July 15, 2024

Alberta Transportation and Economic Corridors
4th Floor, Provincial Building
4920 – 51st Street
Red Deer, Alberta
T4N 6K8

Tony Penney, P.Eng.
Construction Engineer

Dear Mr. Penney:

CON0022160 Central Region GRMP Instrumentation Monitoring
Site C003; H872:06, km 0.278 Burma Park Slide
Section C – 2024 Spring Readings

1 GENERAL

Five standpipe piezometers (SPs) (SP92-12, SP92-13, and SP07-11 through SP07-13) were read at the C003 site in the Central Region on May 14, 2024 by Aden Shipton, E.I.T. of Klohn Crippen Berger Ltd. (KCB). These instruments were read as part of the Central Region Geohazard Risk Management Program (GRMP). The site is located on Hwy 872:06, km 0.278, approximately 0.5 km north of the Battle River crossing and 10 km north of Brownfield, Alberta. The approximate site coordinates are 5806345 N, 471780 E (UTM Zone 12, NAD 83). A site plan is presented in Figure 1.

The geohazard at the C003 site consists of a large, deep-seated landslide along the north valley slope of the Battle River. The slide crosses both lanes of Hwy 872:06 from northwest to southeast. An erosion gulley is also present in the west (southbound) ditch, indicating the presence of highly erodible or dispersive soils. Previous remedial actions at this site include:

- 1998 – The installation of 150-mm-diameter perforated pipe along the west (southbound) ditch and below the highway surface elevation to intercept groundwater flows. The perforated pipe was installed at the base of a 2 m thick gravel drain. The invert elevation of the pipe ranges from approximately elevation 655 m at the upstream end and elevation 646 m at its outlet.
- 2003 – Paving and subgrade improvements. Since 2003, regular asphalt patching has been required at the site.

Geotechnical site investigations (test pit and drilling programs) have been completed at the C003 site in 1990, 1991, 1992, 2000, and 2007. Instruments were installed during the 1992 investigation, and replacement instruments were installed during the 2000 and 2007 investigations. During the 2007

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investigation, the encountered stratigraphy was as follows: silty clay interbedded with sand overlying bedrock, which was identified as clay shale with bentonitic and sandstone layers.

Alberta Transportation and Economic Corridors (TEC) requested a call-out inspection at the site on June 24, 2022 due to additional movement indicated by pavement distress (e.g., cracking and settlement) and guardrail deflection. KCB completed the call-out inspection on July 12, 2022 and the call-out report was issued to TEC on September 9, 2022.

1.1 Instrumentation

In 2021, KCB began reading the instruments at the C003 site as part of the GRMP. TEC did not request KCB to complete readings before 2021 due to most of the instruments being inoperable, and no significant changes being observed during the Central Region GRMP Section B inspections. As part of the 2019 Section B inspection, KCB read the instruments at the site to assess which SPs were operable, measure water levels inside the SPs (if operable), and to measure the depth of shearing in the SIs (all inoperable). Instrumentation installation details are tabulated in Table 1.1. Instrument locations are presented in Figure 1.

Between 1992 and 2007, several slope inclinometers (SIs), pneumatic piezometers (PNs), and SPs were installed to monitor depth of movement and groundwater conditions, respectively. Some of these instruments have since become inoperable (e.g., destroyed, sheared, or lost), including all 14 SIs and all 4 PNs as detailed in Table 1.1 (see table notes). Only 5 of 12 SPs remain operable.

Some of the inoperable instruments are protected by above-ground casing protectors or tires backfilled with earth. The operable SPs are protected by above-ground polyvinyl chloride (PVC) pipe casing protectors.

The operable SPs were read using a Heron Water Level Meter.

Table 1.1 Instrumentation Installation Details

Instrument ID	Instrument Type	Date Installed[1]	UTM Coordinates[2] (m)		Ground Surface Elevation[2] (m)	Stick Up (m)	Depth[1] (mbgs[3])	Depth Sheared[1] (mbgs[3])	Condition
			Northing	Easting					
~~SI92-01~~	~~SI~~	~~Sep. 24, 1992~~	~~Unknown~~	~~Unknown~~	~~655~~	~~0.9~~	~~37.5~~	~~9.5~~	~~Inoperable[4]~~
~~SI92-02~~	~~SI~~	~~Sep. 24, 1992~~	~~Unknown~~	~~Unknown~~	~~650~~	~~1.2~~	~~16.4~~	~~5.8~~	~~Inoperable[4]~~
~~SI92-03~~	~~SI~~	~~Sep. 25, 1992~~	~~Unknown~~	~~Unknown~~	~~659~~	~~0.9~~	~~40.5~~	~~12.0~~	~~Inoperable[4]~~
~~SI92-04~~	~~SI~~	~~Sep. 26, 1992~~	~~Unknown~~	~~Unknown~~	~~653~~	~~0.9~~	~~34.4~~	~~9.5~~	~~Inoperable[4]~~
~~SI92-05~~	~~SI~~	~~Sep. 27, 1992~~	~~Unknown~~	~~Unknown~~	~~650~~	~~0.9~~	~~25.3~~	~~N/A~~	~~Inoperable[5]~~
~~SI92-06~~	~~SI~~	~~Sep. 28, 1992~~	~~Unknown~~	~~Unknown~~	~~649~~	~~1.0~~	~~16.2~~	~~4.0~~	~~Inoperable[4]~~
~~SI92-07~~	~~SI~~	~~Sep. 28, 1992~~	~~Unknown~~	~~Unknown~~	~~658~~	~~1.2~~	~~19.5~~	~~13.0~~	~~Inoperable[4]~~
~~SI00-08~~	~~SI~~	~~Nov. 14, 2000~~	~~Unknown~~	~~Unknown~~	~~658~~	~~0.6~~	~~23.7~~	~~11.5~~	~~Inoperable[4]~~
~~SI00-09~~	~~SI~~	~~Nov. 13, 2000~~	~~Unknown~~	~~Unknown~~	~~657~~	~~0.6~~	~~20.7~~	~~11.0~~	~~Inoperable[4]~~
~~SI00-10~~	~~SI~~	~~Nov. 14, 2000~~	~~Unknown~~	~~Unknown~~	~~653~~	~~0.6~~	~~17.6~~	~~7.5~~	~~Inoperable[4]~~
~~SI07-11~~	~~SI~~	~~Oct. 23, 2007~~	~~Unknown~~	~~Unknown~~	~~658~~	~~0.6~~	~~23.6~~	~~11.8~~	~~Inoperable[4]~~
~~SI07-12~~	~~SI~~	~~Oct. 24, 2007~~	~~Unknown~~	~~Unknown~~	~~656~~	~~0.66~~	~~20.5~~	~~12.0~~	~~Inoperable[4]~~
~~SI07-13~~	~~SI~~	~~Oct. 24, 2007~~	~~Unknown~~	~~Unknown~~	~~653~~	~~0.7~~	~~17.5~~	~~8.0~~	~~Inoperable[4]~~
~~SI07-14~~	~~SI~~	~~Oct. 24, 2007~~	~~Unknown~~	~~Unknown~~	~~650~~	~~0.8~~	~~14.5~~	~~12.9~~	~~Inoperable[4]~~
~~PN92-8A~~	~~PN~~	~~Sep. 24, 1992~~	~~Unknown~~	~~Unknown~~	~~656~~	~~N/A~~	~~17.7~~	~~N/A~~	~~Inoperable[8]~~
~~PN92-10A~~	~~PN~~	~~Sep. 25, 1992~~	~~Unknown~~	~~Unknown~~	~~658~~	~~N/A~~	~~21.2~~	~~N/A~~	~~Inoperable[8]~~
~~PN92-12A~~	~~PN~~	~~Sep. 26, 1992~~	~~Unknown~~	~~Unknown~~	~~653~~	~~N/A~~	~~14.9~~	~~N/A~~	~~Inoperable[8]~~
~~PN92-15A~~	~~PN~~	~~Sep. 27, 1992~~	~~Unknown~~	~~Unknown~~	~~649~~	~~N/A~~	~~12.2~~	~~N/A~~	~~Inoperable[8]~~
~~SP92-08~~	~~SP~~	~~Sep. 24, 1992~~	~~Unknown~~	~~Unknown~~	~~655~~	~~0.69~~	~~18.7~~	~~Unknown~~	~~Inoperable[6]~~
~~SP92-09~~	~~SP~~	~~Sep. 26, 1992~~	~~Unknown~~	~~Unknown~~	~~655~~	~~1.2~~	~~5.5~~	~~Unknown~~	~~Inoperable[6]~~
~~SP92-10~~	~~SP~~	~~Sep. 26, 1992~~	~~Unknown~~	~~Unknown~~	~~658~~	~~0.8~~	~~6.1~~	~~N/A~~	~~Inoperable[6]~~
~~SP92-11~~	~~SP~~	~~Sep. 26, 1992~~	~~Unknown~~	~~Unknown~~	~~658~~	~~1.1~~	~~10.0~~	~~N/A~~	~~Inoperable[6]~~
SP92-12	SP	Sep. 26, 1992	5806320	471788	654	0.11	16.4	N/A	Operable
SP92-13	SP	Sep. 26, 1992	5806320	471788	654	0.02	7.6	N/A	Operable
~~SP92-14~~	~~SP~~	~~Sep. 27, 1992~~	~~Unknown~~	~~Unknown~~	~~649~~	~~1.0~~	~~5.1~~	~~Unknown~~	~~Inoperable[6]~~
~~SP92-15~~	~~SP~~	~~Sep. 27, 1992~~	~~Unknown~~	~~Unknown~~	~~649~~	~~1.1~~	~~12.2~~	~~Unknown~~	~~Inoperable[6]~~
SP07-11	SP	Oct. 23, 2007	5806382	471788	658	0.18	13.9	N/A	Operable
SP07-12	SP	Oct. 24, 2007	5806320	471788	656	0.15	11.5	N/A	Operable
SP07-13	SP	Oct. 24, 2007	5806290	471788	653	0.0	9.9	N/A	Inoperable
~~SP07-14~~	~~SP~~	~~Oct. 24, 2007~~	~~5806259~~	~~471787~~	~~650~~	~~0.7~~	~~5.4~~	~~N/A~~	~~Inoperable[7]~~

Notes:

[1] Instrument installation details taken from reports prepared by previous consultants or AT.

[2] Coordinates and ground surface elevations have not been surveyed. Ground surface elevations were estimated from July 2018 survey data and coordinates were taken with a handheld GPS with a horizontal accuracy of ± 5 m.

[3] Meters below ground surface (mbgs).

[4] SI92-01 through SI92-07 (excluding SI92-05), SI00-08 through SI00-10, and SI07-11 through SI07-14 have all sheared at depths between approximately 4 m and 13 m below ground surface.

[5] SI92-05 was damaged near top of casing in 2006.

[6] SP92-08, SP92-09, SP92-14, and SP92-15 are blocked. SP92-10 and 11 are damaged.

[7] SP07-14 was buried between the fall 2021 and spring 2022 readings and is inoperable.

[8] PN92-8A, PN92-10A, PN92-12A, and PN92-15A are damaged (no air return).

[9] SP92-12, SP92-13, and SP07-13 were damaged between the fall 2023 and spring 2024 readings. KCB suspects the damage was caused by vehicle activity.

2 INTERPRETATION

2.1 General

For the operable SPs, the recorded water levels were converted to an equivalent water elevation and plotted relative to ground surface elevation and the screen elevation for each instrument.

The piezometer data plots are included in Appendix I and a summary of the piezometer data is provided in Table 2.1.

No data is available for the instruments at this site between 1994 and 2000, or 2011 and 2020 except for one reading taken in 2019 (as described in Section 1.1).

2.2 Zones of Movement

No operable SIs remain at the site. SI92-01 through SP92-07 (excluding SI92-05, which was damaged before shearing), SI00-08 through SI00-10, and SI07-11 through SI07-14 have all sheared at depths between approximately 4 m and 13 m below ground surface (approximately elevation 643 m to 647 m).

Table 2.1 Standpipe Piezometer Reading Summary

Instrument ID	Date			Ground Surface Elevation (m)	Screen Depth (mbgs[1])	Water Level		
	Installed	Previous Reading	Most Recent Reading			Previous Reading (mbgs[1])	Most Recent Reading (mbgs[1])	Change from Previous Reading (m)
SP92-12	Sep. 26, 1992	Sep. 19, 2023	May 14, 2024	654	16.4	2.5	2.6	-0.1
SP92-13	Sep. 26, 1992	Sep. 19, 2023	May 14, 2024	654	7.6	2.5	2.8	-0.3
SP07-11	Oct. 24, 2007	Sep. 19, 2023	May 14, 2024	658	13.9	2.1	2.3	-0.2
SP07-12	Oct. 24, 2007	Sep. 19, 2023	May 14, 2024	656	11.5	3.7	4.0	-0.3
SP07-13[2]	Oct. 24, 2007	Sep. 19, 2023	May 14, 2024	653	9.9	2.3	0.1	2.2

Notes:
[1] Meters below ground surface (mbgs).
[2] SP07-13 was dry before the September 8, 2022 readings.
[3] The stickup of SP07-13 was sheared at ground surface before the May 14, 2024, reading and the instrument did not have a PVC cap at the time of the reading. Surface runoff entering the standpipe was observed during the spring 2024 readings.

2.3 Interpretation of Monitoring Results

No instrumentation data is available for the site between 1994 and 2000, or 2011 and 2020 except for one reading taken in 2019. Additionally, all the SIs are inoperable, so no movement data is available for KCB to interpret.

Previously, KCB's assessment was the movement being recorded in the SIs may be due to localized sliding only in the area of the pavement cracking. However, upon review of aerial photos taken using our Unmanned Aerial Vehicle (UAV) and site observations made during the 2021 Section B inspection and 2022 call-out inspection, the extent and depth of sliding appears to be larger than previously thought. The C003 site appears to be in a more active zone of sliding within a larger landslide mass along the north valley slope of the Battle River.

Based on the available historical data, the zone of movement recorded in the SIs appeared to be relatively discrete and occurring at or just above the contact with bedrock in the overlying clay or sand. Prior to being sheared, some of these instruments recorded moderate to high rates of movement (between 30 mm/year and 55 mm/year).

Ongoing movement at the site may have caused damage to the operable SPs below the current measured water level. During the spring 2024 readings, the bottom casing depth of the SPs were measured with a cloth tape and compared to the installation depth to assess if the instruments have sheared. Each of the active standpipe piezometers appear to have sheared within a 2.6 m zone between the elevations of 646.0 m and 648.6 m, which is consistent with the shearing depth of the inoperable SIs at C003. This indicates that there likely a localized failure zone between elevation 646.0 m and elevation 648.6 m. There is now a concern with the reliability of the water levels recorded in the SPs as the instruments could be blocked or allowing groundwater to flow through casing fractures above or below the screen elevation.

It is difficult to assess the current movement trends for the site since all the SIs are inoperable. TEC could consider installing one replacement SI at this site to further our understanding of movement depths and rates at this site. Alternatively, TEC could consider getting InSAR data or other change detection surveys to assess ground surface motions for not only the area affecting the entire highway, but the entire slide mass.

Water level recorded in all the SPs (except SP07-13, see below) have been steady or decreasing since spring 2022 (between 0.15 m and 2.30 m decrease between spring 2022 and spring 2024). These instruments were not read between 2011 and 2020, except for one reading taken in 2019, making it difficult to assess the long-term trends of these instruments. As the slide on the north valley wall of the Battle River is relatively large, there may be additional mechanisms contributing to the continued movement being observed at the site since 2021, such as continued movement after the initial acceleration that appears to have happened in 2022, as indicated by increased damage to the pavement in 2022. The drainage improvements installed in 1998 and 2003 may only be effective for higher water levels below the highway.

Based on the piezometer data, it is likely that the movement observed in 2022 (increased pavement cracking, settlement, and guardrail deflection) at the site occurred in response to elevated groundwater levels within the slide mass. Movement between 2022 and 2023 was difficult to assess due to pavement patching between the fall 2022 and spring 2023 readings, and again between the spring and fall 2023 readings. However, during the spring 2024 readings, transverse pavement cracking (in both the northbound and southbound lanes), pavement heaving, and guardrail settlement (on the west shoulder) was observed. This indicates that the deep-seated slide is active and there is ongoing movement at the site.

The variation in water level recorded between SI92-12, SP92-13, SP07-11 and SP07-12, and SP07-13, may be due to these instruments being installed on either side of a culvert that receives flows from a wet area upslope and to the east of the instruments. Whereas water levels recorded in the instrument upslope to the north have remained relatively steady or decreasing since the spring of 2021, while the water level recorded in SP07-13 has been increasing (approximately 1.1 m) since spring of 2021.

Historically, SP07-13 (instrument downslope to the south) has been dry since installation. However, since fall of 2022, steadily increasing water levels from approximately 4.2 m and 3.1 m below ground surface were recorded in this instrument. KCB suspects the water in the instrument may be due to slope movement shearing the SP casing, resulting in groundwater infiltrating and partially filling the casing. Between the fall 2023 and spring 2024 readings, SP07-13 was broken off at ground surface (likely due to snow clearing activities). KCB suspects that surface water may be flowing into the standpipe, resulting in higher-than-actual water levels at SP07-13.

3 RECOMMENDATIONS

3.1 Future Work

The reading frequency for all operable instruments should be reduced from twice per year (spring and fall) to once per year (spring only).

The site should continue to be inspected by TEC's Maintenance Contract Inspector (MCI) and every two-years as part of the Central Region GRMP Section B inspections.

Recommendations for this site include:

- Complete a drilling and instrumentation installation program to assess ground conditions and install:
  - one SI to below bottom-of-river elevation (and below the depth of the previously installed SIs) to assess if a deeper basal plane underlies the C003 site; and,
  - four to six vibrating wire piezometers (VWPs) in the east and west highway ditches with data loggers to assess for short-term fluctuations (i.e., increases and decreases) in water level in response to periods of heavy or prolonged rainfall or freshet infiltration that would not be captured by the current bi-annual reading frequency of the site.

- Complete a desktop study and a design for the site, that includes installing a new drainage system on the west ditch of the highway that is deeper than the current system to lower the groundwater table, and protecting (e.g., armoring with riprap) the west highway ditch against erosion.
- Consider initiating a change detection program with InSAR or other methods to assess not only movements near the highway, but over the entire slide mass.

3.2 Instrument Repairs and Maintenance

Casing protectors should be installed for the SPs. SP92-12, SP92-13, and SP07-13 were damaged between the fall 2023 and spring 2024 readings, and was likely caused by snow clearing activities or all-terrain vehicles.

4 CLOSING

This report is an instrument of service of Klohn Crippen Berger (KCB). The report has been prepared for the exclusive use of Alberta Transportation and Economic Corridors (Client) for the specific application to the Central Region Geohazard Risk Management Program (Contract No. CON0022160), and it may not be relied upon by any other party without KCB's written consent.

KCB has prepared this report in a manner consistent with the level of care, skill and diligence ordinarily provided by members of the same profession for projects of a similar nature at the time and place the services were rendered. KCB makes no warranty, express or implied.

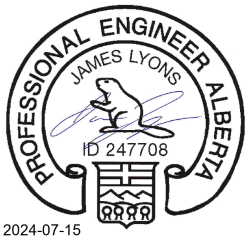
Use of or reliance upon this instrument of service by the Client is subject to the following conditions:

1. The report is to be read in full, with sections or parts of the report relied upon in the context of the whole report.
2. The observations, findings and conclusions in this report are based on observed factual data and conditions that existed at the time of the work and should not be relied upon to precisely represent conditions at any other time.
3. The report is based on information provided to KCB by the Client or by other parties on behalf of the client (Client-supplied information). KCB has not verified the correctness or accuracy of such information and makes no representations regarding its correctness or accuracy. KCB shall not be responsible to the Client for the consequences of any error or omission contained in Client-supplied information.
4. KCB should be consulted regarding the interpretation or application of the findings and recommendations in the report.
5. This report is electronically signed and sealed and its electronic form is considered the original. A printed version of the original can be relied upon as a true copy when supplied by the author or when printed from its original electronic file.

Please contact the undersigned if you have any questions or comments regarding this report.

Yours truly,

KLOHN CRIPPEN BERGER LTD.

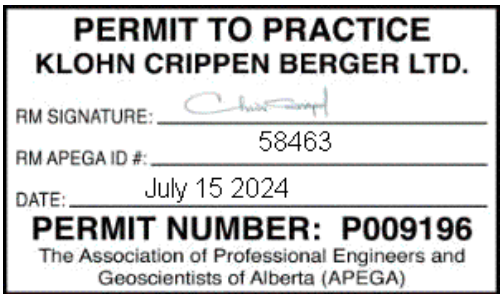


2024-07-15

James Lyons, P.Eng.
Civil Engineer

Aden Shipton, E.I.T.
Civil Engineer-in-Training

JL:bb



ATTACHMENTS
Figure
Appendix I Instrumentation Plots

FIGURE

Legend

- Slope Inclinometer (SI)
- Standpipe Piezometer (SP)
- Culvert
- Fence
- Guardrail

0 50 Meters

NOTES:
1. HORIZONTAL DATUM: NAD83
2. GRID ZONE: UTM Zone 12N
3. IMAGE SOURCE: World Imagery, ESRI ArcGIS Online Souce date January 2018 (Paintearth County No. 18)
4. Strikethrough indicates instrument is inactive.

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PROJECT: CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE: Site Plan
C003 - Burma Park Slide
Hwy 872:06, km 0.278

SCALE	PROJECT No.	FIG No.
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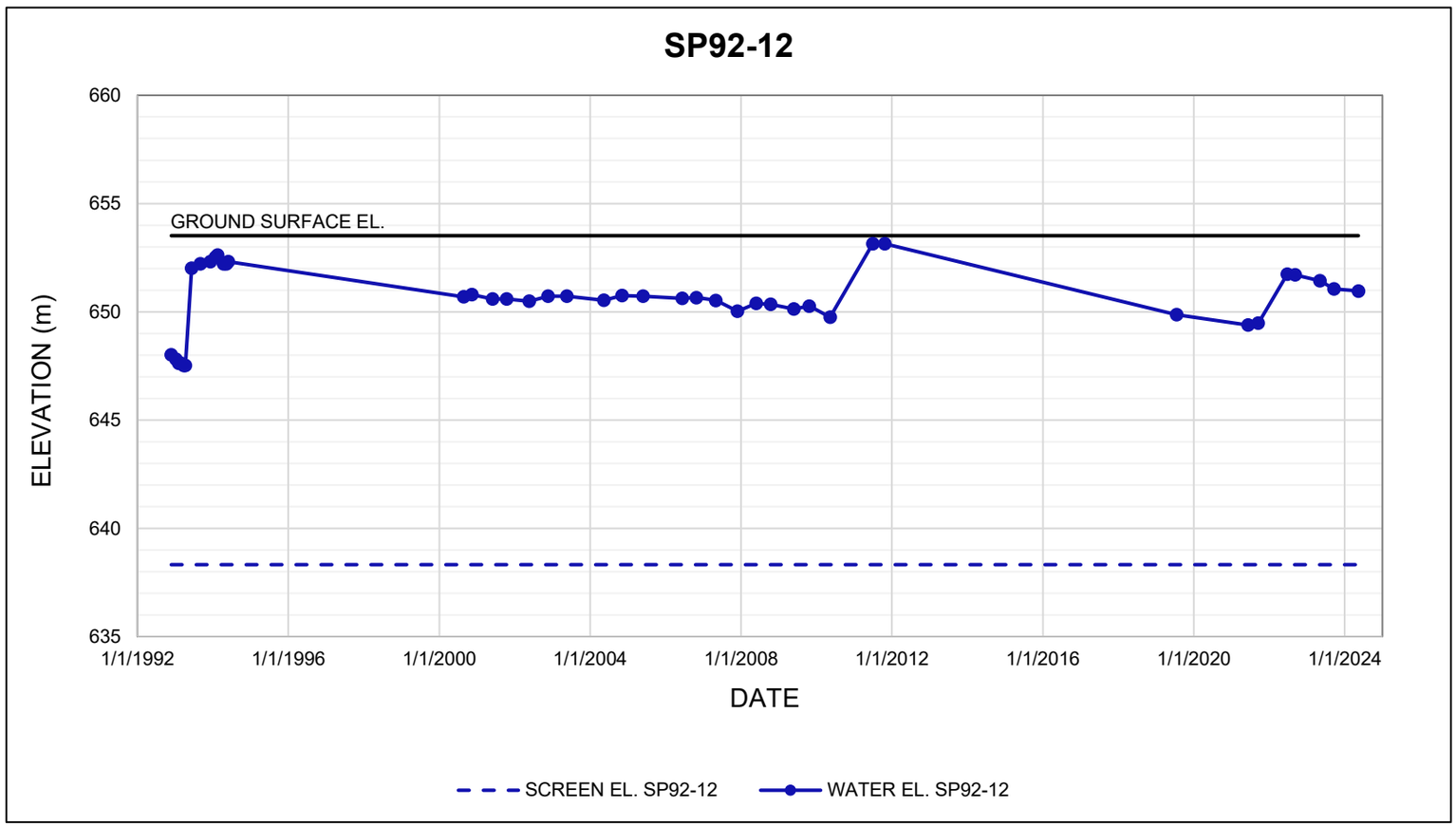
APPENDIX I

Instrumentation Plots



CLIENT Alberta

Klohn Crippen Berger

PROJECT
CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE
Piezometer Data
C003 - Burma Park Slide
Hwy 872:06; km 0.278

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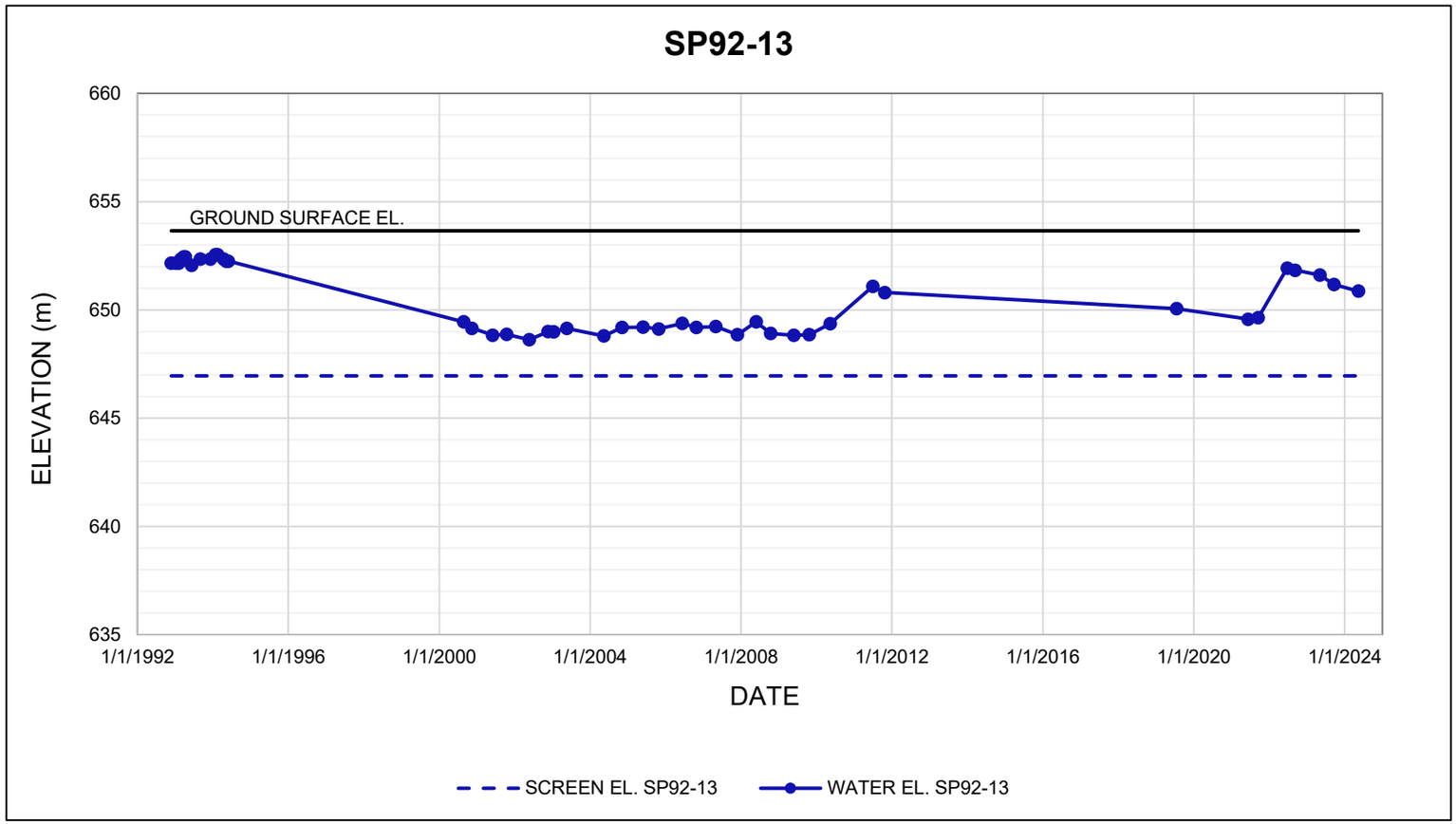

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PROJECT: CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM

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Hwy 872:06; km 0.278

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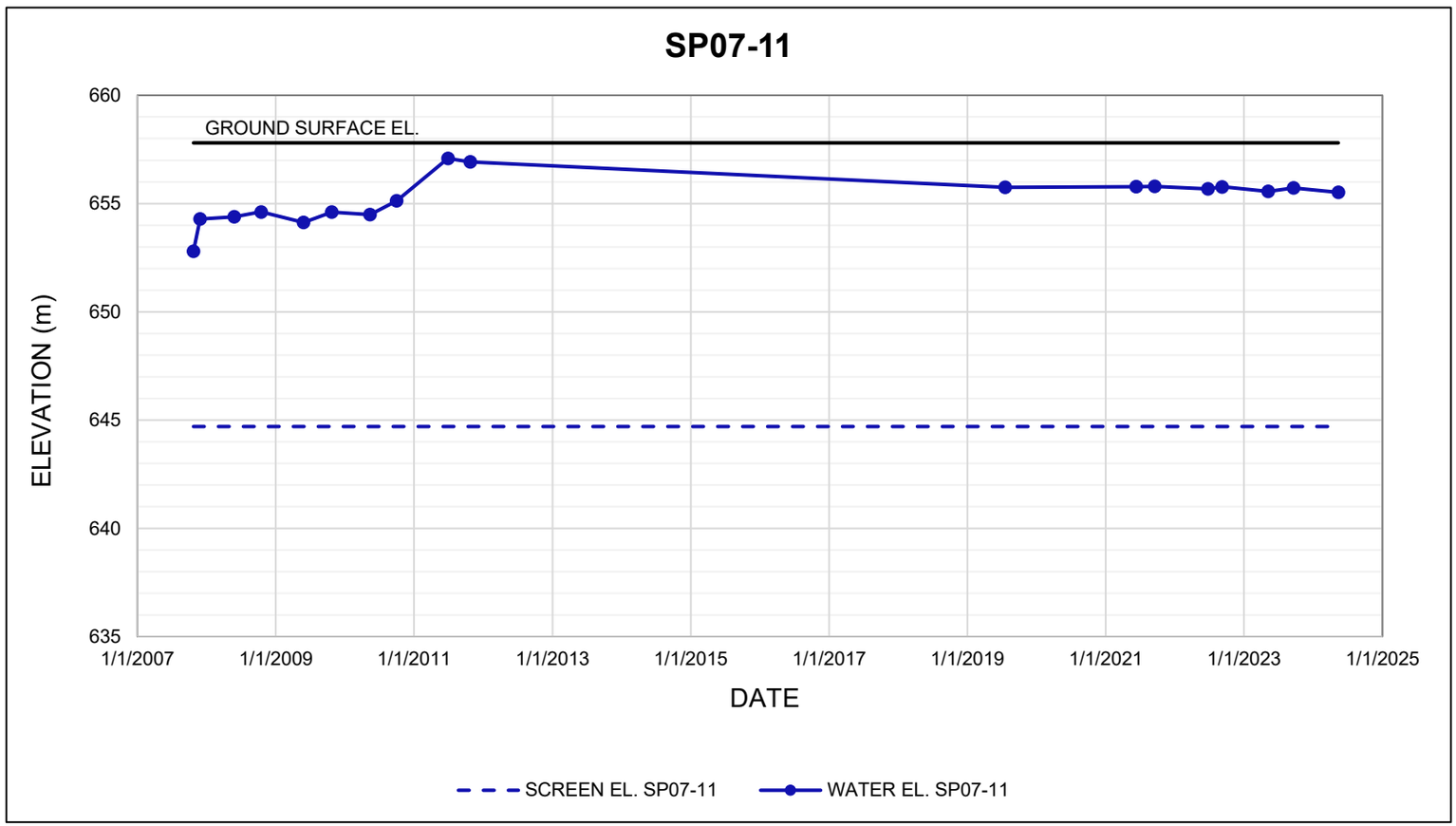

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TITLE

Piezometer Data
C003 - Burma Park Slide
Hwy 872:06; km 0.278

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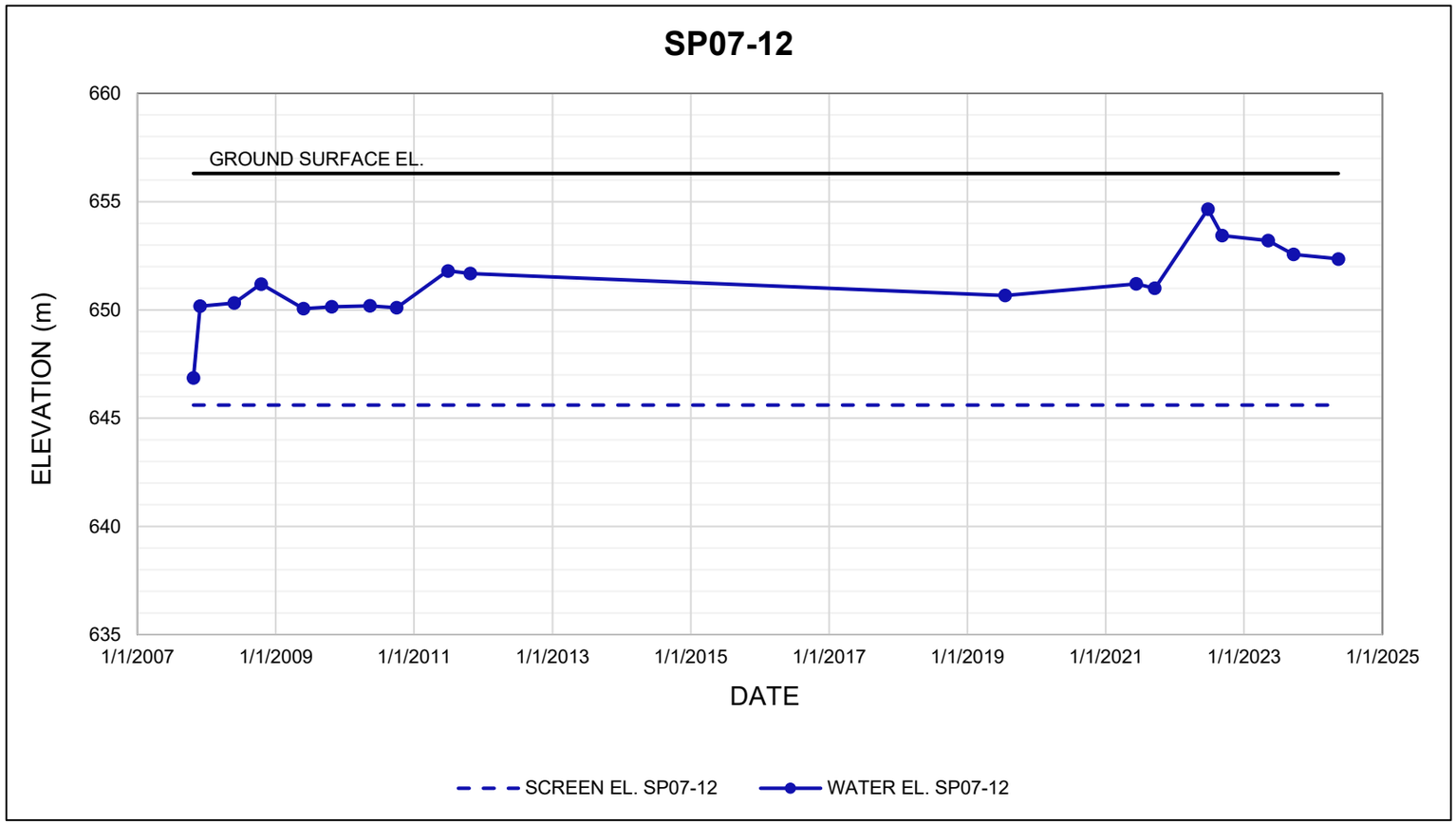

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PROJECT	CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM
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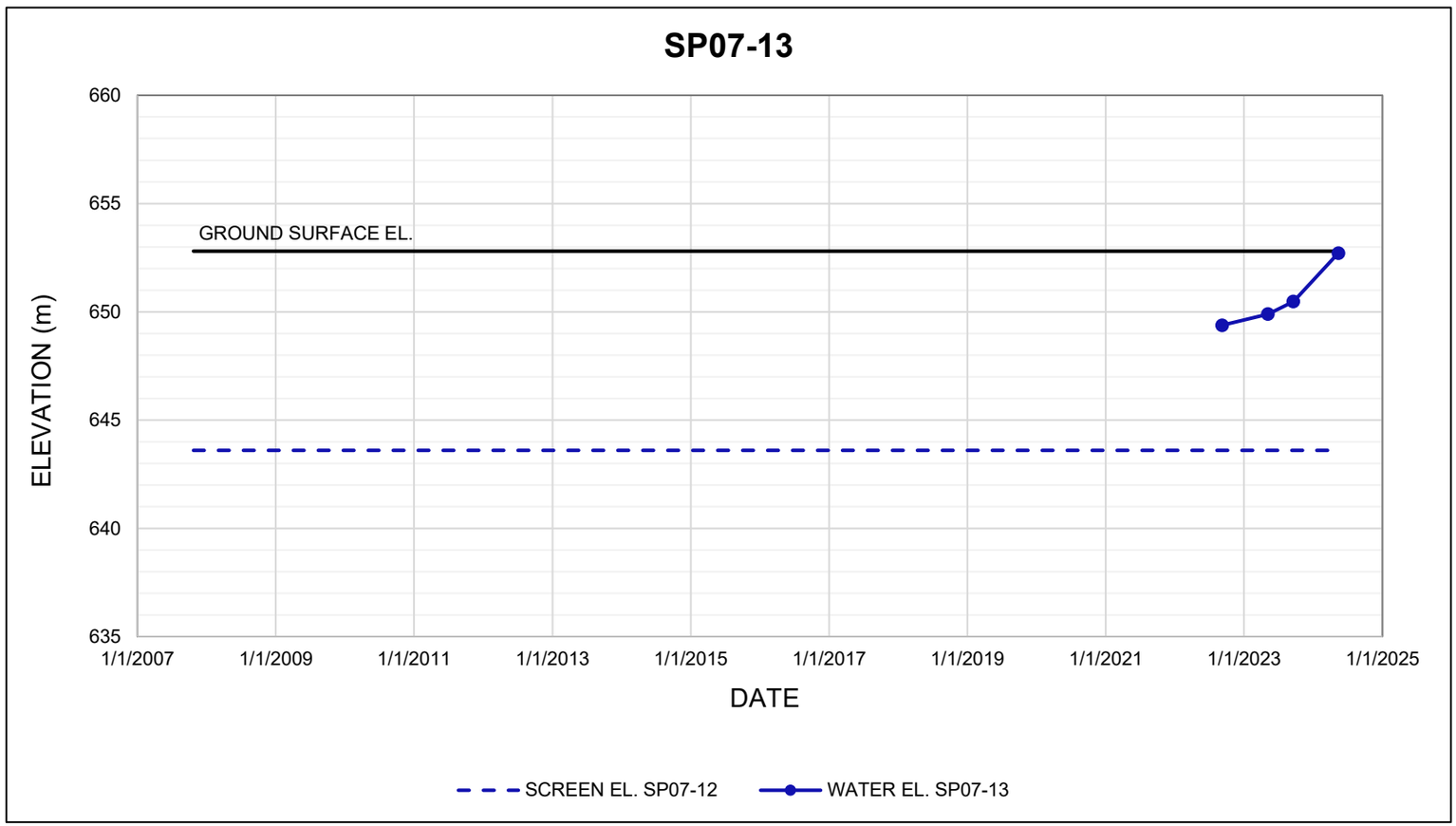

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Piezometer Data
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