12 April 2012
CG25352.400

Mr. Ross Dickson
Alberta Transportation
2nd Floor - 803 Manning Road NE
Calgary, AB T2E 7M8

Dear Ross:

Re: S40 – HIGHWAY 848:02 - DOROTHY SINKHOLES SITE
REPORT ON NOVEMBER 21, 2011 SITE INSPECTION

Please find enclosed the report on the November 21, 2011 inspection of the above-noted site.

If you have any questions or require any further information, please do not hesitate to contact the undersigned at (403) 387-1855

Yours truly,

AMEC Environment & Infrastructure,
a division of AMEC Americas Limited

Tyler Clay, B.A.Sc., E.I.T
Geological Engineer

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1.0 INTRODUCTION

AMEC Environment & Infrastructure (AMEC), a division of AMEC Americas Limited, attended a call-out request to a sinkhole damaged area along Highway 848 near Dorothy, Alberta on November 21, 2011. The call-out request was made by Mr. Ross Dickson of Alberta Transportation (AT). The site inspection was performed by Mr. Tyler Clay, E.I.T., of AMEC.

The purpose of the site inspection was to:

- Inspect a section of the gravel highway that has been damaged in the past by sinkholes developing within the road surface without warning.
- Provide a preliminary assessment of the hazard conditions and associated risk to the highway.
- Provide preliminary recommendations for mitigative measures, along with recommendations for further investigation and assessment of the hazard conditions.

The call-out site inspection was authorized under AT Consulting Services Agreement CE061/08.

2.0 SITE LOCATION AND BACKGROUND

The site is located in 4-027-17 W4M, approximately 1.35 km west of Dorothy, Alberta, along Highway 848, 1.2 km southwest of the junction of Highway 848 and Highway 570, southwest of the Red Deer River. This segment of Highway 848 is a gravel, two lane undivided roadway at a hairpin turn segment of a switchback that winds up through a tributary valley draining towards the Red Deer River. Figure 1, attached, shows the overall site layout and the relative location of the highway to the surface drainage and sinkhole features.

The call-out site inspection was requested by AT after both AT and maintenance contractor personnel noted erosion damage in and around the road surface. It was described that the sinkholes developed without warning and were repaired by backfilling with gravel.

AMEC's understanding is that the November 2011 inspection was the first to date and this site has not been part of AT's Central Region GeoHazard database.

3.0 NOVEMBER 21, 2011 SITE OBSERVATIONS

A site plan is attached as Figure1. Key observations from the site inspection are outlined below and shown in the attached photographs:

1. AMEC was shown three areas along a 150 to 200 m long section of the road by the MCI during the November 2011 inspection that were indicated to have had sinkholes develop within the last year (shown on Figure 1). The MCI indicated the sinkhole formed without warning and did not seem to be preceded by significant rainfall events. At the time of the inspection, the previously damaged areas had been repaired by backfilling with gravel and there was no evidence within the road surface of cracking or settlement.

2. AMEC inspected the area surrounding the affected highway section and found numerous sinkholes in the ditches and gullies at the site. Approximately 6 separate sinkholes were identified (shown on Figure 1), the largest were greater than 2 m wide and deep and some appeared to connect to subsurface drainage "tunnels" (see Photos 1 and 2). The majority of these sinkholes were within 25 m distance from the road surface.
3. The surrounding slopes and sinkholes were observed to be composed of highly/erodible soils of sandy silt. These soils were observed to overly sandstone bedrock in the deep ravine north of the road.
4. Two culvert outlets were observed along the slope towards the ravine north of the road. There was significant erosion of the soils around culvert outlets and one of the culverts was broken near the outlet. The culvert inlet locations were not confirmed during the inspection, but one possible culvert inlet is shown on Figure 1.

4.0 DISCUSSION AND ASSESSMENT

It is hypothesized that groundwater flow along the bedrock surface caused erosion/piping of the erodible soils, leading to void formation and eventual sinkhole collapse. If this is the case, the sinkholes have the potential to form without any surficial evidence prior to collapse and identifying their location prior to surfacing becomes difficult. The rate of the subsurface erosion is also unknown and this limits the usefulness of subsurface investigation or surface-based geophysical surveys to determine where voids may be developing (i.e. if the sinkholes form rapidly it would not be practical to map out dynamic void locations within a single survey). Subsurface water movements are thought to be the underlying cause of the sinkholes, however; an effort to alter groundwater flow in an area of this size would be a complicated and expensive feat. It is likely more practical to manage and limit the surface water infiltration into the road subgrade and decrease the development rate of the voids while simultaneously treating surface erosion issues.

5.0 RISK LEVEL

AMEC recommends the following Risk Level for this site, based on AT's general geohazard risk matrix:

- Probability Factor of 7, based on the active sinkhole formation in the area surrounding this segment of the highway and a perceptible development rate.
- Consequence Factor of 8, reflecting the fact that the sinkholes form with little warning, could potentially be large enough to cause damage to vehicles and/or injuries and warrant a road closure/detour pending repair of the sinkhole(s).

Therefore, the recommended Risk Level is 56 (i.e. 7 x 8).

6.0 RECOMMENDATIONS

Short Term and Ongoing Maintenance

- Sinkholes that develop in the road surface should be treated as a maintenance issue by backfilling with either dirty gravels (fines ≥ 20%) or pumped grout. These backfill materials are judged to serve as an economical and practical way for the MCI to repair developing sinkholes and keep this segment of the highway trafficable; however, they provide a temporary fix and will not prevent future sinkhole development. The advantages of grout as a backfill material include relatively fast deployment and ability to fill channels and other areas that traditional fill cannot reach. Grout is generally not very permeable to water flow and will not prevent subsurface flow and piping around the treated area that may lead to future sinkholes. Dirty gravels can be placed quickly and easily by the MCI but may not fill all areas contained within a sinkhole area (i.e. underground channels connecting sinkholes). Gravels with a significant amount of fines are more water permeable than the grout backfill. Subsurface flow and potential piping within a gravel treated zone will likely occur at a relatively slower rate than around an area treated with grout. Clean gravels should not be used as backfill since this may create preferential pathways for the surface water and increase the rate of erosion. The MCI may want to consider having a gravel/fill stockpile at or nearby the site to ensure that repairs can be performed immediately following sinkhole formation. The location of any sinkholes should be documented.
- The site should be inspected by maintenance personnel daily. AT should consider constructing gates on either end of the segment at risk to allow for rapid closure of this segment of the highway.
- Warning signs and reduced speed limit signs should be placed at the site.
- Surface water within the right-of-way should be carefully managed to limit infiltration into the road subgrade. Impermeable liners (e.g. polyethylene moulded) should be installed along the road ditches and gullies within the right-of-way. Culverts should be maintained and repaired as necessary to effectively intercept surface flow and direct it away from the right-of-way in a controlled manner that does not cause additional erosion. At least one of the culverts currently in place was observed to be in damaged condition during the inspection. The ongoing maintenance of impermeable liners and robust culverts would likely be a major effort.

Long Term / Permanent Repair

- Long term repair options for this site are limited due to its size and complexity. If areas of the road were found to be consistently damaged by this type of erosion, AT could consider constructing a more significant repair option. Potential repairs could include excavating erodible soils and rebuilding with designed fill and geosynthetics or constructing pile supported slabs to span known void locations.
- To reduce the risk level at the site, further study is required to determine the site conditions. A conceptual investigation could include a geophysical and sub-surface investigation to check for voids and correlate geophysical data with the actual site conditions. It may be

possible to use geophysics to detect voids, but this would require further study and, as previously discussed, would provide limited value if the sinkholes formed rapidly.

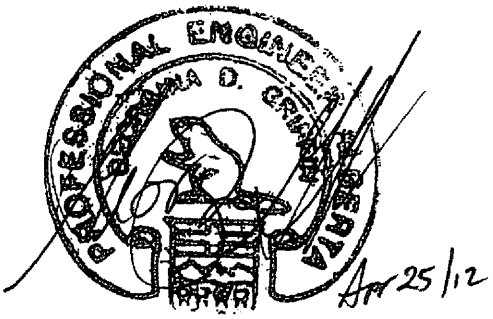
7.0 CLOSURE

This report has been prepared for the exclusive use of Alberta Transportation for the specific project described herein. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it are the responsibility of such third parties. AMEC Environment & Infrastructure, a division of AMEC Americas Limited, cannot accept responsibility for such damages, if any, suffered by any third party as a result of decisions made or actions based on this report. This report has been prepared in accordance with accepted geotechnical engineering practices. No other warranty, expressed or implied, is made.

We trust that this meets your needs at this time. Please contact the undersigned if you have any questions or require any further information.

Respectfully Submitted,

AMEC Environment & Infrastructure,
a division of AMEC Americas Limited



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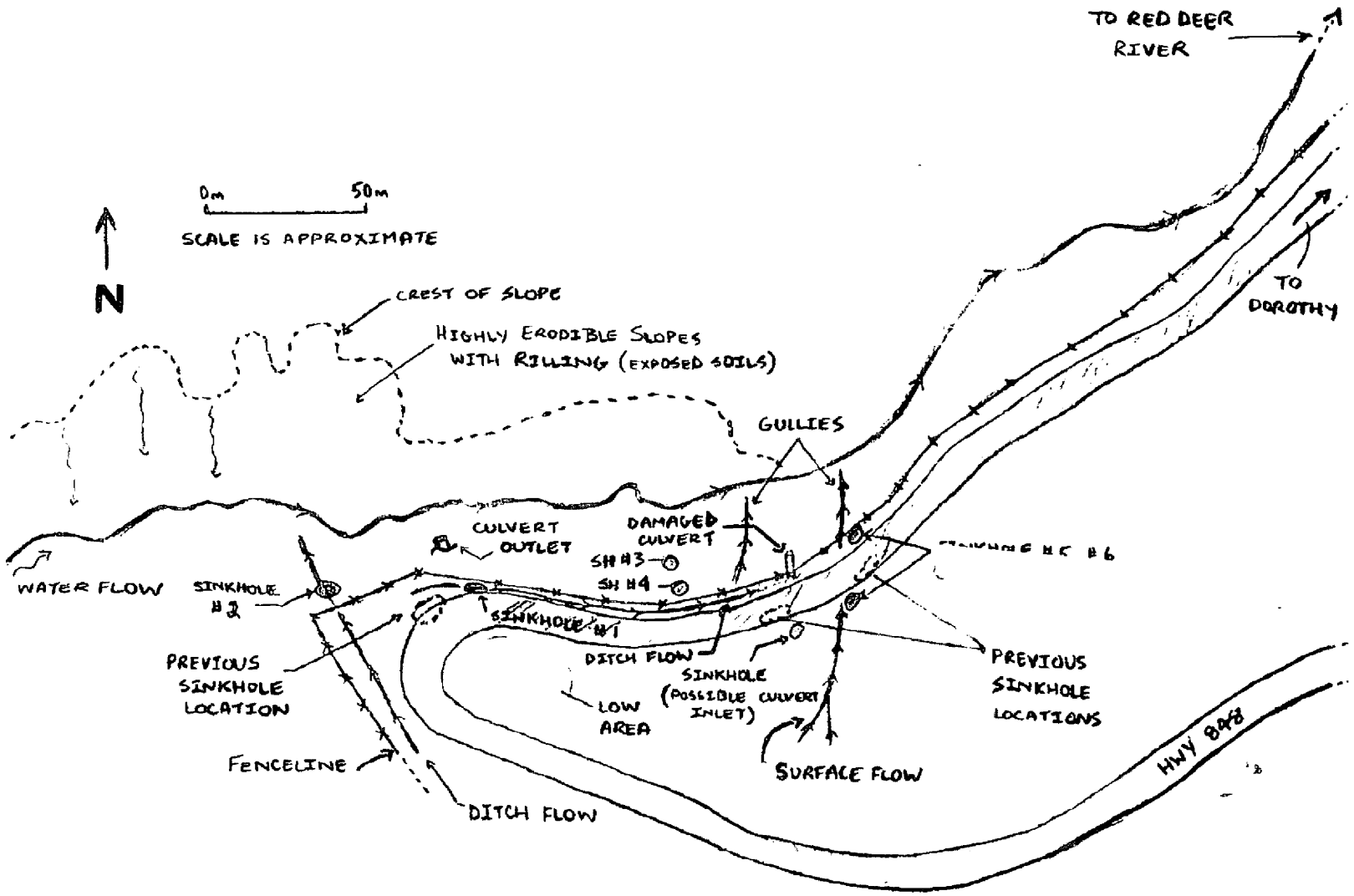
Geological Engineer

Georgina Griffin, M.Eng., P.Eng.
Associate Geotechnical Engineer

APEGA Permit to Practice No. P-04546

Reviewed by:
Ertan Ozmen, M.Sc., P.E., P.Eng.
Associate Geotechnical Engineer

Attachments: Figures 1
Photos 1 to 6



Note:

Based on the November 21, 2011 inspection observations.

Scale and locations are approximate.

Client: Alberta Transportation		Figure 1	
Project: S40 - Hwy 848 - Dorothy Sinkholes Site		Date: Apr-12	Revision:
Site Sketch		Job No. CG25352.400	
		File No.: hwy848_figures.xlsx	

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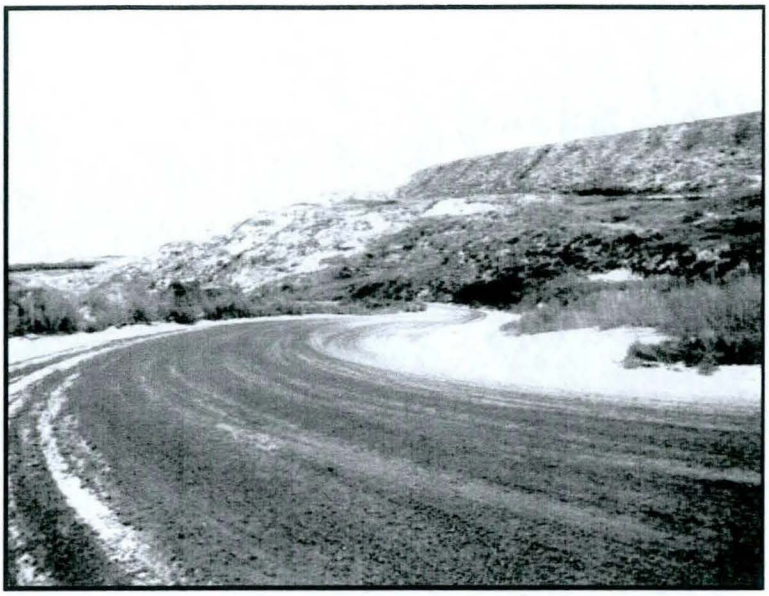

Photo 1 (left)
Standing at the hairpin turn where previous sinkhole damage was reported by the MCI. Facing towards the east.
(Photo Date: November 21, 2011)

Photo 2 (above)
Standing at the same location as Photo 1, facing the opposite direction towards the northwest. The highly erodible slopes with rilling can be seen. A deep ravine has formed at the bottom of these slopes.
(Photo Date: November 21, 2011)

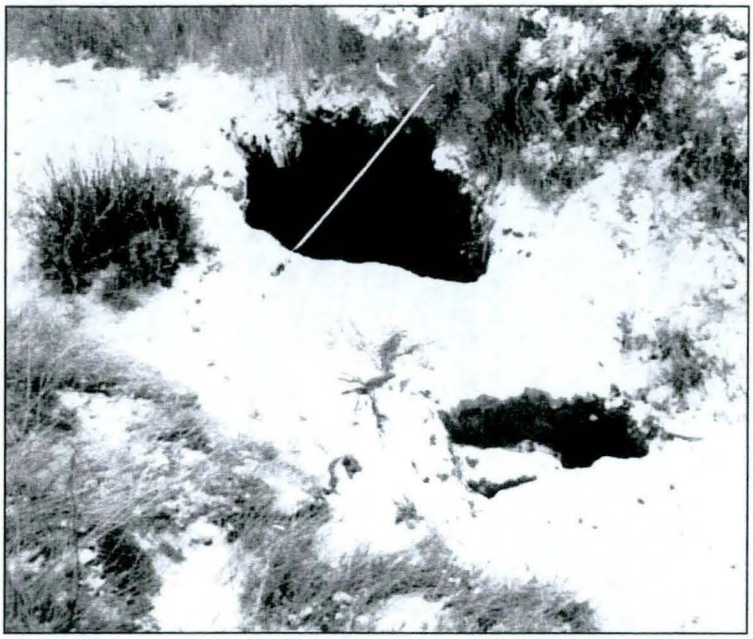

Photo 3 (top)
These sinkholes were found in a ditch channel that drained towards the north into the deep ravine north of the road. The main hole measured 2 m long, 1.3 m wide and 1.6 m deep. The locations of the sinkholes are marked on the site sketch as sinkhole #2.
(Photo Date: November 21, 2011)

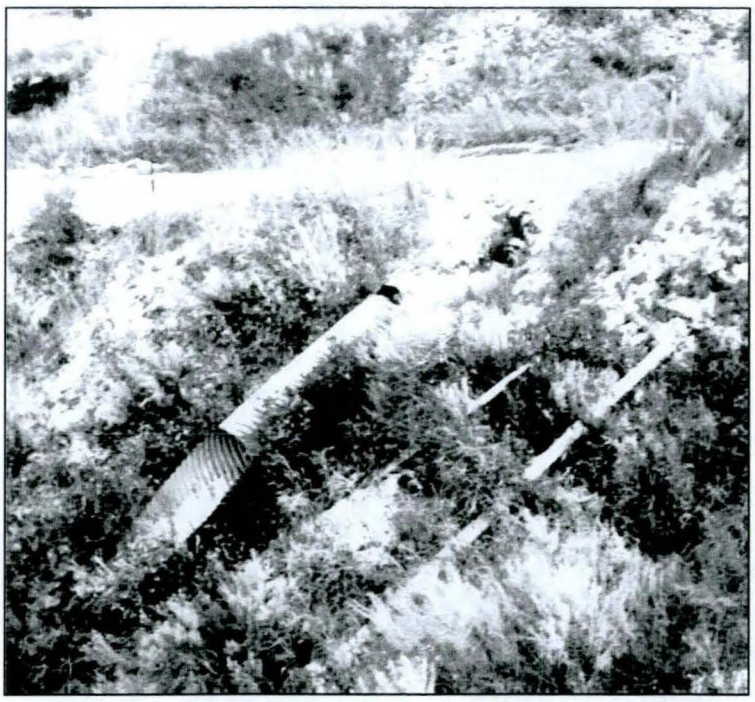

Photo 4 (bottom)
The damaged culvert on the north side of the highway (noted on site sketch). Appears to have been undermined from erosion and collapsed under its own unsupported weight.
(Photo Date: November 21, 2011)

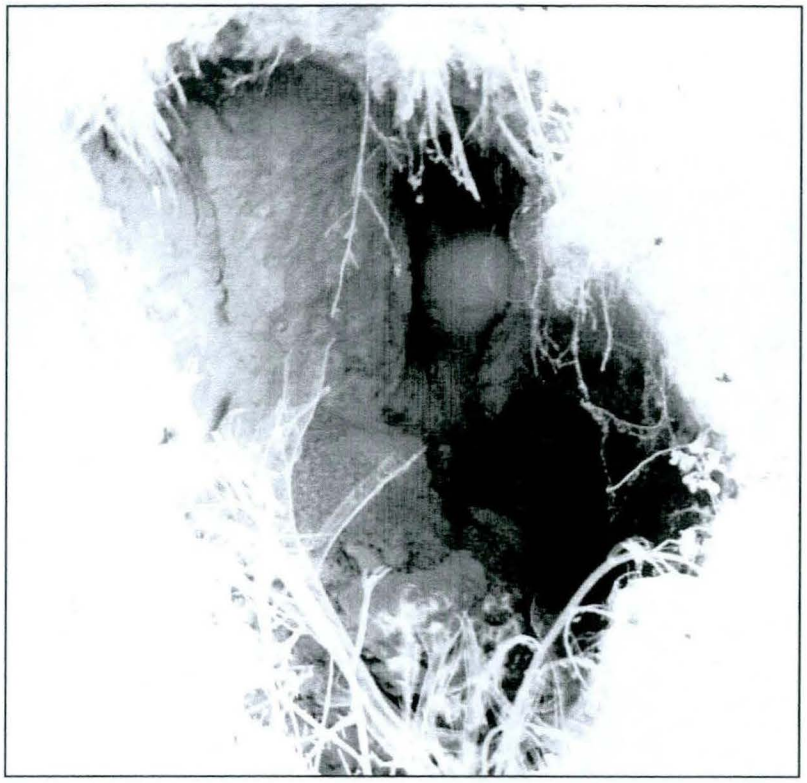

Photo 5 (above)
This sinkhole was found on the north side of the road and appeared to have an underground channel connected to it. This sinkhole was located at sinkhole #4 on the site sketch.
(Photo Date: November 21, 2011)

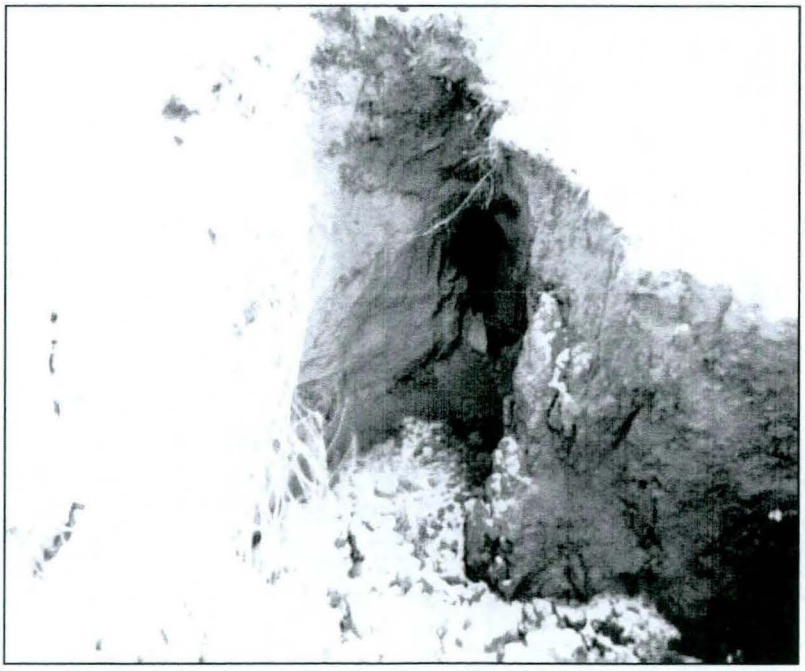

Photo 6 (bottom)
This sinkhole was found on the north side of the road and also appeared to have an underground channel connected to it. This sinkhole was located at sinkhole #5 on the site sketch.
(Photo Date: November 21, 2011)