July 15, 2024

Alberta Transportation and Economic Corridors
Main Floor, Provincial Building
9621 – 96th Avenue
Peace River, Alberta
T8S 1T4

Robert Senior
Construction Technologist

Dear Mr. Senior:

CON0022166 Peace Region (Grande Prairie District – South) GRMP Instrumentation Monitoring Site GP034; H40:38, km 21.016 Slide South of Kakwa River
Section C – 2024 Spring Readings

1 GENERAL

Two slope inclinometers (SIs) (SI17-2 and SI17-3) and five pneumatic piezometers (PNs) (PN17-2A/B, and PN17-6A/B) were read at the GP034 site in the Peace Region (Grande Prairie District – South) (GP South Region) on May 23, 2024, by Tim Hillman, E.I.T. of Klohn Crippen Berger Ltd. (KCB). These instruments were read as part of the GP South Region Geohazard Risk Management Program (GRMP). The site is located on Hwy 40:38, km 21.016. The approximate site coordinates are 6028755 N, 399896 E (UTM Zone 11, NAD 83). A site plan is presented on Figure 1.

The geohazard at the GP034 site consists of a landslide in a 25-m-high sidehill highway embankment fill, approximately 500 m upslope (east) from the edge of the Kakwa River.

Previous remedial actions completed at the GP034 site include the enlargement of an existing toe berm in 2020. Foundation movements and cracking of the asphalt in response to toe berm construction resulted in work being halted. Significant asphalt cracking continued into the spring and fall of 2021.

In 2017, a geotechnical site investigation, which included installing instruments, was conducted at GP034 by the previous consultant. The encountered stratigraphy was as follows: clay fill, overlying rafted clay shale, overlying clay till, and overlying bedrock consisting of siltstone and sandstone.

1.1 Instrumentation

KCB has been reading the instruments at this site since the spring of 2021. Instrumentation installation details are tabulated in Table 1.1. Instrument locations are shown on Figure 1. Any instruments not included in Table 1.1 or shown on Figure 1 are assumed to be inoperable and are not presented or discussed herein.

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In 2017, 4 SIs and 12 piezometers were installed at the site by the previous consultant to monitor movement and groundwater conditions, respectively. Some of these instruments are now inoperable (e.g., destroyed, sheared, or lost), as detailed in Table 1.1 (see table notes).

The instruments are protected by above-ground casing protectors.

The operable SIs were read using the same metric RST Digital MEMS Inclinometer System that has been used to read the SIs since KCB took over the readings in June 2021. The operable PNs were read using an RST C109 pneumatic piezometer readout.

Table 1.1 Instrumentation Installation Details[1]

Instrument ID	Instrument Type	Date Installed	UTM Coordinates (m)		Ground Surface Elevation[2] (m)	Stick Up (m)	Depth (mbgs[3])	Condition
			Northing	Easting				
SI17-2	SI	Feb. 08, 2017	6028705	399849	865.9	0.9	16.8	Operable
SI17-3	SI	Feb. 07, 2017	6028714	399799	854.6	0.7	18.0	Operable
~~SI17-5~~	~~SI~~	~~Feb. 06, 2017~~	~~6028627~~	~~399835~~	~~870.3~~	~~0.7~~	~~15.5~~	~~Inoperable[4]~~
~~SI17-6~~	~~SI~~	~~Feb. 09, 2017~~	~~6028647~~	~~399786~~	~~857.3~~	~~0.8~~	~~17.5~~	~~Inoperable[4]~~
~~PN17-1A~~	~~PN~~	~~Feb. 07, 2017~~	~~6028699~~	~~399878~~	~~865.4~~	~~N/A~~	~~4.6~~	~~Inoperable[6]~~
~~PN17-1B~~	~~PN~~	~~Feb. 07, 2017~~	~~6028699~~	~~399878~~	~~865.4~~	~~N/A~~	~~8.0~~	~~Inoperable[6]~~
PN17-2A	PN	Feb. 08, 2017	6028705	399849	865.9	N/A	7.9	Operable
PN17-2B	PN	Feb. 08, 2017	6028705	399849	865.9	N/A	10.0	Operable
~~PN17-3A~~	~~PN~~	~~Feb. 07, 2017~~	~~6028714~~	~~399799~~	~~851.6~~	~~N/A~~	~~4.1~~	~~Inoperable[7]~~
~~PN17-3B~~	~~PN~~	~~Feb. 07, 2017~~	~~6028714~~	~~399799~~	~~851.6~~	~~N/A~~	~~10.2~~	~~Inoperable[7]~~
~~PN17-4A~~	~~PN~~	~~Feb. 08, 2017~~	~~6028620~~	~~399864~~	~~870.3~~	~~N/A~~	~~5.0~~	~~Inoperable[6]~~
~~PN17-4B~~	~~PN~~	~~Feb. 08, 2017~~	~~6028620~~	~~399864~~	~~870.3~~	~~N/A~~	~~9.0~~	~~Inoperable[6]~~
~~PN17-5A~~	~~PN~~	~~Feb. 06, 2017~~	~~6028627~~	~~399835~~	~~870.1~~	~~N/A~~	~~12.0~~	~~Inoperable[7]~~
~~PN17-5B~~	~~PN~~	~~Feb. 06, 2017~~	~~6028627~~	~~399835~~	~~870.1~~	~~N/A~~	~~14.9~~	~~Inoperable[7]~~
PN17-6A	PN	Feb. 09, 2017	6028647	399786	857.3	N/A	6.0	Operable
PN17-6B	PN	Feb. 09, 2017	6028647	399786	857.3	N/A	12.0	Operable[8]

Notes:

[1] Instrument installation details taken from reports and data files prepared or provided by the previous consultant(s) or TEC. Instrument coordinates and stick ups (where applicable) were confirmed by KCB with a handheld GPS (accuracy of ± 5 m) and tape measure, respectively.

[2] Ground surface elevations were measured prior to construction and need to be re-surveyed.

[3] Meters below ground surface (mbgs). Bottom reading depth for operable SIs and tip depth for piezometers. Either bottom reading or casing depth for inoperable SIs.

[4] SI17-5 and SI17-6 have sheared at an approximate depth of 7.3 m and 6.7 m below ground surface, respectively.

[6] PN17-1A, PN17-1B, PN17-4A, and PN17-4B were destroyed in 2020 during construction.

[7] PN-3B, PN17-5A, and PN-5B have not stabilized for at least two readings and are no longer being read. During the spring 2024 reading, a reading was obtained in PN-3A for the first time since the fall 2020 readings. Another reading of PN-3A is needed to confirm if the instrument is reliable.

8 PN17-6B did not stabilize between the fall 2020 and fall 2022 readings.

2 INTERPRETATION

2.1 General

For the operable SIs, the cumulative displacement, incremental displacement, and displacement-time data was plotted in the A-direction (i.e., the direction of the A0-grooves) and the X-direction (i.e., the direction of maximum movement obtained at a skew angle from the A0-grooves). SI17-2 and SI17-3 have skew angles of 15° and 35°, respectively, measured clockwise from the direction of the A0-grooves.

For the operable PNs, the recorded porewater pressures were converted to an equivalent water/piezometric elevation and plotted relative to ground surface elevation and the tip elevation for each instrument.

The SI and piezometer data plots are included in Appendix I, and a summary of the SI and piezometer data is provided in Table 2.1 and Table 2.2, respectively. The SI data plots presented herein include data for readings taken with both the previous consultants' and KCB's SI reading equipment.

2.2 Zones of Movement

Discrete movement (i.e., occurring on a defined failure plane) is being recorded in:

- SI17-2 between an approximate depth of 9.3 m and 10.8 m below ground surface (elevation 856.6 m to 855.1 m) at the bottom of a clay till foundation unit overlying bedrock (siltstone); and
- SI17-3 between an approximate depth of 13.0 m and 14 5 m below ground surface (elevation 841.6 m to 840.1 m) in a clay foundation unit overlying bedrock (clay shale).

Distributed movement is also being recorded in SI17-3 from the top of the casing to an approximate depth of 4.5 m below ground surface in the fill placed during late-2020 construction.

2.3 Interpretation of Monitoring Results

The rate of foundation movement being recorded in SI17-2 and SI17-3 was relatively slow and steady (less than 5 mm/year) between February 2017 (installation date) and October 2020, but increased up to approximately 212 mm/year and 5,519 mm/year, respectively, when construction began in late-2020. Since January 2021, the rate of foundation movement recorded in SI17-2 and SI17-3 (recorded in the clay till and clay units between two clay shale layers, respectively) has decreased significantly and is currently less than 5 mm/year. Increased movement, which could impact the highway, may occur in response to periods of heavy or prolonged rainfall, resulting in higher groundwater conditions.

Table 2.1 Slope Inclinometer Reading Summary

Instrument ID	Date				Ground Surface Elevation[1] (m)	Depth of Movement (mbgs[2])	Direction of Movement, Skew Angle[3]	Movement (mm)		Rate of Movement (mm/year)		
	Initialized	Previous Maximum Cumulative Movement Recorded	Previous Reading	Most Recent Reading				Maximum Cumulative	Incremental Since Previous Maximum Cumulative	Previous Maximum	Most Recent Reading	Change from Previous Reading
SI17-2	Feb. 08, 2017	Sep. 07, 2023	Sep. 07, 2023	May 23, 2024	865.9	8.3 – 10.8	X-Direction, 15°	49.0	3.2	211.6	4.6	0.7
SI17-3	Feb. 08, 2017	Jun. 06, 2023	Sep. 07, 2023	May 23, 2024	854.6	0.0 – 4.5	X-Direction, 35°	255.9	2.2	5519.4	3.4	4.4
		Sep. 07, 2023				13.0 – 14.5	X-Direction, 35°	74.4	1.9	866.9	2.6	-2.5

Notes:
[1] Ground surface elevations were measured prior to construction and should be surveyed.
[2] Meters below ground surface (mbgs).
[3] Skew angle of the X-direction measured clockwise from the A-direction. The azimuths of the A0-grooves in the SIs were measured by KCB with a magnetic compass in June 2022.

Table 2.2 Pneumatic Piezometer Reading Summary

Instrument ID	Serial No.	Date			Ground Surface Elevation[1] (m)	Tip Depth (mbgs[2])	Water Level		
		Installed	Previous Reading	Most Recent Reading			Previous Reading (mbgs[2])	Most Recent Reading (mbgs[2])	Change from Previous Reading (m)
PN17-2A	37443	Feb. 08, 2017	Sep. 07, 2023	May 23, 2024	865.9	7.9	6.3	5.7	0.6
PN17-2B	37439	Feb. 08, 2017	Sep. 07, 2023	May 23, 2024	865.9	10.0	9.7	7.7	2.0
PN17-6A	37444	Feb. 09, 2017	Sep. 07, 2023	May 23, 2024	857.3	6.0	0.7	2.1	-1.4
PN17-6B	37433	Feb. 09, 2017	Sep. 07, 2023	May 23, 2024	857.3	12.0	7.3	8.2	-0.9

Notes:
[1] Ground surface elevations were measured prior to construction and should be surveyed.
[2] Meters below ground surface (mbgs).

Since November 2020, shallow movements have been recorded in the upper 4.5 m of SI17-3 in the clay fill placed during late-2020 construction. This shallow movement is believed to be causing the pavement cracking observed on site and may be an extension upwards along the backscarp, associated with deeper movement. The rate of shallow movement recorded in SI17-3 in late-2020 is difficult to assess due to the SI casing being extended in November 2020. Between December 2020 and April 2021, the rate of movement decreased to approximately 15 mm/year, before increasing to approximately 230 mm/year in June 2021. Since September 2021, the rate of recorded movement has been decreasing and is now less than approximately 5 mm/year.

Between November 2020 and June 2022, a relatively steady increase in porewater pressure (between approximately 2.5 m and 2.9 m, respectively) was recorded in PN17-2A and PN17-2B, which are located at the crest of the highway embankment. Between June 2022 and June 2023, a decrease between approximately 1.1 m and 2.5 m was recorded in these instruments.

Between late-2020 and June 2021, a large porewater pressure increase (up to approximately 10 m) was recorded in PN17-6A, which is installed beneath the toe berm crest. Between June 2021 and June 2022, a steady decrease of approximately 7.3 m was recorded in this instrument.

The increase and decrease in porewater pressure recorded in PN17-2A, PN17-2B, and PN17-6A can most likely be attributed to construction-induced porewater pressure response and post-construction porewater pressure dissipation, respectively. Since June 2023, porewater pressures recorded in these instruments have fluctuated up to approximately 2.9 m, likely in response to seasonal variations in precipitation and freshet infiltration.

PN17-6B did not stabilize between November 2020 and September 2022. Since September 2022, porewater pressures recorded in this instrument have been relatively steady.

3 RECOMMENDATIONS

3.1 Future Work

All operable instruments should continue to be read twice per year (spring and fall). Spring readings should be completed after late-May or early-June, due to the risk of water inside the instrument casings being frozen earlier in the year.

The site should continue to be inspected by the Maintenance Contract Inspector (MCI) and as part of the GP South Region GRMP Section B inspections.

3.2 Instrument Repairs and Maintenance

PN17-1A/B and PN-4A/B were destroyed in 2020 during construction and should be replaced. PN-3A/B and PN-5A/B have also become inoperable since installation (i.e., readings do not stabilize) and they should be replaced.

During the spring 2024 reading, a reading was obtained from PN-3A for the first time since the fall 2020 readings. Another reading of PN-3A is needed to confirm if the instrument is reliable.

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 GP South Geohazard Risk Management Program (Contract No. CON0022166), and it may not be relied upon by any other party without KCB's written consent.

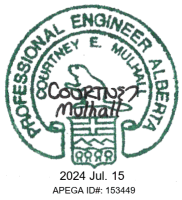
KCB has prepared this report in a manner consistent with the level of care, skill and diligence ordinarily provided by members of the same profession for projects of a similar nature at the time and place the services were rendered. KCB makes no warranty, express or implied.

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.

Yours truly,

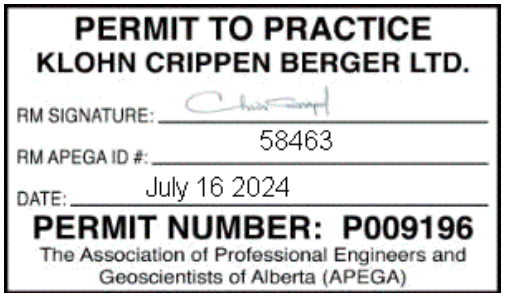
KLOHN CRIPPEN BERGER LTD.



Courtney Mulhall, M.Sc., P.Eng.
Geotechnical Engineer

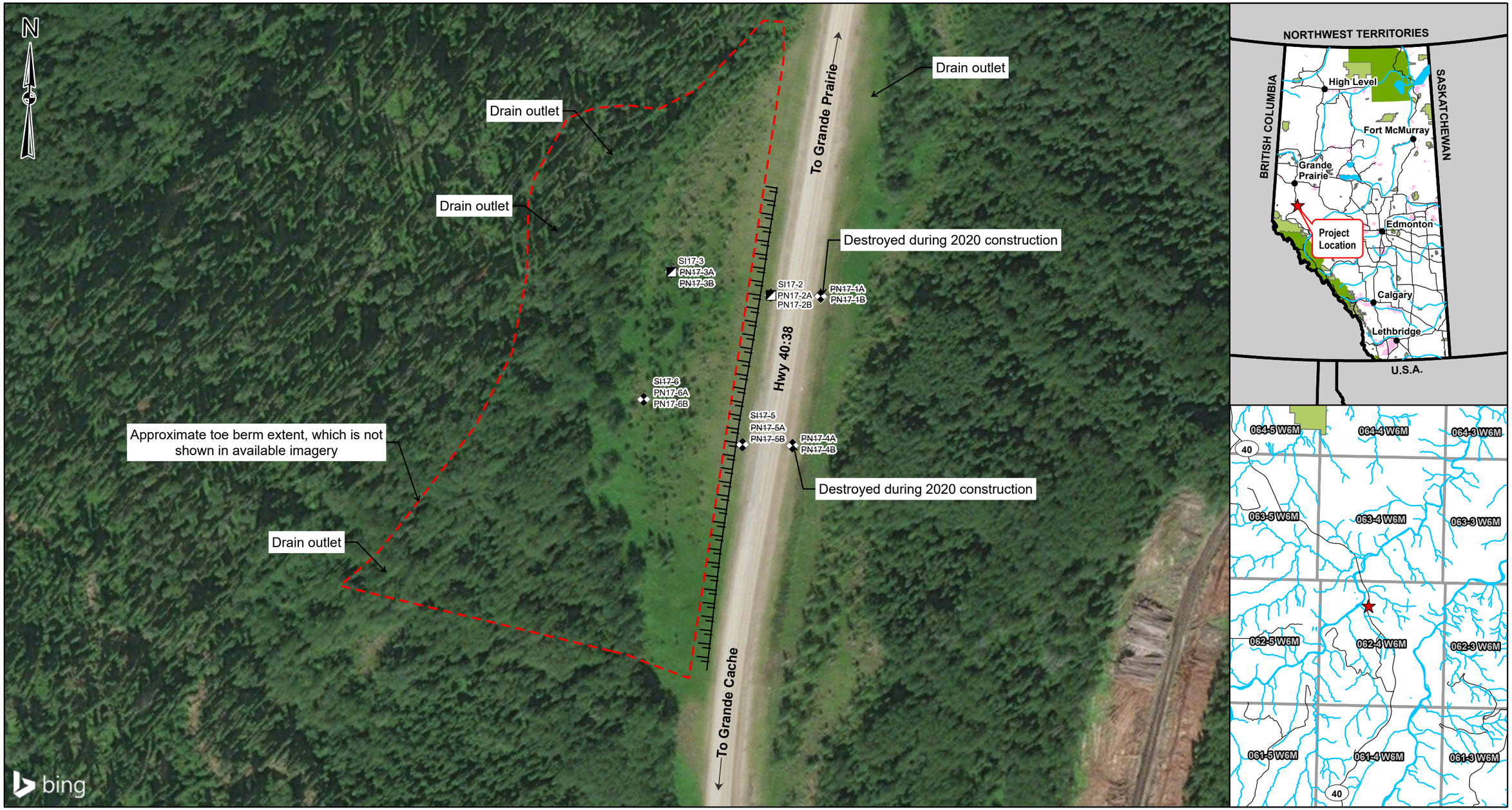
Tim Hillman, E.I.T.
Geotechnical Engineer-in-Training

CM/TH/GB:bb



ATTACHMENTS
Figure
Appendix I Instrumentation Plots

FIGURE



Legend

- Approximate Pneumatic Piezometer (PN) Location
- Approximate Slope Inclinometer (SI) Location
- Crest
- Approximate Extent of Toe Berm

0 100 Metres

NOTES:
1. HORIZONTAL DATUM: NAD83
2. GRID ZONE: UTM ZONE 11N
3. IMAGE SOURCE: 2022 MICROSOFT CORPORATION, 2022 MAXAR, CNES
4. INSTRUMENT LABELS THAT ARE INDICATED WITH STRIKE THROUGH TEXT ARE INOPERABLE.

CLIENT: Alberta

Klohn Crippen Berger

PROJECT: PEACE REGION (GRANDE PRAIRIE DISTRICT-SOUTH) GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE: Site Plan
GP034 - Slide South of Kakwa River
Hwy 40:38, km 21.016

SCALE	PROJECT No.	FIG No.
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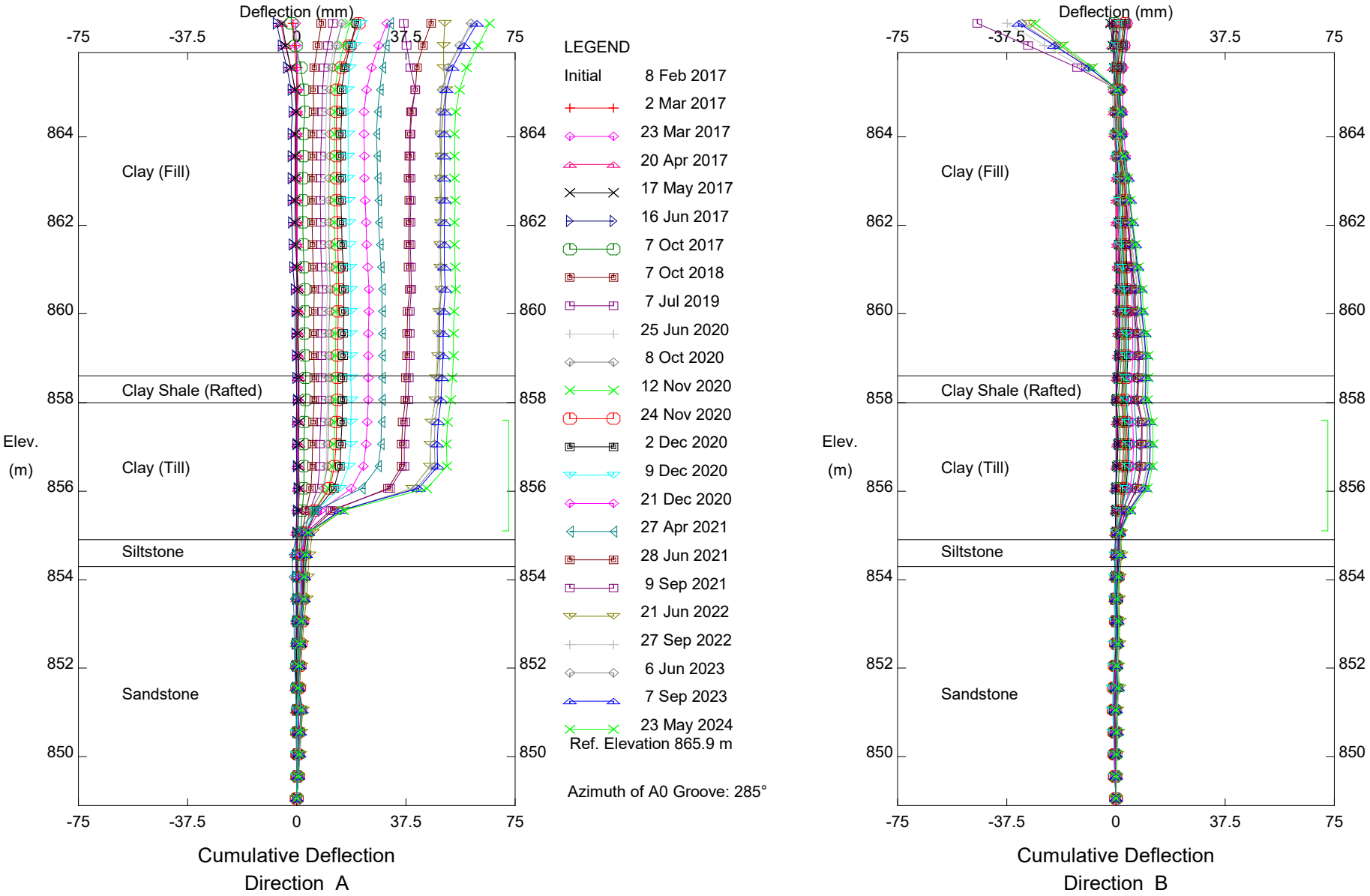
APPENDIX I

Instrumentation Plots

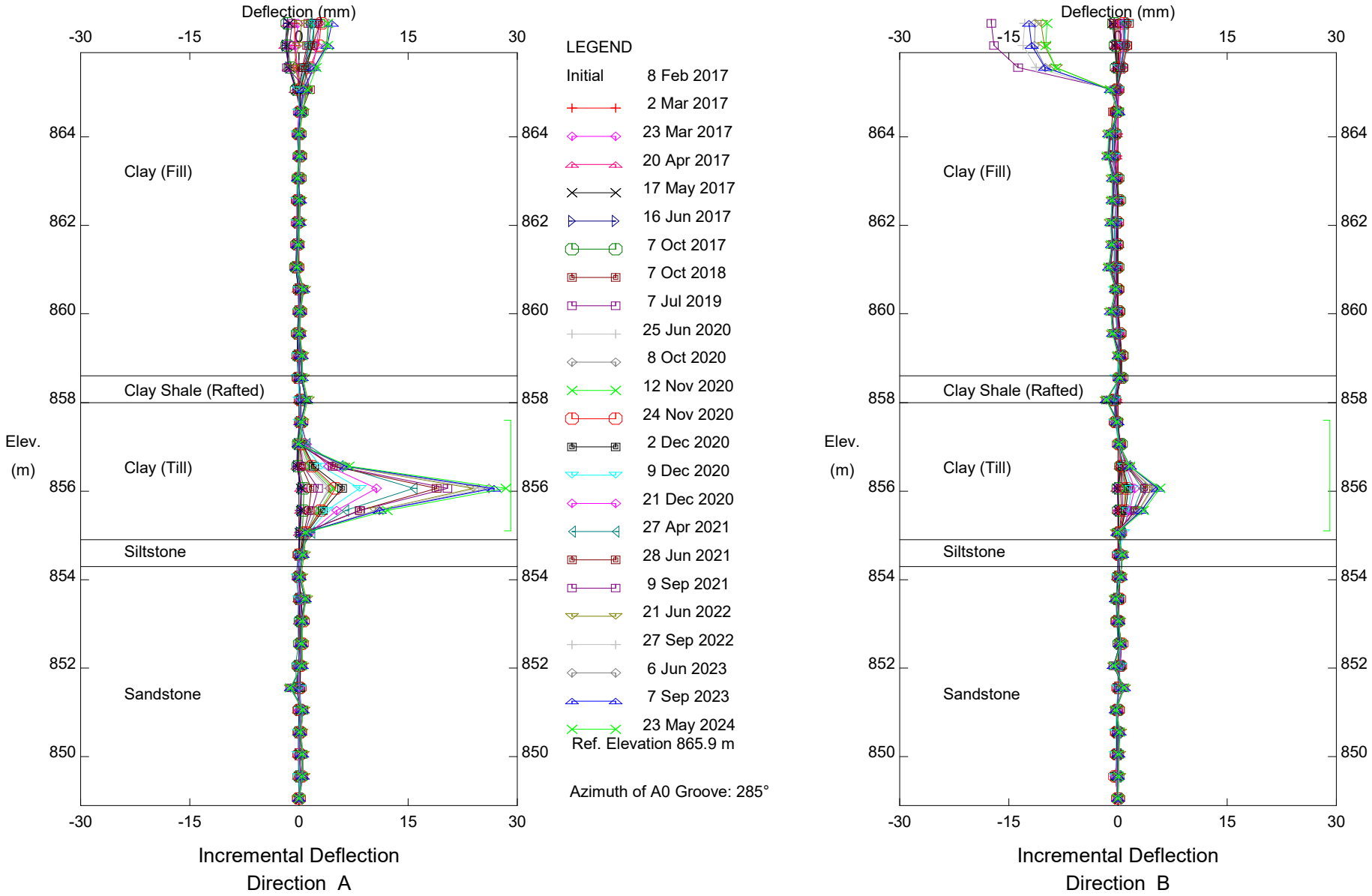
Klohn Crippen Berger - Edmonton



GP034; H40:38, Inclinometer SI17-2

GP034; H40:38, km 21.016 Slide 2.9 km South of Kakwa River Bridge
Alberta Transportation

Klohn Crippen Berger - Edmonton



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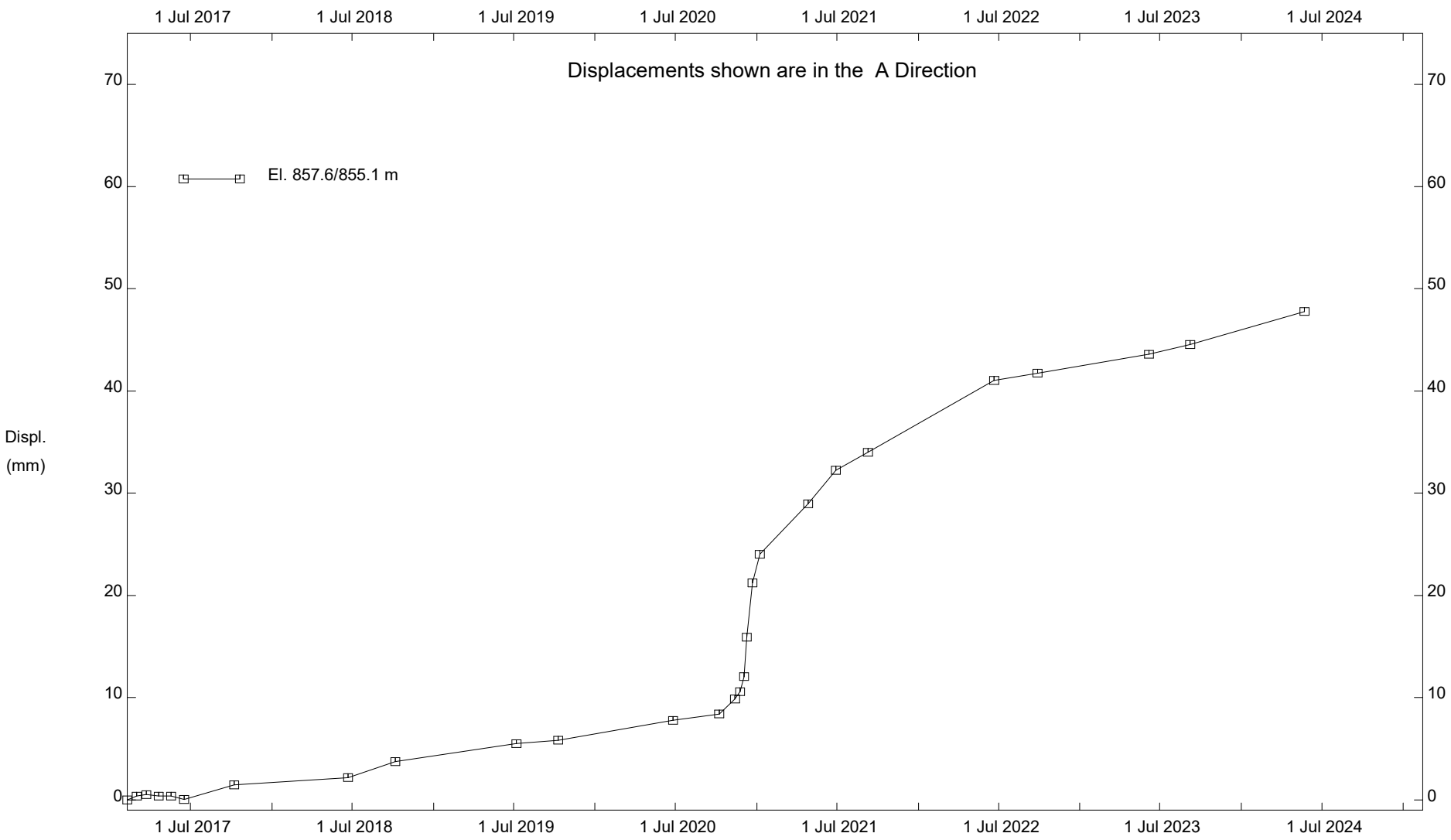
Alberta Transportation

Klohn Crippen Berger - Edmonton



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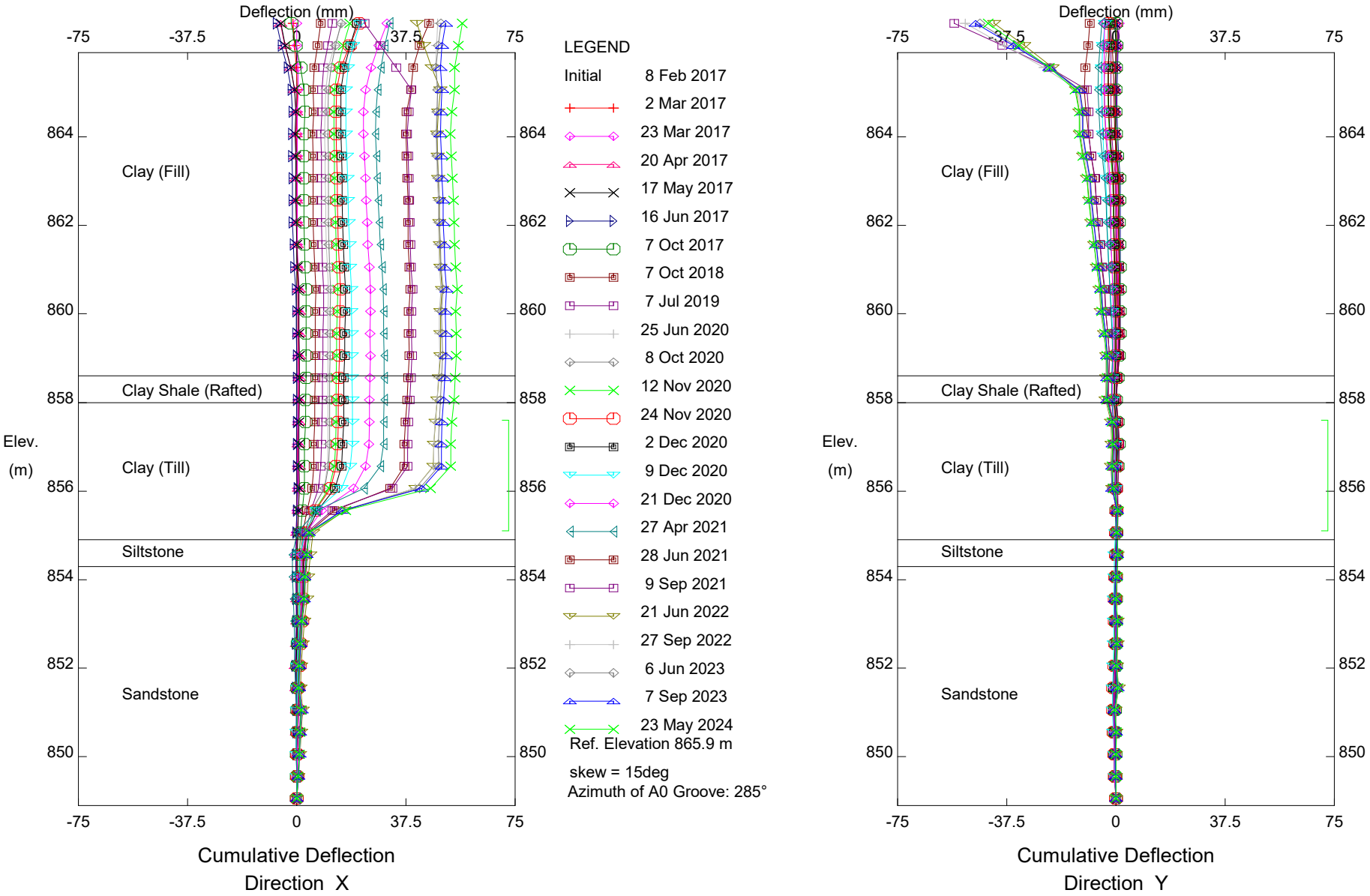
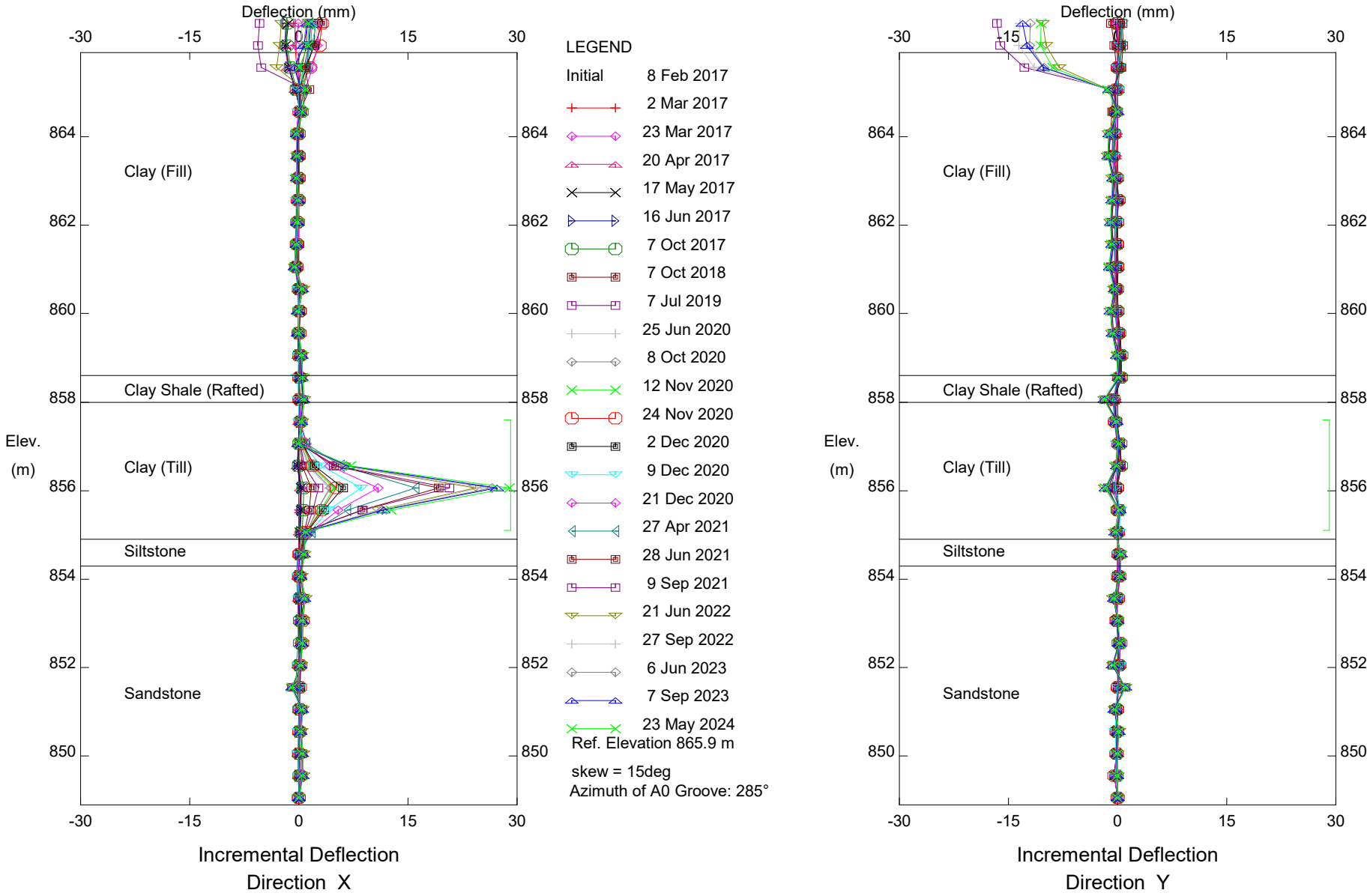
Klohn Crippen Berger - Edmonton



GP034; H40:38, Inclinometer SI17-2

GP034; H40:38, km 21.016 Slide 2.9 km South of Kakwa River Bridge
Alberta Transportation

Klohn Crippen Berger - Edmonton



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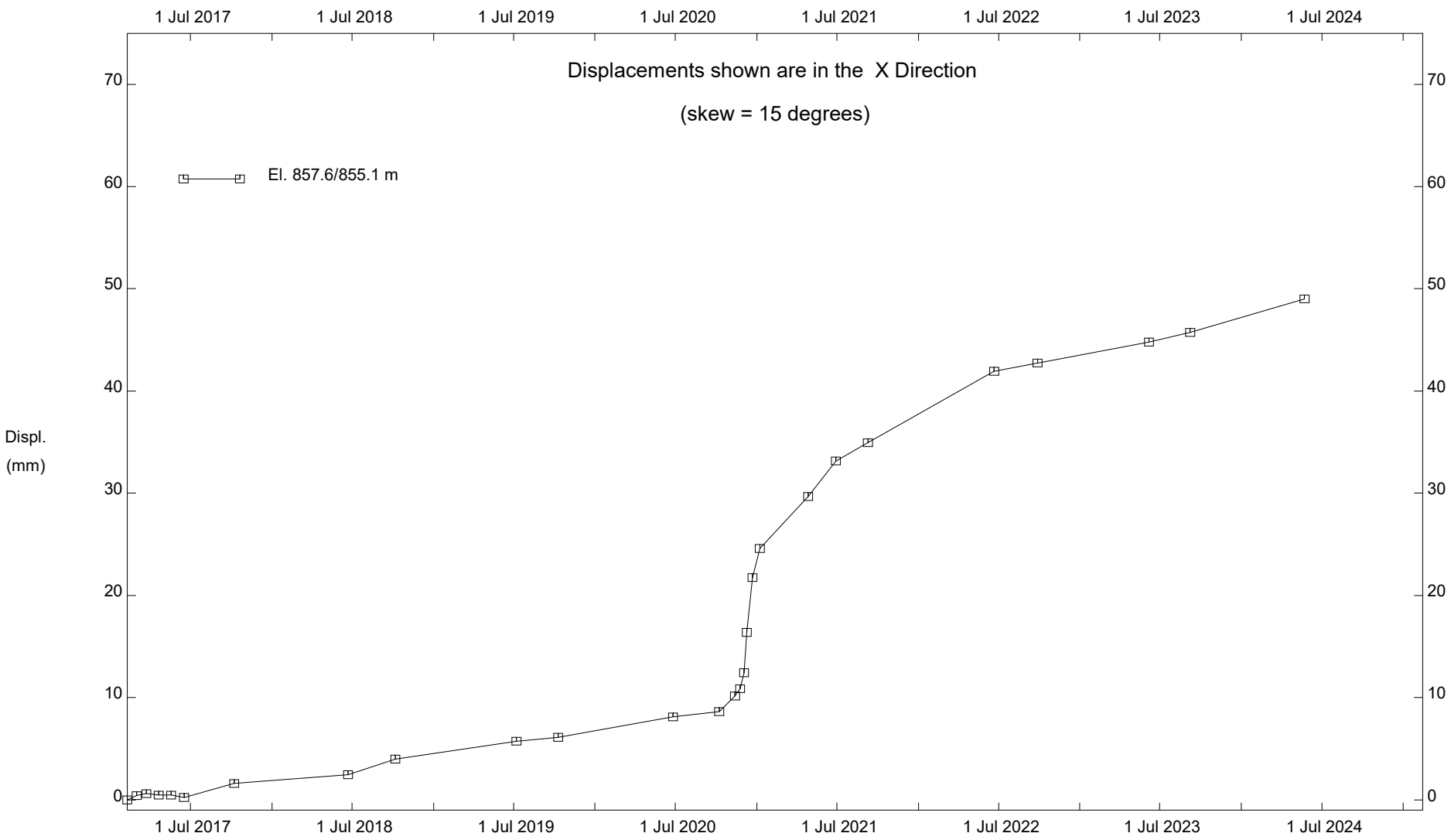
GP034; H40:38, km 21.016 Slide 2.9 km South of Kakwa River Bridge
Alberta Transportation

Klohn Crippen Berger - Edmonton



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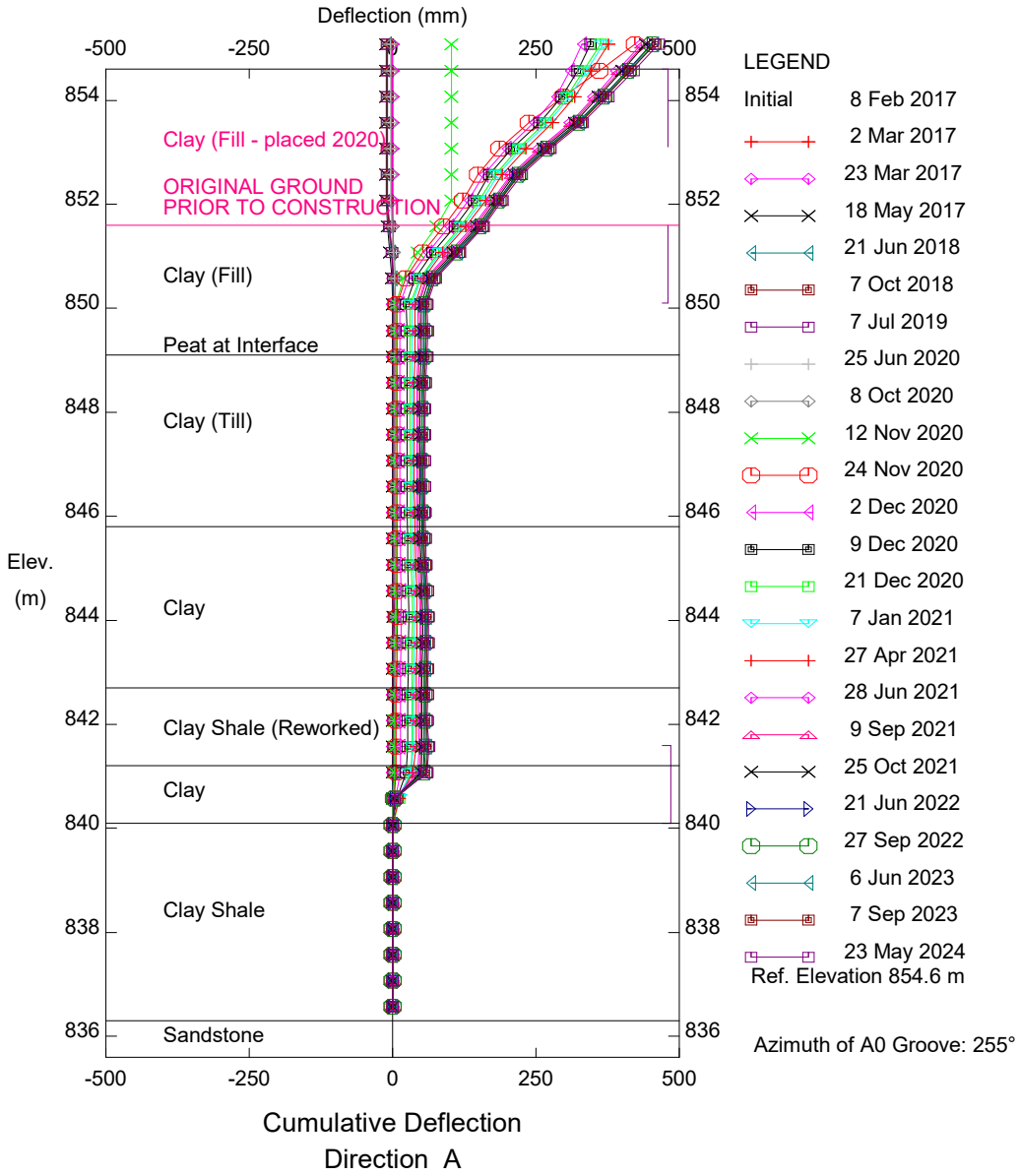
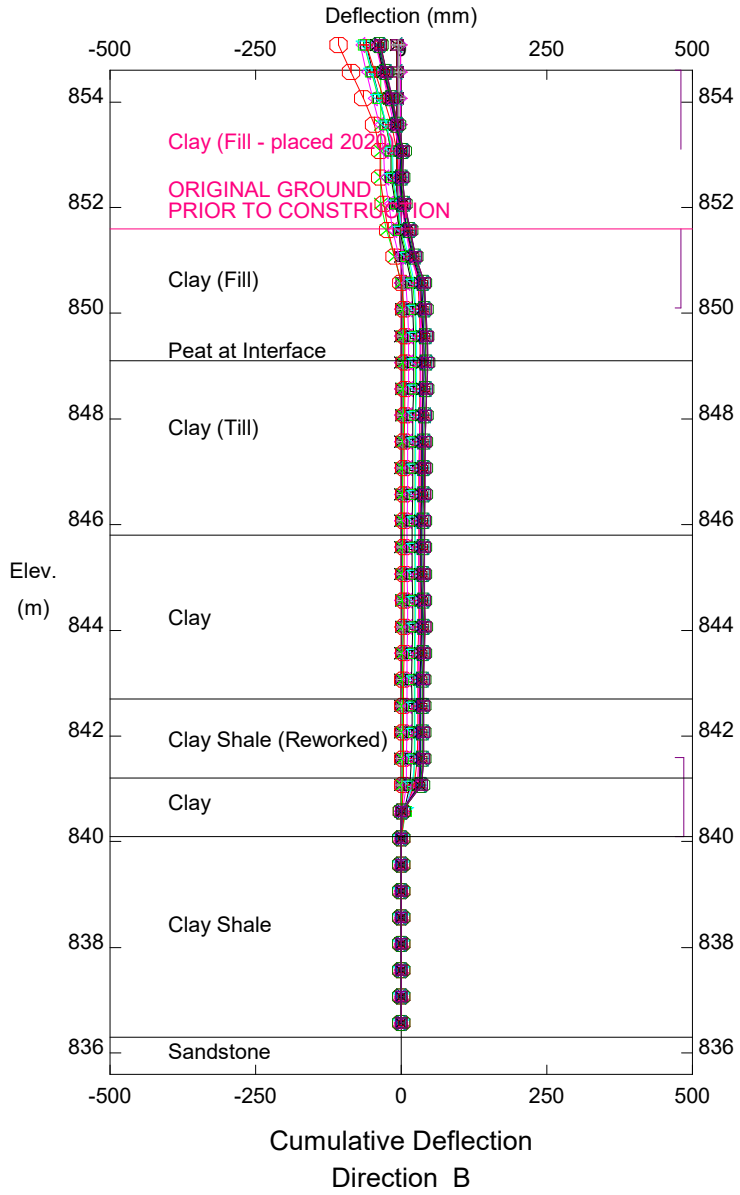
Klohn Crippen Berger - Edmonton





GP034; H40:38, Inclinometer SI17-3

GP034; H40:38, km 21.016 Slide 2.9 km South of Kakwa River Bri
Alberta Transportation

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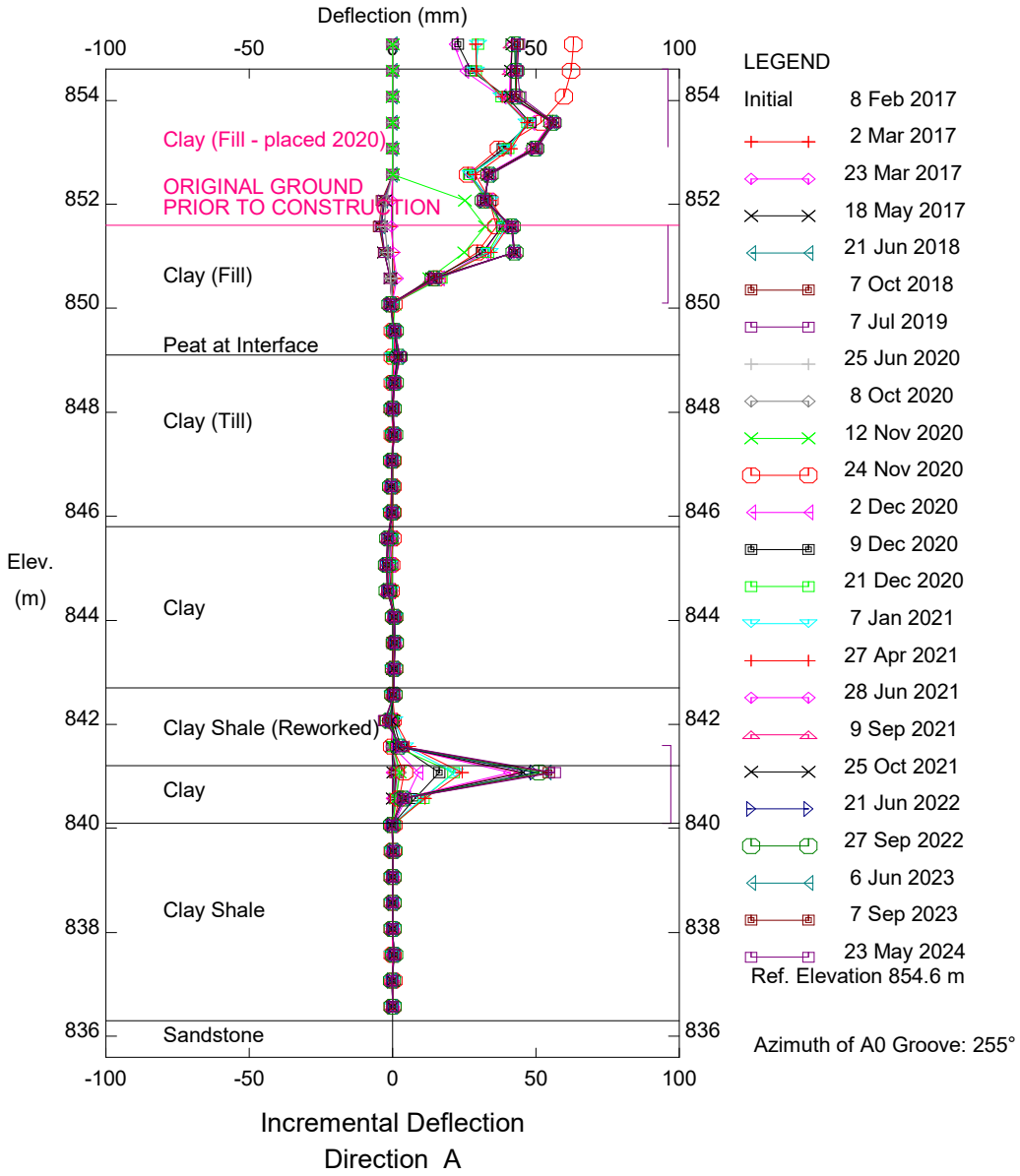

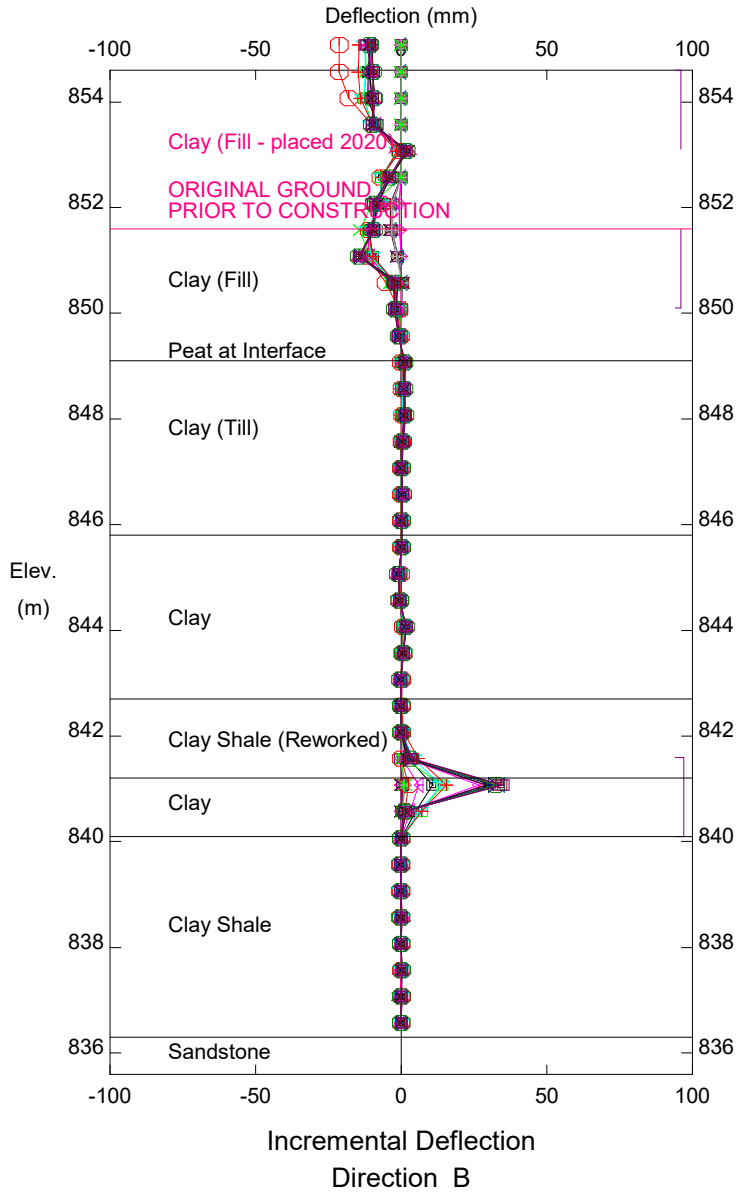

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Alberta Transportation

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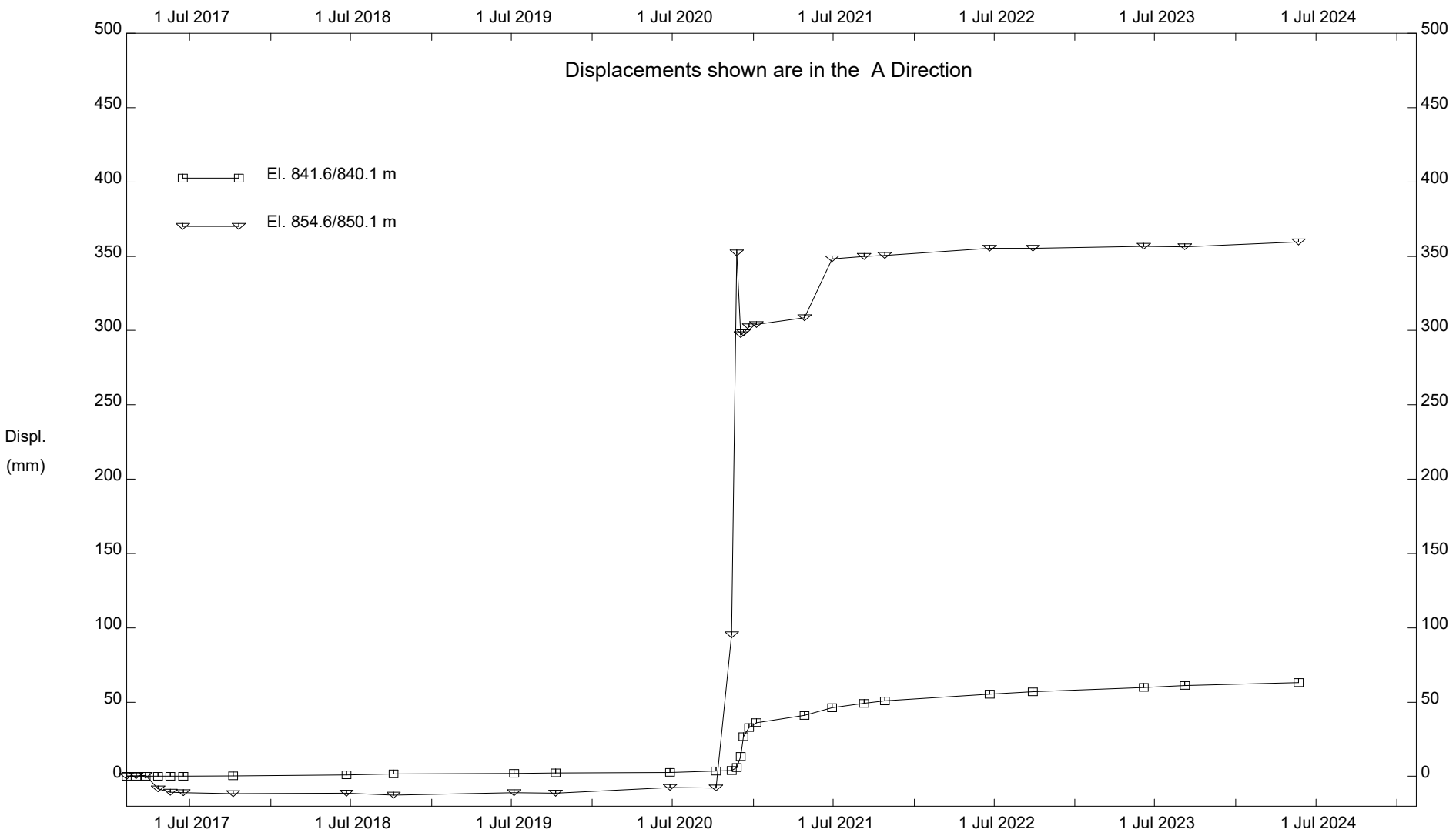

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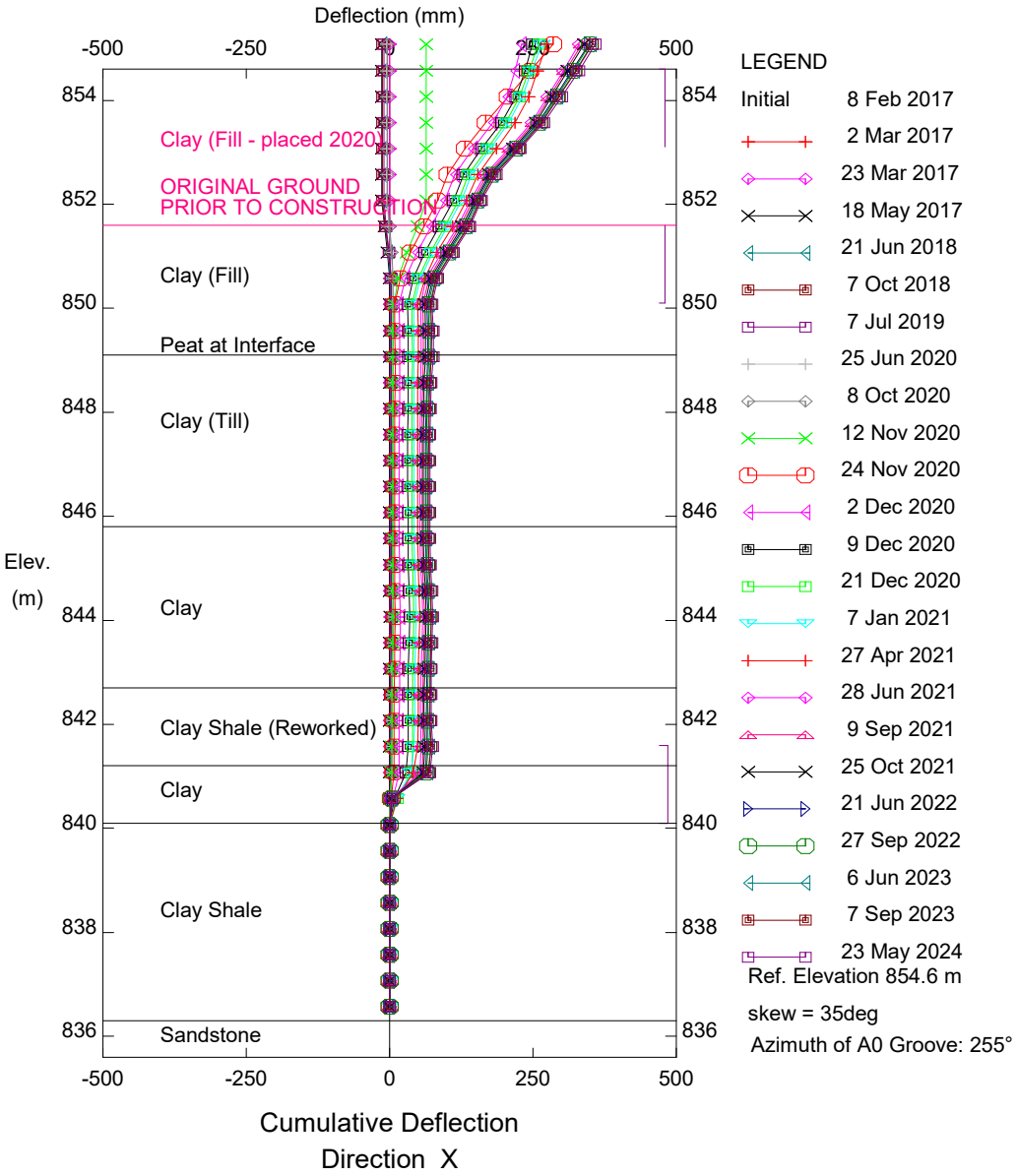
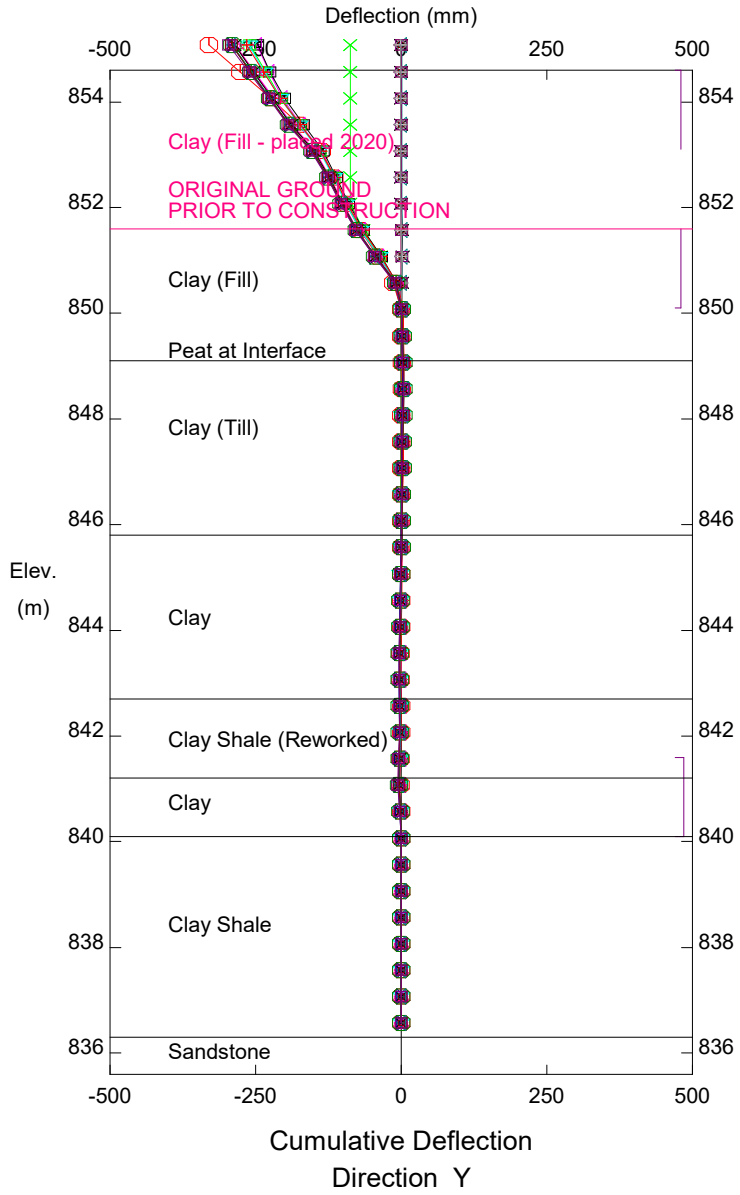
Klohn Crippen Berger - Edmonton

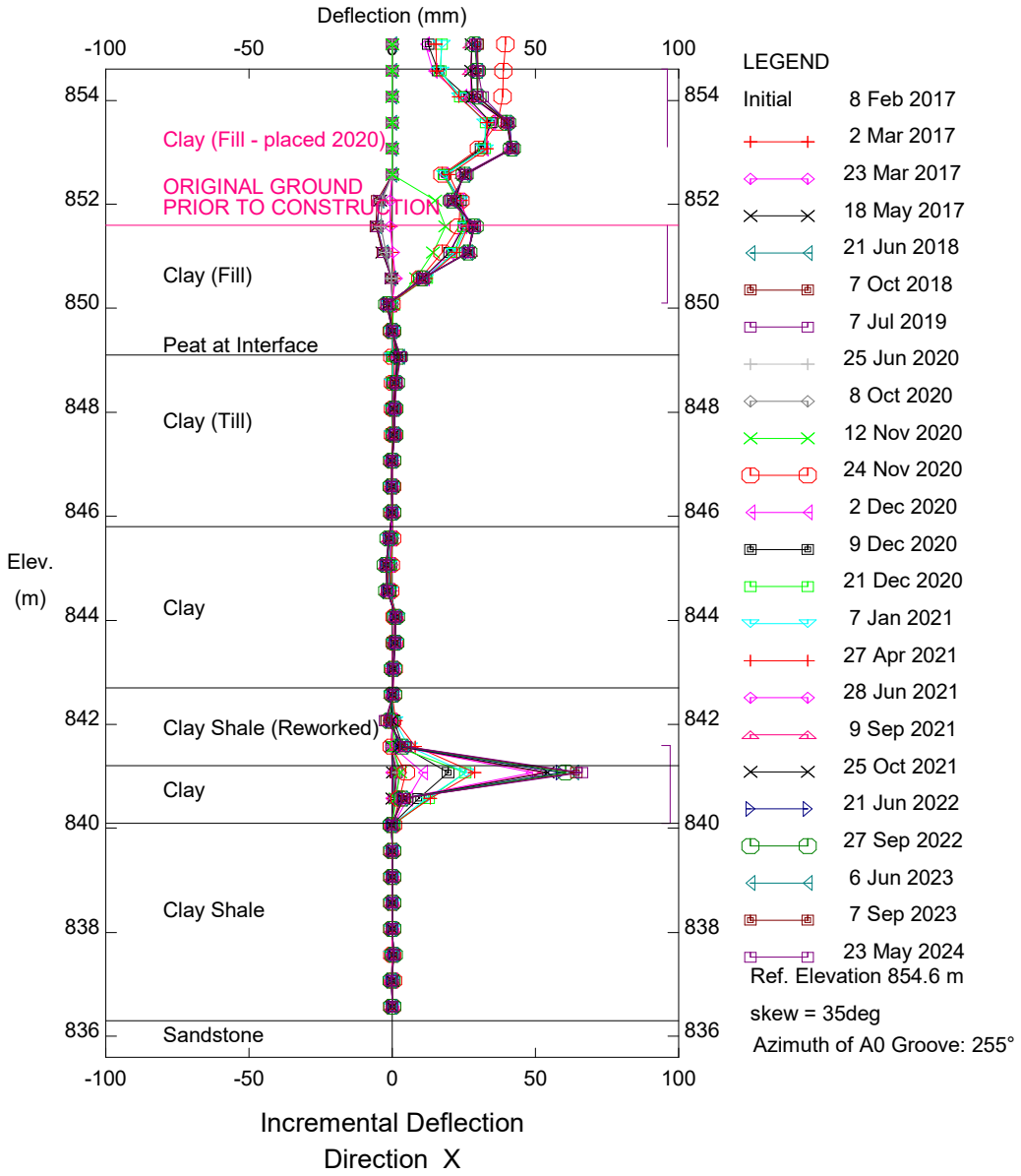


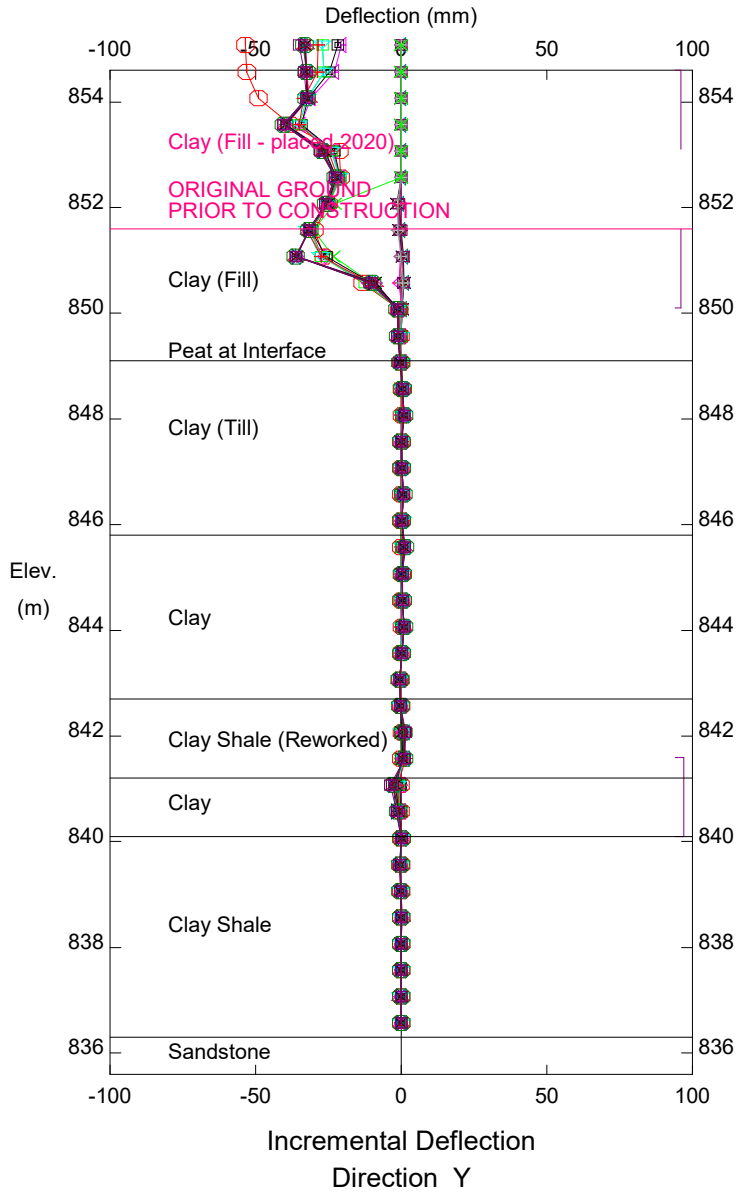


GP034; H40:38, Inclinometer SI17-3

GP034; H40:38, km 21.016 Slide 2.9 km South of Kakwa River Bri
Alberta Transportation

Klohn Crippen Berger - Edmonton





GP034; H40:38, Inclinometer SI17-3

GP034; H40:38, km 21.016 Slide 2.9 km South of Kakwa River Bri
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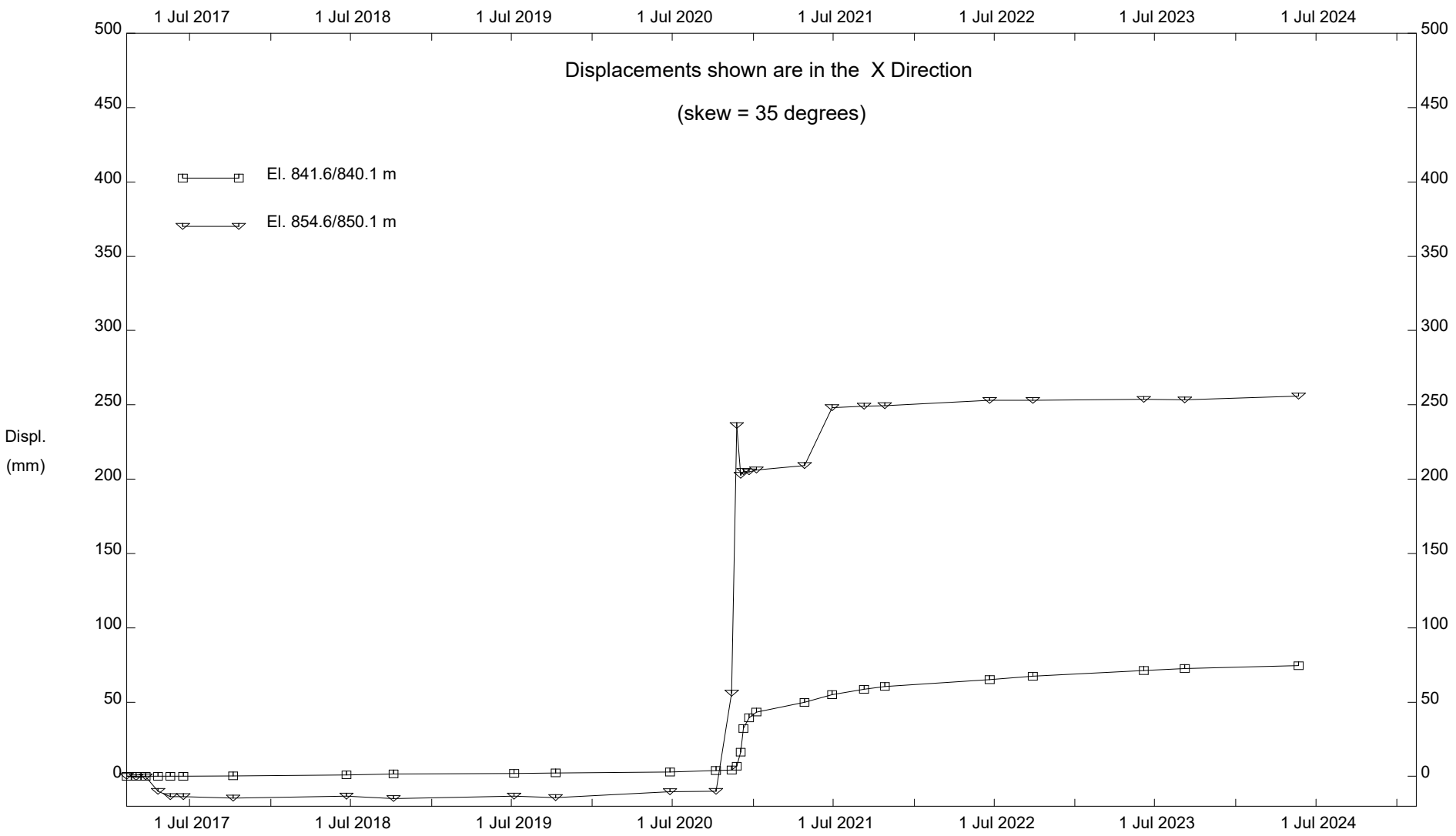

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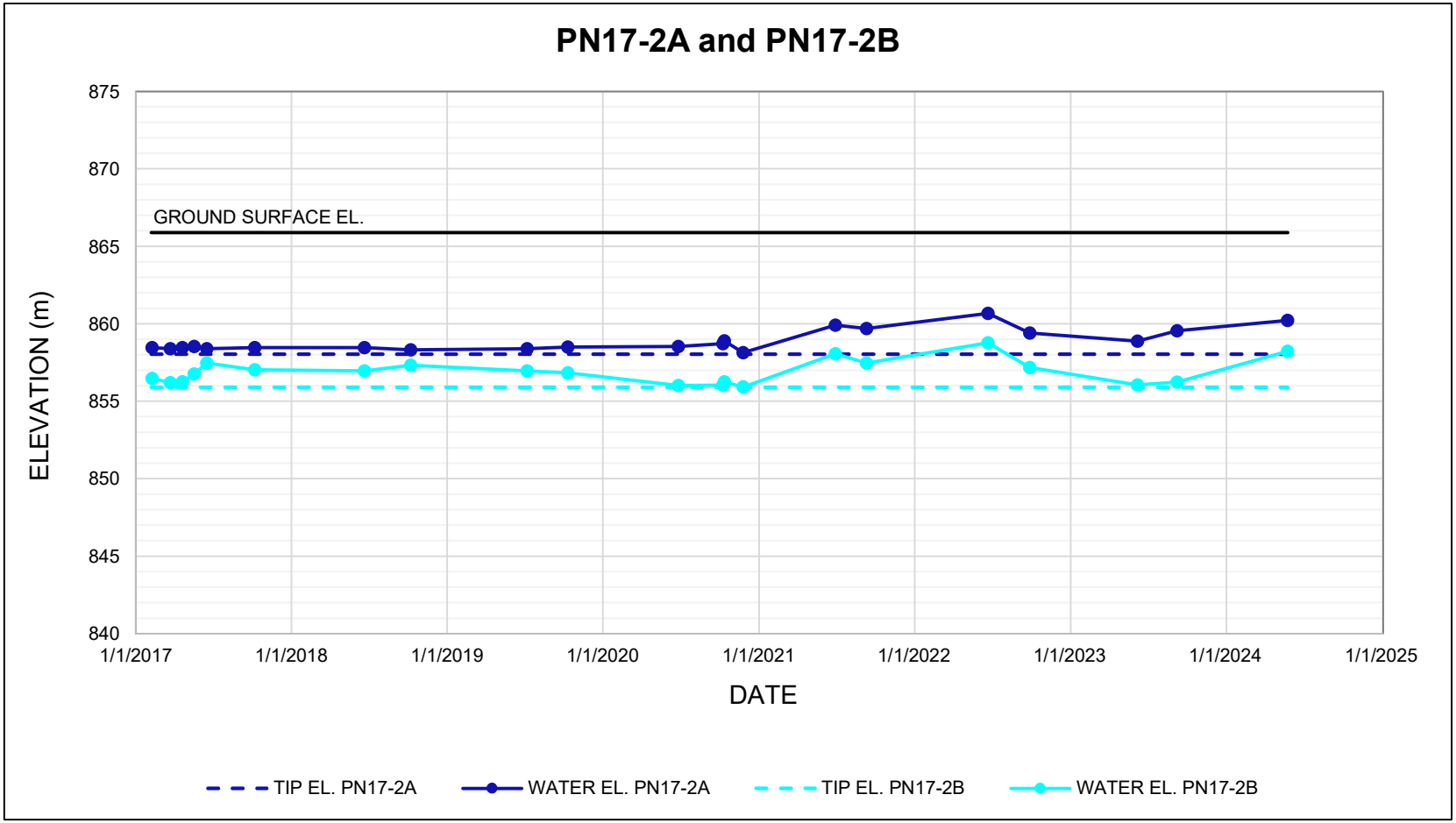


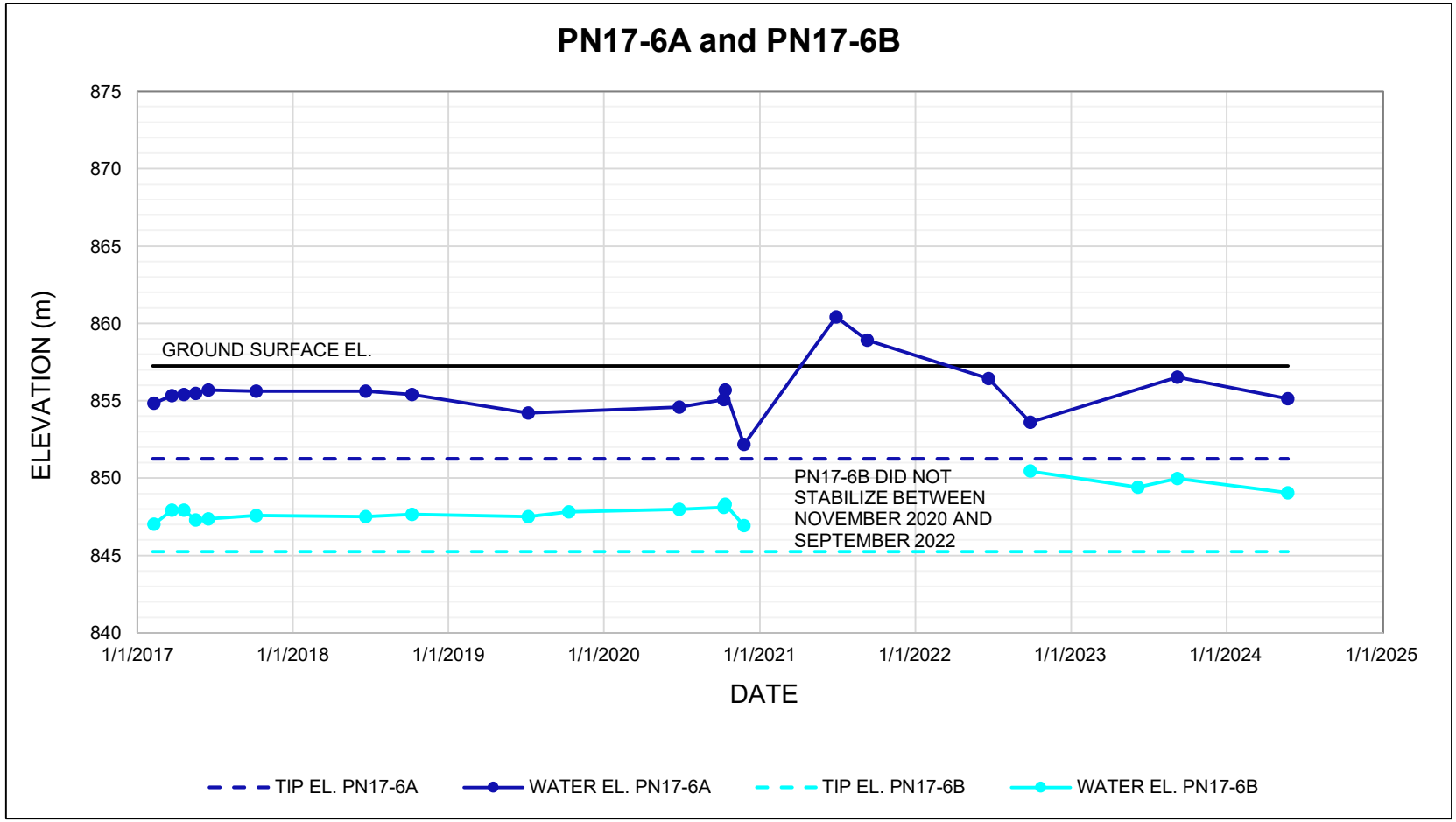
NOTES:
1. PIEZOMETER DATA OBTAINED BEFORE JUNE 28, 2021, PROVIDED TO KLOHN CRIPPEN BERGER LTD. BY ALBERTA TRANSPORTATION AND ECONOMIC CORRIDORS ON JUNE 25, 2021.
2. GROUND SURFACE ELEVATION MEASURED PRIOR TO CONSTRUCTION AND NEEDS TO BE UPDATED.

CLIENT
Alberta
Klohn Crippen Berger

PROJECT
PEACE REGION (GRANDE PRAIRIE DISTRICT - SOUTH)
GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE
Piezometer Data
GP034 - Slide 2.9 km S. of Kakwa River Bridge
Hwy 40:38, km 21.016

SCALE	PROJECT No.	FIG No.
--	A05116A01	



NOTES:
1. PIEZOMETER DATA OBTAINED BEFORE JUNE 28, 2021, PROVIDED TO KLOHN CRIPPEN BERGER LTD. BY ALBERTA TRANSPORTATION AND ECONOMIC CORRIDORS ON JUNE 25, 2021.
2. GROUND SURFACE ELEVATION MEASURED PRIOR TO CONSTRUCTION AND NEEDS TO BE UPDATED.

CLIENT
Alberta
Klohn Crippen Berger

PROJECT
PEACE REGION (GRANDE PRAIRIE DISTRICT - SOUTH)
GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE
Piezometer Data
GP034 - Slide 2.9 km S. of Kakwa River Bridge
Hwy 40:38, km 21.016

SCALE	PROJECT No.	FIG No.
--	A05116A01	