lot 4 Plan 9491, 485 and 559 Lower Viewmount Road. While the lower slope portions of these properties do exhibit active landslide features, the houses at 485 and 559 are set back from the crest of the slope somewhat and to date do not appear to have experienced significant landslide related ground movements. Such movement cannot be ruled out in the future should the landslide retrogress

5. Although not widespread, smaller scale slope instabilities (either natural or triggered by development) can also be expected on the remaining old (abandoned) river valley sidewall slope sections depending on local geological conditions, drainage and development activity.

6. A smaller scale, more localized fill failure was confirmed on Lower Viewmount Road in the vicinity of the driveway access to 1037 Lower Viewmount Road. The failure involves an approximately 50 m long fill section of the road, the driveway fill for 1037 and some site fill adjacent to the 1037 residence. The fill failure may also affect the septic piping and portion of a lagoon on 1037. Additional movement is likely, and expansion of movement to the point where it might affect the house foundation cannot be ruled out.

7. Significant slope erosion has been caused by a drainage channel/ditch discharging on to the slope at the rear of 559 Lower Viewmount Road. This erosion has created additional slope instabilities along the length of the eroded gully and at the crest of the valley slope at the rear of the property. If left uncorrected, it is conceivable that larger scale slope failures could develop over time which might become an issue for stability of the residence.

Based on the results of the preliminary geotechnical assessment, it is AMEC's professional opinion that there is a significant risk to private property in parts of the study area from landsliding on the existing and old river valley sidewall slopes created by the Bulkley River. The risk is judged to be high to extreme in the area of the identified deep-seated landslide directly adjacent to the river, and low to moderate on other portions of the valley sidewall slope depending on location and development activity. In order to mitigate the risk to present and future property developments from landsliding, AMEC has provided a number of preliminary recommendations which are detailed in section **6.0 RECOMMENDATIONS** of this report.

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1.0 INTRODUCTION

AMEC Earth & Environmental (AMEC), a division of AMEC Americas Limited has undertaken a preliminary geotechnical assessment of potential slope stability terrain hazards in the vicinity of Lower Viewmount Road, near Smithers BC on behalf of the Regional District of Bulkley-Nechako (Regional District).

The information that has been brought to AMEC's attention includes:

- A BC Ministry of Transportation and Highways (MoT) letter, dated November 23, 1989 referring to an area of possible ground movement along Lower Viewmount Road (former old alignment of Highway 16). The letter characterized "land subsidence" as having affected the road right-of-way and two parcels of adjacent private property (Lot 2 Plan 8862, Lot A Plan 11423, and Lot B Plan 11423) to the west of the road.

- Reports dating from the early part of 2003, received by the Regional District regarding a residence at 195 Lower Viewmount Road (Lot 1 Plan 9401) which seems to have been experiencing "land settlement" related problems. Additional correspondence from the landowner in 2005 indicated that there was a possible landslide affecting the structural integrity of the residence.

The Regional District commissioned AMEC to conduct a preliminary geotechnical assessment of potential slope stability terrain hazards which may be present in the area. The scope of AMEC's preliminary geotechnical assessment was outlined in AMEC's proposal document (P06-008) to the Regional District dated January 26, 2006. Formal authorization to proceed with the assessment was provided to AMEC in a letter from the Regional District (Mr. Bruce Bourdon, Director of Planning) dated February 28, 2006.

The location of the overall assessment region is indicated on Figure 1 (Appendix A). At the Regional District's request, the study region was segmented into two areas. Study Area A, in the centre of the study region was delineated to represent the zone of higher concern and priority for field review, and an extended Study Area B was designated in adjoining portions of the region where preliminary assessment by air photograph review only was requested at this time. These areas are depicted on Figures 2 and 3.

The remainder of this report describes AMEC's preliminary assessment and provides recommendations for management of the potential terrain hazards in the study area.

2.0 METHODOLOGY

In conducting our preliminary geotechnical assessment, AMEC carried out the following tasks:

- Contacted Regional District staff for available historic background information, mapping, building inspection records, correspondence, property ownership records and other information relevant to the study area.

- Contacted Ministry of Transportation (Steve Uyesugi P.Eng., District Manager, and Gordon Hunter P.Eng., Geotechnical Engineer) regarding any relevant file information that they may have regarding the area.

- Contacted former Ministry of Transportation staff (Frank Maximchuck, P.Eng., former Geotechnical Engineer, and Loren Kelly, P.Eng., former District Manager) regarding any relevant information they may be aware of.

- Contacted a number of current property owners (by telephone and in person) to interview them regarding their knowledge of the area, site development, and any potential ground movement issues that they may be aware of. At the time of first contact, permission to enter the subject properties for reconnaissance was solicited from the owners.

- Obtained and reviewed background building inspection records, topographic mapping, aerial photography, water well records and published geological mapping.

- Conducted a two day field reconnaissance of the study area (April 19 and 20, 2006) to review ground features, geologic conditions, evidence of ground movements, drainage conditions, structural distress to buildings (if any), and details of local water wells and septic disposal systems. Estimates of slope angles and distances were made with hand held instruments, and digital photographs of various features were taken.

- Prepared this report.

AMEC's original proposed scope of service had tentatively included a provision for survey of two slope cross sections in the area of reported distress to the roadway referred to in the MoT letter of November 23, 1989. However, during the course of the field reconnaissance it became clear that the slope issues were somewhat different than originally envisioned, and this task was therefore omitted in favor of wider field reconnaissance and assessment of adjacent slope areas.

3.0 SITE DESCRIPTION

3.1 TOPOGRAPHIC SETTING

The study region is located within the Bulkley Valley, a broad (approximately 20 km wide) northwest-southeast trending, glacially sculpted valley located between the Hudson Bay Range to the west and the Babine Mountains to the east. At the study location, the topography is dominated by local entrenchment of the modern Bulkley River channel into the older, broad glacial valley bottom. In the vicinity, the meandering Bulkley River has created its own local cutbank and sidewall slopes, flood plain and a series of stepped relict terraces associated with downcutting of the river into the older valley bottom.

Study Areas A and B are located about 2 km due east of Smithers, and comprise a segment of the east bank of the river and adjoining relict terraces, about 2.3 km long and 0.5 to 1 km wide. At this location, the Bulkley River has created an approximately 50 to 60 m high natural cutbank and sidewall slope. The nominal river elevation at the site is 465 m ASL,, and the old glacial valley bottom, designated herein as the “upper terrace level” ranges from 515 to 525 m ASL in elevation. In the central portion of the study region, the Bulkley River is located directly against and erodes the toe of its eastern valley sidewall. However, in the adjoining reaches to this central section, the Bulkley River channel has historically meandered away from its eastern valley sidewall and is separated from the toe of the slope by modern flood plain terrace deposits. At these locations the eastern valley sidewalls are no longer directly influenced by channel erosion and flow of the Bulkley River, except potentially under extreme flood conditions. Consequently, these slope segments can be described as abandoned or old river valley slopes.

The terrain upslope from and east of the of the study areas is formed by a series of northwest-southeast trending bedrock-controlled ridges. These glacially sculpted ridges protrude 80 to 100 m in elevation above the surrounding upper terrace (old glacial valley bottom) level. Besides the Bulkley River, the only other significant natural water bodies in the vicinity of the study region are Call Lake (located 1 km southeast of the study region between two bedrock controlled ridges) and Canyon Creek (which crosses the old glacial valley bottom to the northeast of the study area).

The original Highway 16 road alignment through the area crossed down the northernmost section of the abandoned river valley slope within Study Area A and looped around to cross the Bulkley River at a bridge crossing on the flood plain. In the late 1960’s a new Highway 16 crossing of the Bulkley River was opened, just to the south of the study region and the old highway alignment reverted to the present local road network. Through the study region, Upper Viewmount Road, the middle section of Old Babine Lake Road and Lower Viewmount Road represent what was the historic Highway 16 route through the area. Specifically, Lower Viewmount Road descends down the river sidewall slope from the upper terrace to the modern floodplain of the Bulkley River. The section of Lower Viewmount Road which traverses the sidewall slope was constructed by a series of 2 to 10 m high soil cuts on the northbound (east) side of the road and 2 to 7 m high fills on the southbound (west) side of the road. The southernmost segment of Old Babine Lake Road was constructed up the southern section of the valley sidewall in the early 1970’s to provide a shorter route from the present Highway 16 location. Some significant cuts and fills, estimated up to 30 m in height were required to construct this portion of the road.

Land clearing and physical property development (mainly for farms and residential acreages) has taken place gradually over the years, on both sides of Lower Viewmount Road and Old Babine Lake Road. Development was originally most prevalent on the flatter topography of the Bulkley River floodplain and the upper terrace levels (above and below the river valley sidewall slope). However, since the late 1970's, residential properties have been developed that are on and immediately adjacent to both the modern and abandoned river valley slopes.

Figures 1 though 4 in Appendix A depict the approximate locations of the landforms, terrain and topographic features described above on both topographic and aerial photography base plans. Figures 2 and 4 also illustrate the approximate locations of property boundaries within the study region, and include street numbers for developed properties and legal descriptions of undeveloped parcels), which are used to reference specific property locations in later sections of the report (e.g. 195 = 195 Lower Viewmount Road). Photos 1 through 4 in Appendix B depict the general topography of the study area.

3.2 GEOLOGY

The surficial and bedrock geology of the Bulkley Valley has been mapped by various federal government and provincial agencies. The bedrock in the study region is obscured by thick deposits of glacial and post glacial soil deposits. The larger broad glacial valley bottom (upper terrace level) is covered with a thick (>2 m) thickness of glacial till (ground moraine), while the lower elevations of the Bulkley River and its associated floodplain and alluvial terraces areas are dominated by sands and gravels (Tipper 1994, Clague 1984, Tipper 1976, Tipper 1971).

The underlying bedrock geology has been mapped as faulted and folded sedimentary rocks of the lower cretaceous Skeena Group. These rocks typically consist of marine sandstones, mudstones (Ryan, 1993); micaceous greywacke, black to dark grey shale, with minor conglomerate and coal (Tipper, 1976), greywacke, siltstone, mudstone, conglomerate, and minor coal (Carter & Kirkham, 1969). Two outcrops of bedrock were observed during AMEC's field reconnaissance, which were consistent with the published geological mapping. Outcrops of tilted dark grey to black shale with thin seams of sandstone were observed in the river valley slope below the Harris Auto Wrecking site (3471) and in an eroded gulley on the north section of the old river valley slope (below 559). These locations are depicted on Figure 4 (Appendix A) and in Photos 47-48, 56-58 (Appendix B)

3.3 GROUNDWATER

Formal published reports and/or mapping specific to the groundwater conditions in the immediate study region were not available. However, British Columbia Government on-line databases (Ministry of Sustainable Resources – Land Information BC, Ministry of Environment - Water Well Data Base, Ministry of Environment – BC Water Resources Atlas) were referenced for available water well information. Property owners were also interviewed about what they knew about their individual wells. A map of recorded well locations and associated well log records retrieved from the on-line data base applications are included in Appendix C. It should be noted that water well information from these sources must be considered as only partially valid, as there are a number of factors which typically influence the correctness and completeness of this data. These include the likelihood that the databases can be incomplete (i.e. lacking any reference entries for existing wells), or may be incomplete and/or inaccurate with respect to individual well records. (i.e. containing incomplete or unverified information,

inaccurate/approximate location and depth information, and the logged descriptions of geology encountered by the drillers are interpretations which do not follow a standard reporting system).

Despite the potential shortcomings in the available data, some trends are discernable. A significant number of properties in the study region derive their water from shallower (often dug) wells up to 10 m in depth located in the sands and gravel deposits of the Bulkley River flood plain and lower alluvial terrace levels. Attempts to establish reliable water wells from the upper terrace level appear to have met with mixed success. The underlying geology at these upper elevations is not conducive to groundwater supply, being primarily dominated by a thick layer of clay till overlying bedrock, both of which have low permeability and generally make poor aquifers. Most of the wells attempted from the upper terrace level are reported to have been drilled to depths ranging from approximately 45 m to in excess of 185 m. These wells typically encountered impermeable clay till soils over bedrock. The bedrock was reportedly encountered at depths ranging from 30 to 50 m. When the drilled wells were not dry, they seemed to derive their water from immediately on top of the encountered bedrock or from fractures within the bedrock. Well yields are typically quite low and probably rely upon intersecting many water bearing fractures over great lengths in the bedrock.

Due to the predominantly clay till soils at surface, most of the homes in the upper elevations of the study area cannot rely on in-ground septic disposal. The majority of the sites use lagoons sited on each property. However, a few locations (particularly some of the earlier homes) report the use of septic fields and/or septic mounds.

4.0 SITE ASSESSMENT

4.1 AIR PHOTOGRAPHY

In order to supplement available topographic mapping (which was only available at a relatively small scale of 1:20,000), AMEC procured and reviewed several sets of historic stereo aerial photography providing coverage of the study region. These air photos were reviewed for natural topographic/terrain features, drainage patterns, geologic features, development activities and indications of natural hazards (landsliding). The individual air photos reviewed are listed in the Reference (Appendix E) section of this report. The major terrain features identified are depicted on Figures 3 and 4. Table 1 also summarizes some of the features observed. In the most recent aerial photography (2003), many of the original terrain features and in some cases original ground levels, have been obscured by development activities (houses, roads, cuts, fills etc.). However, by reviewing various historic air photos a sense of the original topography and how it was affected by development over time can be acquired. The following are some key observations from the air photo review:

- In 1949, the only development in the area consisted of agricultural fields and some gravel roads. The main road (pre-cursor to Highway 16) crossing of the Bulkley River followed an alignment that corresponds with present day Upper Viewmount Road, Old Babine Lake Road, Hynes Road, and an old trail/access road that descends down the old river valley slope below present day 661 and 559 Lower Viewmount Road. The remnants of even older trails or possibly waterline right-of-ways can be seen crossing the river valley slope directly to the south of 559 Lower Viewmount Road.

- By 1955, the old Highway 16 alignment had been constructed down the old river valley slope to the north, following the present day alignment of what is now Lower Viewmount Road. A large cut and several smaller cuts and fills were created to construct the road. Land use was still primarily agricultural, and a dairy building had been constructed on the flood plain at the toe of the hill (1460).

- As of 1959, some initial site clearing and earthworks (cut and fill) had taken place at the current Harris Auto Wrecking site (3471).

- By 1973, the old Bulkley River bridge crossing had been abandoned, Highway 16 had been relocated to its current location, and a new connector for Old Babine Lake Road had been established with a large cut and fill up the southern section of the old river valley slope. Gravel extraction development had taken place on the flood plain adjacent to the Old Babine Lake Road construction. Auto wrecking operations and a building had been established at 3471, and a house had been constructed east of Lower Viewmount Road at 1083 on a local terrace level on the upper portion of the old river valley slope. Also, the remnants of the old helicopter base (previously constructed by Okanagan Helicopters and subsequently relocated to Smithers) are visible at what is now 661. Some home sites had been developed east of Upper Viewmount Road and Old Babine Lake Road, west of Glover Road, and northeast of Lower Viewmount Road. At some of these sites, some large dug-outs or ponds had been constructed, presumably for agricultural water supply purposes.

- By 1983, home sites had been developed at 661, 882, 1037, 1600, and 1991 in Study Area A. Some earthwork (cut and fill) was likely conducted to develop the house site and related road access at 1037. Some minor filling and clearing appears to have taken place on the upper portion of the currently vacant Lot 4 Plan 9401 between 355 and 385. Additional homes had been constructed to the northeast and southwest (in Study Area B).

- By 1992, home sites had been constructed at 265, 825, 895, 980, and 1085. Significant earthworks (cutting and filling) appears to have taken place at 825 and 895 to establish house sites or related road access. Trails, presumably individual shared water lines for wells along the river and/or on the flood plain had been developed up the valley slope in the vicinity of 265, 559, and 1085, and septic lagoons had been constructed on the slope at 265, 355, and 1037. Most of the existing home sites in Study Area B had been established.

- By 2003, the majority of the present day development had taken place. Of significance, homes had been constructed at 195, 485, and 559. Lagoons were also constructed on the slope below these sites. At 559, the pre-existing surface drainage had been diverted into a channel along the north side of the property. Evidence of an erosion channel on the face of the slope and a debris fan of eroded material in the field below the slope are visible. A failure of the old road fill below 559 is also visible.

The most significant feature identified on the aerial photography, and persistent across all the various dates of air photos is the presence of a deep-seated landslide feature between the uppermost portion of Lower Viewmount Road and the Bulkley River. This location is on the outside bend of the Bulkley River, where the river flows directly against the toe of the valley sidewall slope. Where an otherwise smooth curve or arc segment would be expected for this

channel bedform, this reach of the channel exhibits a pronounced and abrupt bulge of land which protrudes out into the main river channel. This feature extends downstream (north) from the Harris Auto Wrecking property (3471) to the point where the Bulkley River swings back westerly out into the floodplain (southerly extremity of 559), a distance of about 340 m. A corner of 3471, and significant portions of 195, 265, 355, Lot 4 Plan 9401, 485 and 559 span this landslide feature. The upper boundary (main scarp) of the landslide is clearly evident across 195, 265, and 355, but is less obvious across Lot 4, 485 and 559. Based on review of the air photo imagery available (which spans almost 55 years), it appeared that most of the houses above the valley slope were built just above and behind the main scarp location of the landslide. However two houses appeared to be very close (265 and 355) to the main scarp, and unfortunately one house (195) appears to have been inadvertently constructed right at or partly on the main scarp.

It is likely that there is a transition from landslide terrain to the south and the relatively undisturbed old abandoned valley sidewall slope to the north within the 559 property. From here to the north extremity of the study region, there was little if any, evidence observed on the air photos of significant slope failures or natural hazards along the old river valley slope. Some evidence of minor surficial movements related to historic erosion and creation of this natural terrain feature were visible on some of the older photographs, but further evidence of smaller scale local and/or surficial slope movements are obscured by photo scale, vegetation, and property development (cut/fill) activities.

Immediately upstream and south of the identified landslide feature (below Harris Auto Wrecking, Lot 1 Plan 11141, and 1085 Lower Viewmount Road), there is a relatively uniform, steep erosion slope adjacent to the Bulkley River. As evidenced by the presence of only partial vegetation cover and exposed mineral soils consistently apparent on all of the airphotos reviewed, the river appears to be periodically eroding the toe of this section of the valley sidewall. AMEC considers that the active instability present at this part of the site represents shallow slumping and raveling of the slope, i.e. with no apparent indications of deep-seated ground movement present. Further south and upstream of this channel reach, (extending south from 985) the Bulkley River is separated from the old river valley slope by a low elevation floodplain terrace. No indications of significant slope failures or natural hazards on the old river valley slope were observed on the air photos south of this part of the study region. Some evidence of minor surficial movements related to historic erosion and creation of the valley sidewall slope were visible on some of the older photographs, but more recent evidence of smaller scale local and/or surficial slope movements is typically obscured by photo scale, vegetation, and property development (cut/fill) activities.

Review of the aerial photography coverage of properties comprising Study Area B east of Lower Viewmount and Old Babine Lake Road did not indicate the presence of any significant natural hazard terrain. While there are house sites located on some steeper slopes in the area above the upper terrace level, they appear to be developed mostly on fairly stable till and/or bedrock controlled slopes. Though there may be some potential for localized ground movement to occur in these areas related to natural or constructed slopes, such zones are anticipated to be of limited area, shallow, and difficult to detect based solely on review of aerial photography.

4.2 FIELD ASSESSMENT

AMEC's field reconnaissance concentrated on Study Area A of the study region. During the field reconnaissance a number of private properties were visited and some property owners were interviewed. Particular attention was paid to the locations of initially reported distress: the Lower Viewmount Road fill failure in the vicinity of Lot 2 Plan 8862, Lot A Plan 11423, and Lot B Plan 11423 (which corresponds to approximately 825 through 1037 Lower Viewmount Road); the house at Lot 1 Plan 9401 (195 Lower Viewmount Road) and terrain features of interest noted in the background and air photo reviews. Details of observations on individual properties are summarized on Table 1 (in Appendix A), noted on Figure 4, and are also illustrated in the appended photographs. Some of the more important observations follow:

1037 Lower Viewmount Road (Photos 5-13)

The segment of Lower Viewmount Road in the vicinity of Lot 2 Plan 8862, Lot A Plan 11423, and Lot B Plan 11423 was reviewed for indications of the ground movement referenced by the MoT letter of November 23, 1989 (copy included in Appendix E). Starting opposite the driveway entrance for 1083 and proceeding southerly in the south bound (uphill) lane for a distance of approximately 50 m there was a cracked and patched section of asphalt pavement (Photos 5, 6). This appears to represent a failure of the local highway fill slope (approximately 10 to 12 m high at a 30 to 34 degree slope) and the fill placed for the driveway on Lot 3 Plan 8862 (1037 Lower Viewmount Road). In developing the home site on the lot (1037), it appeared that a partial cut into clay tills comprising the natural slope had been made and that fill had been placed both north of and down slope (west) of the house location (Photos 7,8). There also appeared to be some wet areas and the remnants of an old septic field adjacent to the toe of the fill placed for the driveway entrance. Below the fill area a septic lagoon had been constructed on or into the natural slope. No obvious toe area for fill failure was observed, but some indications of slow soil creep and/or fill settlement were observed down slope of the driveway fill and down slope of the house. Conversations with the owners indicated that they did not feel their house foundation had been subject to any ground movement. Some small cracks were observed on the external corners of the basement level foundation (Photo 9).

Based on our observations at the site, AMEC considers that the zone of possible ground disturbance and instability observed appears to be smaller and in a somewhat different location than that described in the MoT letter, or perhaps that the location sketch attached with the original letter was not accurate, or was intended to show a general location only. Upon reviewing MoT files for the area we discovered some photographs (Photos 10-13) taken in 1989, where the area of ground disturbance referenced matches that identified by AMEC which currently only appears to affect an approximately 50 m long section of Lower Viewmount Road and an adjoining portion of Lot 3 Plan 8862 (1037).

195 Lower Viewmount Road (Photos 14-23)

The house at 195 Lower Viewmount Road was closely examined and the home owner was interviewed regarding the history of house construction and foundation movements. The house was constructed in 1994 as a single storey, timber frame structure with a concrete basement that daylights at the rear of the structure. The owner reports that while he built slightly back from the slope down to the river, the foundation area was dry at the time of construction and appeared to be all on native ground (i.e. hard clay till, no fill placement). A few years after construction of the house, the owner reports that a significant crack developed across the

basement floor and the rear (down slope) end of the house had apparently settled. Despite several attempts to fix the cracked basement, including replacing the basement floor slab and doing extensive drainage works around the foundation perimeter and underneath the floor slab, movement continued. To cope with the movement, the owner replaced the rear portion of concrete slab with a flexible wooden floor, and has created a system of leveling jacks along the foundation which he uses to periodically re-level the house. To date there has been approximately 23 cm of vertical displacement and 75 to 100 mm of horizontal separation. The owner estimates that the rate of settlement is about 2 to 2.5 cm per year.

Lateral foundation cracks and distortion of the house due to settlement at the rear was quite obvious during the field visit. Directly to the rear and down slope from the house, the main valley sidewall slopes down to the southwest at a moderately steep gradient (30 to 35°) over a distance of about 30 to 40 m to where a septic lagoon has been constructed. At the time of our field visit a linear depression and ground crack (several cm wide with vertical displacement of up to 30 cm) was visible extending across the lawn on both sides of the house and directly in line with the observed cracking through the house. The steep slope section and ground crack were traced laterally onto adjoining properties and it appeared that these features represent the current main scarp location of an active deep-seated landslide feature, as identified on the air photographs described in the preceding Section 4.1 of this report.

Landslide into Bulkley River (Photos 24-45)

The surface characteristics of the landslide feature observed on the air photography and located directly behind 195 Lower Viewmount Road were examined in the field. The main scarp of the landslide was easily traced from the north edge of the Harris Auto Wrecking property (3471), across properties at 195, 265 and 355 Lower Viewmount Road. At 265, there was evidence of recent movements on the steep scarp, which at that location was situated within just a few meters of the rear of the house. At 355 the house was located several meters back from (north of) the sidewall slope and scarp location, but a steep portion of the scarp appeared to have been regraded within the recent past. Further to the north, across the next property parcel which was undeveloped (Lot 4 Plan 9401) and the developed properties at 485 and 559, the crest of the slope was less distinct and no obvious indications of recent ground movement were noted. This area still appeared to represent the scarp of the landslide feature, but also appeared to have experienced less displacement and/or was a transitional area to a less active portion of the valley sidewall slope which continues to the north.

Below the crest of the river valley sidewall slope and steeper upper scarp area, the terrain was generally irregular, ridged, hummocky, with various areas of tilted vegetation and occasional areas of ponded water, all of which are considered typical ground surface manifestations of terrain subject to deep seated and continuing landslide movement. The overall gradient of the slope was estimated to be between 19 and 25° from horizontal, with some locally steeper segments ranging from 35° to nearly vertical. Many features of the ground surface were masked or obscured by vegetation cover and some of the access trail, earthworks, water line and septic disposal development that has taken place over the years. However, landslide features were quite distinct on the sloped portions of 195, 265, 355, Lot 4 Plan 9401, 485 and the southeastern half of 559. Where developed, the owners of these properties seem to have taken advantage of natural benches or depressions on the slope surface to construct septic lagoons. Some of these locations appeared to represent small grabens (zones of landslide-created closed depressions between displaced blocks of ground). Soils exposed on the slope appeared to consist of clay till and/or colluvium derived from clay till.

Along the river bank, a fairly obvious bulge or landslide toe thrust was visible. Some pockets of soft high plastic clay soils were observed in the toe bulge at river level, along with clay tills and/or colluvium derived from the till. On the downstream section of the landslide toe area, exposures of layered, interbedded, silts, sands, and high plastic clay overlain by till were observed in the faces of eroded banks.

Directly upstream from the obvious landslide toe area (below 3471, Harris Auto Wrecking), the valley sidewall slope has a relatively uniform, moderately steep (35 to 40°) gradient (Photos 45, 46). This segment of the sidewall slope appeared to be relatively dry, was sparsely vegetated in some areas, and subject to periodic toe erosion by the river, slope wash, and surficial raveling of exposed soils. No terrain attributes typical of deep seated landslide activity were observed. Soils exposed on the slope were comprised of primarily clay till, with minor sand and gravels and/or colluvium derived from these materials. An outcrop of dark grey, thin-bedded, fractured shale or siltstone was observed on the lower portion of the slope (Photos 47, 48). The bedding orientation observed had a southeasterly strike roughly sub-parallel to the river channel and valley sidewall, with a moderate dip out of the slope at approximately 35°.

Old Road (Trail) Alignment (Photos 49-58)

AMEC's field reconnaissance also included a review of soil and slope conditions along the old road access (now a trail) and slope area below 559 and 661 Lower Viewmount Road. At this location, the old road access was historically constructed across the valley sidewall slope using side hill cut and fill techniques. The main cut slope (immediately below 661) appeared to have been constructed in relatively dry clay till soils, was 10 to 20 m in height, and cut at a relatively uniform gradient of 33 to 35°, with some isolated locally steeper sections. The cut slope appeared to be relatively stable, and subject only to minor surficial raveling and creep movements.

On the down slope (south) side of the trail, a series of fills had been placed on the natural slope extending down to the field/floodplain below. These old fills were on the order of 10 to 20 m in height with a 35° slope and exhibited mostly minor surface sloughing in various areas. A larger and significant failure of the old fill was observed on the lower half of the old road alignment (Figure 4, Photo 51). This feature comprised 1 to 2 m of vertical displacement over a horizontal distance of about 20 to 25 m, and seemed to have been recently active, as fresh tension cracks were observed on the ground surface of the slide area.

Approximately two thirds of the way down the road alignment, and directly below the residence at 559, the natural valley sidewall slope begins to transition from a uniform gradient to more disturbed and varied terrain similar to the landslide feature observed further to the south. However, above the valley sidewall at this location, the natural surface drainage had been redirected into an excavated channel/ditch along the property line between 559 and 661. The natural surface water drainage pattern from Lower Viewmount Road and agricultural lands to the east originally focused surface runoff near the center of 559. This pattern was reported to have been altered to the present configuration to accommodate house development on 559. Some of the new drainage enters an ornamental pond area on 661, and from there flows in the ditch along the property line and down over the crest of the valley sidewall slope. The discharge of drainage from the new channel had eroded/incised a significant new gully 4 to 5 m deep extending down the face of the sidewall and across the old road alignment below (Photos 52-56). A small debris fan of sediment eroded from the gully has been deposited on the

field/floodplain below. The approximate locations of the gully and fan are illustrated on Figure 4. Formation of the gully has undermined adjacent slope areas and appeared to have triggered small active slides on either side of the gully, including a location directly below the lawn area at the rear of 559. Of note, the gully sidewalls provided an exposed profile of the native soils present on that section of the slope. The upper soils exposed appeared to be predominantly clay tills, however just above the elevation of the old road, an outcrop of dark grey shale and siltstone (similar to the bedrock outcrop below 3471 described above) was present in the gully bottom, with clayey tills draped directly onto the bedrock surface (Photos 57-58).

Other Areas of River Valley Sidewall Slopes

In addition to the areas described above, AMEC also examined other areas of development and natural steeper slopes (old river valley sidewall slopes) within Study Area A (Photo 59-61). Generally these other slope areas appeared to be relatively stable, although there were areas where there was some evidence of shallower naturally occurring shallow slope movements and soil creep that would be expected on natural slopes. The steeper cut section above the sharp bend in Lower Viewmount Road (extreme northwest end of Study Area A) certainly appeared to be over steepened for local soil conditions and subject to some surficial sliding and slope wash (Photo 62). A small failure (Photo 63, 64) was also observed in a wet till soil cut created to provide an access road for recent timber clearing on Lot 1 Plan 1141 (south of Harris Auto Wrecking). However, within Study Area A, other than that discussed above, no other obvious signs of deep-seated ground instability affecting natural slopes, and/or artificial slopes was noted during the field reconnaissance.

5.0 ASSESSMENT AND CONCLUSIONS

Based on AMEC's background research, air photo review, and field reconnaissance of the study region, it is clear that parts of Study Area A are subject to slope stability and terrain hazard concerns, which should be taken into consideration by land use planning and building development regulatory agencies. In general, the primary natural terrain hazard identified by AMEC as part of this study is the potential for ground movement and landslide activity along both the current Bulkley River valley sidewall slope, and abandoned or relict segments of river valley sidewall slopes between the lower elevation modern floodplain terraces, and upper level "prehistoric" valley bottom forming the broader Bulkley Valley. The most significant current hazard is the active landslide feature located on an outside bend of the Bulkley River where the river impinges directly on and actively erodes the toe of the valley sidewall slope. Although not widespread, smaller scale slope instabilities (either natural or triggered by development) can also be expected on the remaining old (abandoned) river valley sidewall slope sections depending on local geological conditions, drainage and development activity. A summary of key observations and conclusions arising during the course of the assessment is provided below:

1. The river valley sidewall slope within the study region appears to have been formed by a combination of ancient and modern river erosion into the broader valley bottom. The slope consists primarily of a thick layer of glacial till underlain by fine grained thin-bedded sedimentary (shale) bedrock.

2. A significant, active deep-seated landslide feature (pre-dating 1949, the date of the earliest available air photos) is present in part of Study Area A on the outside bend of the Bulkley River. This feature currently affects major portions of properties between and including 195 to 559 Lower Viewmount Road. The causative factors of the landslide

remain to be determined conclusively, but this ground movement is likely related to a combination of several attributes of local terrain conditions including active erosion by the Bulkley River, at a location where bedrock may be absent (i.e. there may be a local depression or pre-glacial side channel in the underlying bedrock), and/or the presence of a weak pre-glacial, clay deposit underlying the till at that specific location (i.e. in a local depression in the bedrock surface). Groundwater (concentrated from natural and from anthropogenic sources such as leaky water systems, irrigation, leaking septic lagoons, and redirected surface drainage) may also be a significant contributor to the landslide movement. Figure 5 provides a series of schematic cross sections which illustrate the ground topography and possible/inferred subsurface conditions at and adjoining the landslide feature. The approximate locations of the sections are shown on Figure 4. Please note that all of the locations of features illustrated on the sections are approximate only and have not been established by detailed ground surveying.

3. The house at 195 Lower Viewmount Road appears to have been inadvertently constructed across an active portion of the main scarp of the landslide. It is possible that the house was either built too close to the pre-existing landslide scarp (either on original ground or old fill), or the landslide has since retrogressed and created a new crack (and new main scarp location) running directly through the center of the house. Vertical displacements through the house have averaged 2 to 2.5 cm per year for a total estimated displacement over the last several years of approximately 23 cm. There does not appear to be sufficient room remaining on the property which would provide a suitable and long term setback relocation area for the house. Continued movement of the ground under the house can be expected, driven by river erosion rates, precipitation patterns, and local land use activities.

4. Signs of active movement have also been noted along the main landslide scarp across the properties at 265 and 355 Lower Viewmount Road. Houses on these properties are close to but set back slightly from the observed/inferred upper crest of the landslide feature. To date, these house structures do not appear to have experienced significant landslide related ground movements and corresponding structural distress. However, the possibility of such distress cannot be ruled out in the future, in the event that further movement or expansion (retrogression) of the slide area occurs. Manifestations of ground disturbance have occurred on both of these properties where water lines and septic lines cross the main scarp and landslide area, and frequent breaks have been reported.

5. The location of the main scarp of the landslide is less distinct across Lot 4 Plan 9491, 485 and 559 Lower Viewmount Road. This may be because the landslide is less active in these areas, or that much of the scarp has been obscured by development activity. While the lower slope portions of these properties do exhibit active landslide features, the houses at 485 and 559 are set back from the crest of the slope somewhat and to date do not appear to have experienced significant landslide related ground movements. Such movement cannot be ruled out in the future should the landslide retrogress.

6. There are a number of water lines and septic lagoons constructed on and across the landslide. Water from line breaks and leakage from lagoons as the ground moves can be expected to contribute to local saturation of the soils, groundwater recharge and increased porewater pressures down slope, and ultimately landslide movement. Generally, locating water supply, disposal, storage, and transmission facilities on a

landslide and/or diverting surface water onto the surface of a landslide are considered as destabilizing factors with regards to stability of a landslide feature and should be avoided.

7. Continued or renewed movement and possible retrogression (enlargement) of the deep-seated landslide area is likely. Such movement could ultimately affect adjacent structures, properties, utilities and possibly even the Lower Viewmount Road right-of-way over the long term. It is likely (barring any catastrophic climate and run-off events) that the rates of landslide movement and expansion would be relatively slow (in the order of centimeters per year), similar to that experienced over the past 50 to 60 years. However, those rates can be significantly influenced by river erosion activity, precipitation (contributing both groundwater and surface drainage to the slide), and human development activities in and around the slide area. Episodes of more sudden intermittent movement in the order of one or more meters at a time cannot be ruled out and may occur following high water river erosion events, higher than normal precipitation/snow melt events, or sudden and/or extended release of water from artificial sources (water pipes, septic lagoons, ornamental ponds, swimming pools etc.).

8. Further definition of likely rates of movement and the possible extent of landslide retrogression will require extensive and expensive geotechnical investigation. Such investigation would involve detailed topographic mapping, surface movement monitoring, deep drilling investigation, sub-surface ground movement and groundwater instrumentation, laboratory soil/rock strength testing and sophisticated computer aided slope stability analyses. The cost of investigation could likely approach the value of the properties affected (i.e. several hundred thousand dollars or more), and may still not yield cost effective solutions for maintaining residences at current locations over the long term.

9. Currently there is no house development on Lot 4 Plan 9401, and it remains to be seen whether or not there is room for a sufficiently set back ‘safe’ building site on the lot. For this and existing developed lots where relocation of potentially affected houses might have to be contemplated in the future, the determination of a ‘safe’ set back distance will not be simple, and would likely require significant geotechnical investigation, involving some or all of the elements described in item 8, above.

10. A smaller scale, more localized fill failure was confirmed on Lower Viewmount Road in the vicinity of the driveway access to 1037 Lower Viewmount Road. This was the area referred to in the MoT letter dated November 23, 1989 as an area of possible “land subsidence” reported to have affected the road right-of-way and parcels of adjacent private property (Lot 2 Plan 8862, Lot A Plan 11423, and B Plan 11423). It was apparent that the affected area is much smaller than originally suggested, involving only an approximately 50 m long fill section of the road, the driveway fill for 1037 and some site fill adjacent to the 1037 residence. The fill failure may also affect the septic piping and portion of a lagoon on 1037. The cause of the failure was not evident, but may involve one or more of the following items, including: placement of fills at too steep an angle, inadequate fill compaction, weak foundation soils, and possibly trapped groundwater. Additional movement is likely, and expansion of movement to the point where it might affect the house foundation cannot be ruled out. Further geotechnical investigation involving slope surveying, several drill holes, sampling, ground instrumentation, laboratory soil testing, and stability analyses would be required to determine the true

nature of the slide and to determine possible stabilization strategies. The cost of such and investigation could easily be expected to be in the $50,000 to $100,000 range.

11. Significant slope erosion has been caused by a drainage channel/ditch discharging on to the slope at the rear of 559 Lower Viewmount Road. This erosion has created additional slope instabilities along the length of the eroded gully and at the crest of the valley slope at the rear of the property. If left uncorrected, it is conceivable that larger scale slope failures could develop over time which might become an issue for stability of the residence.

12. Immediately upstream of the identified landslide feature (below Harris Auto Wrecking at 3471 and the currently cleared but undeveloped Lot 1 Plan 11141) there is a relatively uniform, steep, but marginally stable slope down to the Bulkley River. This slope appears to consist of glacial till overlying bedrock, and appears to be subject to ongoing toe erosion, slope wash and surficial soil raveling. There are no current signs of deep-seated failure, but some erosion-related retrogression of this slope can be expected over time (driven by river flow levels, overland slope wash and land use activities above the slope). Although the slope does not appear to pose an immediate risk to existing development, geotechnical assessment and consideration of the rate and amount of retrogression would be required to determine 'safe' set back distances for any new development proposed above the slope.

13. A significant number of home sites have been developed on or adjacent to old abandoned river valley sidewalls (i.e. ancient valley slope sections not directly adjacent to the current position of the Bulkley River). For these portions of the study region there have been no reported nor observed deep-seated slope movements. However, at some locations smaller scale natural or development induced ground movements likely exist or could still develop. The fact that there have been relatively few reported problems on these slope areas may be due to inherently better geologic conditions, good construction practices, a desire for privacy and/or to some degree, good fortune. Certainly there are some local places where fills and cuts on the old valley slope are marginally stable and could become a problem in the future, depending on land use activities and precipitation patterns. Geotechnical assessment of developments on or adjacent to the old river valley sidewall slope would be required in order to limit such risks.

6.0 RECOMMENDATIONS

Based on the results of the stability assessment and conclusions presented in this report, it is AMEC's professional opinion that there is a significant risk to private property in parts of Study Area A from landsliding on the existing and old river valley sidewall slopes created by the Bulkley River. The risk is judged to be high to extreme in the area of an identified deep-seated landslide directly adjacent to the river, and low to moderate on other portions of the valley sidewall slope depending on location and development activity. In order to mitigate the risk to present and future property developments from landsliding, the following preliminary recommendations are provided:

Recommendations 1 to 3 have been removed

4. Geologic hazard assessments carried out in support of existing or proposed developments should follow the Association of Professional Engineers and Geoscientists of British Columbia's recently released *Guidelines for Legislated Landslide Assessments for Proposed Residential Development in British Columbia, March 2006.* This document can be accessed online at:

   www.apeg.bc.ca/library/library/guidelines/landslide_guidelines.pdf

5. Existing home owners and residents on or adjacent to the valley slope should be advised of the potential risks from existing slope failures and good practice for development in and around slope areas. Particular emphasis should be placed on informing the owners of property on and adjacent to the identified deep-seated landslide feature in Study Area A along the Bulkley River. For information purposes, a brief list of best practices for land management on sloping terrain is provided in Appendix E of this report.

6. For those properties directly affected by the deep-seated landslide feature (195, 265, 355, Lot 4 Plan 9401, 485, and 559) the following items should be considered to reduce risk from future landslide movements:

   a. limiting future property development, clearing, new building structures, earthworks, and drainage activities subject to review by a geotechnical engineer;
   b. relocating septic lagoons away from the slide area, or retrofitting them with a flexible leak-proof liner system;
   c. eliminating water and septic lines from the slide area, or replacing them with flexible pipes and emergency flow control devices;
   d. local regrading of the ground surface to prevent water from entering the landslide surface or ponding on or behind the landslide area;

e. establishment of a survey monitoring system and periodic review of stability conditions in the area to provide early warning of increased slide activity;
f. procuring a detailed, large scale topographic map of the landslide area (1:1000, 1 to 2 m contours), on which various features could be plotted and tracked over time;
g. relocating structures further from the main slide scarp as it becomes necessary; and
h. reviewing current and/or any planned alterations to surface drainage along the local road network (particularly along Lower Viewmount Road) in conjunction with the Ministry of Transportation with a view to minimizing potential land stability related issues.

7. Relocation or removal of the existing house away from 195 Lower Viewmount Road should be considered. Up until now the owner has been able to develop a reasonably workable system for jacking the house in response to the relatively slow landslide movements experienced to date. Provided the movement rates do not increase drastically, the owner is able to maintain reasonable structural integrity where the existing plumbing, gas and electrical services in the home are not compromised by the movement. However, this system requires a great deal of effort, constant attention and may not be sustainable over the long term by either the current owner or potential future owners. The owner may not be able to respond to sudden and large movements (in excess of more than 30 cm) that could occur randomly without warning or in response to patterns of increased river erosion, precipitation and/or snow melt. In such cases, the occupants may not be able to react before potentially hazardous damage to the structure, gas or electrical services could take place.

8. The fill failure area on Lower Viewmount Road and on the adjacent private property (1037 Lower Viewmount Road) should be formally monitored over time. Should signs of new or increased movement be noted, a more detailed geotechnical assessment to determine cause and potential mitigation options should be considered. Such activities would likely have to involve both the Ministry of Transportation and the property owner.

9. At 559 Lower Viewmount Road, the drainage and erosion problem created down the slope at the rear of the property should be addressed so that further slope instability does not develop to the point of affecting the house structure. Deferring the problem will probably make effectively addressing the situation more expensive in the future. Since the relocation of the natural drainage channel was done by the current owner, and since most all this activity is confined to the owner's lot, carrying out mitigation of this problem would likely be at the discretion of the property owner. However, the owner of the property at the toe of the slope where debris run out could occur would also have an interest.

It is beyond the scope of AMEC's review to identify which party or parties should be responsible for undertaking the recommendations set out above in items 4-9 inclusive, and AMEC expresses no opinion in that regard.

7.0 CLOSURE

This report represents a preliminary geotechnical assessment based information supplied by others, office review and reconnaissance level field assessment. No subsurface geotechnical information from boreholes or instrumentation was available, and sub-surface conditions inferred herein may differ from actual conditions. Further more detailed geotechnical assessment, mapping, and possibly sub-surface geotechnical investigation is contemplated and recommended as part of this report.

This report has been prepared for the exclusive use of the Regional District of Bulkley-Nechako and for possible reference by other designated agencies for the specified application described within. Any use that other parties may make of this report, or any reliance on or decisions to be made based on it are the responsibility of such third parties. AMEC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on information provided in this report. This report has been prepared in accordance with generally accepted geotechnical engineering practices. No other warranty, expressed or implied, is made.

We trust this report provides the information required at the present time. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,

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APPENDIX A

Figure 1	Location Plan
Figure 2	Site Plan - Topography
Figure 3	Airphoto Site Plan – Terrain Features
Figure 4	Airphoto Site Plan – Landslide Features (Study Area A)
Figure 5	Typical Sections (Assumed Geology)
Table A	Property Observation Summary