Klohn Crippen Berger

September 12, 2022

Alberta Transportation
4th Floor, Provincial Building
4920 51 Street
Red Deer, Alberta
T4N 6K8

Tony Penney, P.Eng.
Construction Engineer

Dear Mr. Penney:

CON0022160 Central Region GRMP Instrumentation Monitoring
Site C060; H597:02, km 11.299 Slide East of Blackfalds
Section C – 2022 Spring Readings

1 GENERAL

Two slope inclinometers (SIs) (SI17-C60-01 and SI17-C60-02) and four vibrating wire piezometers (VWPs) (VW42623, VW42624, VW42625, and VW42626) were read at the C060 site in the Central Region on July 27, 2022 by Mr. James Lyons, P.Eng., and Mr. Guerin White, 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 597:02, km 11.299, approximately 9 km east of Blackfalds, Alberta. A tributary creek of the Red Deer River is located at the toe of the slope. The approximate site coordinates are 5802987 N, 317570 E (UTM Zone 12, NAD 83). A site plan is presented in Figure 1.

The geohazard at the C060 site consists of a slide through the foundation of the highway embankment. The slide is located on the south side (eastbound lane) of Hwy 597:02. Issues at this site developed shortly after construction of the highway was completed in 1976. Previous remedial actions at this site include installation of horizontal drains in November 1983 to lower the groundwater table, construction of a toe berm in 1983 with a shear key, construction of a riprap toe berm sometime after 1992, installation of deep horizontal drains in February 2012, and removal of a dip in the highway surface in summer 2012.

In March 2017, KCB conducted a geotechnical site investigation at the C060 site. Drilling was completed by Mobile Augers and Research Ltd. The encountered stratigraphy was as follows: fill (sand overlying medium to high plastic silt and clay), overlying medium plastic silty clay till and/or bedrock (siltstone). It is unclear if the bedrock encountered during the investigation was in situ or rafted in the till. It also appears that organic materials were not stripped before fill placement. The

Klohn Crippen Berger Ltd.
109, 4208 97 St NW ▪ Edmonton AB T6E 5Z9▪ Canada
t 780.444.0706 ▪ www.klohn.com

encountered stratigraphy was consistent with the stratigraphy encountered during a November 2010 drilling investigation conducted by KCB.

1.1 Instrumentation

Instrumentation installation details are tabulated in Table 1.1. Instrument locations are shown in Figure 1. All instruments installed before 2010 are inoperable and are not presented on Figure 1. All instruments installed before November 2010 are inoperable and are not presented or discussed herein.

In November 2010, KCB installed one standpipe piezometer (SP) (SP10-01) and one SI (SI10-01) in boreholes located on the slope between Hwy 597:02 and the toe berm crest. SI10-01 and a replacement SI (SI12-01) installed in September 2012 were sheared by October 2011 and October 2012, respectively.

In March 2017, KCB installed two SIs (SI17-C60-01 and SI17-C60-02) and four VWPs (VW42623, VW42624, VW42625, and VW42626) to monitor depth of movement and groundwater conditions, respectively. SI17-C60-01, VW42623, and VW42625 were installed in a borehole (BH17-C60-01) located in the eastbound lane of Hwy 597:02 and are protected by a flush-mounted casing protector. SI17-C60-02, VW42624, and VW42626 were installed in a borehole (BH17-C60-02) located on the mid-slope bench and are protected by an above-ground casing protector.

The operable SIs were read using the same metric RST Digital MEMS Inclinometer System that has been used to read the SIs since they were re-initialized in 2017, when the SI equipment was changed. The SI data plots presented herein only include data for readings taken with the metric RST equipment that was used to re-initialize the SIs.

The VWPs were read using an RST VW2106 vibrating wire readout.

Table 1.1 Instrumentation Installation Details

Instrument ID	Instrument Type	Date Installed	UTM Coordinates[1] (m)		Ground Surface Elevation (m)	Stick Up (m)	Depth (mbgs[2])	Condition
			Northing	Easting				
~~SI10-01~~	~~SI~~	~~Nov. 18, 2010~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~1.1~~	~~31.2~~	~~Inoperable[3]~~
~~SI12-01~~	~~SI~~	~~Sep. 26, 2012~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~1.0~~	~~30.0~~	~~Inoperable[3]~~
SI17-C60-01	SI	Mar. 09, 2017	5802990	317571	883	-0.3	18.4	Operable
SI17-C60-02	SI	Mar. 10, 2017	5802940	317582	873	3.4	16.9	Operable
~~SP10-01~~	~~SP~~	~~Nov. 19, 2010~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~13.9~~	~~Inoperable~~
VW42623	VWP	Mar. 09, 2017	5802990	317571	883	N/A	6.0	Operable
VW42624	VWP	Mar. 10, 2017	5802940	317582	873	N/A	9.3	Operable
VW42625	VWP	Mar. 09, 2017	5802990	317571	883	N/A	13.0	Operable
VW42626	VWP	Mar. 10, 2017	5802940	317582	873	N/A	14.9	Operable

Notes:
[1] Coordinates and ground surfaces elevations for the instruments installed in 2017 were obtained with a handheld GPS during installation.
[2] Meters below ground surface (mbgs).
[3] SI10-01 and SI12-02 have sheared at an approximate depth of 16 m below ground surface.

2 INTERPRETATION

2.1 General

For 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, where applicable, in the X-direction (i.e., the direction of maximum movement obtained at a skew angle from the A0-grooves). SI17-C60-02 has a skew angle of 19^{o}, measured clockwise from the direction of the A0-grooves.

For the VWPs, the recorded porewater pressure were converted to an equivalent water/piezometric elevation and plotted relative to ground surface elevation and each instruments tip elevation.

The SI and piezometer 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.

2.2 Zones of Movement

Prior to being sheared, movement was being recorded in SI10-01 at an approximate depth of 16 m below ground surface (El. 866 m) at an approximate rate of 75 mm/year. SI12-01 was only read once before shearing, but it also sheared at this depth.

Movement is being recorded in SI17-C60-01 at approximate depths of 2.3 m and 14.3 m below ground surface (El. 880.7 m and El. 868.7 m, respectively), and in SI17-C60-02 at an approximate depth of 11.0 m below ground surface (El. 862.0 m).

Table 2.1 Slope Inclinometer Reading Summary

Instrument ID	Date				Ground Surface Elevation (m)	Depth of Movement (mbgs[1])	Direction of Movement, Skew Angle[2]	Movement (mm)				Rate of Movement (mm/year)		
	Initialized (Re-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
								Before Re-Initialization	After Re-Initialization	Total				
SI17-C60-01	Mar. 30,2017 (Sep. 7, 2017)[3]	Sep. 07, 2017	Jun. 14, 2021	Jun. 27, 2022	883	2.3	A-Direction	2.8	N/A – no discernible movement recorded since re-initialized[2]		2.8	N/A – no discernible movement recorded since re-initialized[2]		
		Jun. 14, 2021				14.3	A-Direction	1.8	14.4	16.2	2.5	15.7	2.4	1.4
SI17-C60-02	Mar. 30,2017 (Jul. 7, 2017)[3]	Jun. 14, 2021	Jun. 14, 2021	Jun. 27, 2022	873	11.0	X-Direction, 19°	N/A – no discernible movement recorded prior to re-initialized[2]	6.4	6.4	0.3	13.3	0.3	-0.8

Notes:
[1] Meters below ground surface (mbgs).
[2] Skew angle of X-direction measured clockwise from the A-direction.
[3] SI17-C60-01 and SI17-C60-02 were re-initialized in July and September 2017, respectively, when the SI equipment was changed.

Table 2.2 Vibrating Wire Piezometer Reading Summary

Borehole ID	Instrument ID / Serial No.	Date			Ground Surface Elevation (m)	Tip 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)
BH17-C60-01	VW42623	Mar. 09, 2017	Sep. 9, 2020	Jun. 27, 2022	883	6.0	2.9	2.1	0.8
	VW42625	Mar. 09, 2017	Sep. 9, 2020	Jun. 27, 2022	883	13.0	8.0	8.0	0.0
BH17-C60-02	VW42624	Mar. 10, 2017	Sep. 9, 2020	Jun. 27, 2022	873	9.3	2.8	2.3	0.5
	VW42626	Mar. 10, 2017	Sep. 9, 2020	Jun. 27, 2022	873	14.9	8.4	8.8	0.4

Notes:
[1] Meters below ground surface (mbgs).

2.3 Interpretation of Monitoring Results

Based on the stratigraphy encountered during the 2010 and 2017 drilling investigations,

- the movement recorded in SI10-01 and SI12-01 (mid-slope) appeared to have occurred at the interface between clay and rafted bedrock.
- the upper and lower zones of movement recorded in SI17-C60-01 (through pavement surface) appear to be occurring in the embankment fill and at the interface between clay and bedrock. The magnitude and rate of movement being recorded in SI17-C60-01 tends to fluctuate, especially near the bottom of the casing. Based on the stratigraphy encountered during the 2010 drilling investigation, we suspect SI17-C60-01 was terminated in rafted bedrock and the toe of the SI could be moving. Although SI17-C60-01 extends below the suspected failure surface, it may not extend deep enough and the recorded fluctuations, especially near the bottom of the casing, are likely caused by movement of the rafted bedrock in the underlying till.
- the movement recorded in SI17-C60-02 (through toe berm crest) appears to be occurring near the interface between the fill and underlying foundation materials.

The rate of movement recorded in SI17-C60-01 and SI17-C60-02 has generally been slow to very slow (less than 7 mm/year and 1 mm/year, respectively), except between May and September 2020 when the rate of movement increased to approximately 16 mm/year and 14 mm/year, respectively, likely due to a wetter-than-average summer.

Some minor movement has been recorded in the B-direction of both SIs, which has been attributed to poor grout backfill and casing settlement, respectively.

Water levels recorded in VW42625, VW42624, and VW42626 (lower piezometer below highway, and piezometers below toe berm crest) have been relatively steady (±0.5 m) since they instruments were installed in 2017, excluding higher-than-typical water levels recorded in September 2020 after a wetter-than-average summer. Water levels recorded in VW42623 (upper piezometer below highway) appear to fluctuate seasonally with the spring readings being lower than fall readings.

Previous assessments of the slope failure and the current instrumentation data suggests that movement is likely in response to periods of heavy or prolonged rainfall, high groundwater conditions, creek erosion at the toe of the slope, and the presence of a rafted bedrock or a weak bedrock layer below the highway. KCB understands that historic rural road construction practices in Alberta often included placing poor quality and/or uncompacted fill below the slopes of the embankment and did not include foundation preparation. As a result, there is a relatively high likelihood that the embankment slopes are weaker due to lack of compaction, and more susceptible to failure due to weak layers (e.g., soft and/or organic soils) left in the foundation.

Current instrumentation data indicates movement is occurring below the crest of the highway embankment and below the crest of the toe berm. As the upper portion of the slide below the

highway continues to move, load will be placed on the lower portion of the slide below the toe berm causing movement of the toe and slope.

3 RECOMMENDATIONS

3.1 Future Work

All operable instruments should continue to be read once per year (spring).

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

Remedial options that have been discussed between KCB and AT include:

- Extending the corrugated-steel-pipe (CSP) slope drain to discharge surface water runoff into the creek and not the toe berm surface;
- Installing a drainage system on the west abutment to intercept any groundwater that may be entering the embankment from the original valley slope;
- Enlarging the toe berm and passing creek flows with a culvert;
- Placing additional riprap at the toe of the slope; and
- Installing a pile wall or a double row of pile walls at the head of the slide.

Currently, unless movements accelerate and impact the highway surface, AT has no plans of repairing this site. Since SI17-C60-01 is recording movement below the highway surface, AT should inspect the road surface regularly.

Infiltration due to periods of heavy or prolonged rainfall or rapid snowmelt could cause an increase in movement rate and impact the highway surface.

3.2 Instrument Repairs and Maintenance

The flush-mounted casing protector cap at BH17-C60-01 was replaced during the spring 2022 readings. No additional instrument repairs or maintenance is required.

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 (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.

September 13 2022
I.D. # 58463

Chris Gräpel, M.Eng., P.Eng.
Senior Civil Engineer, Associate

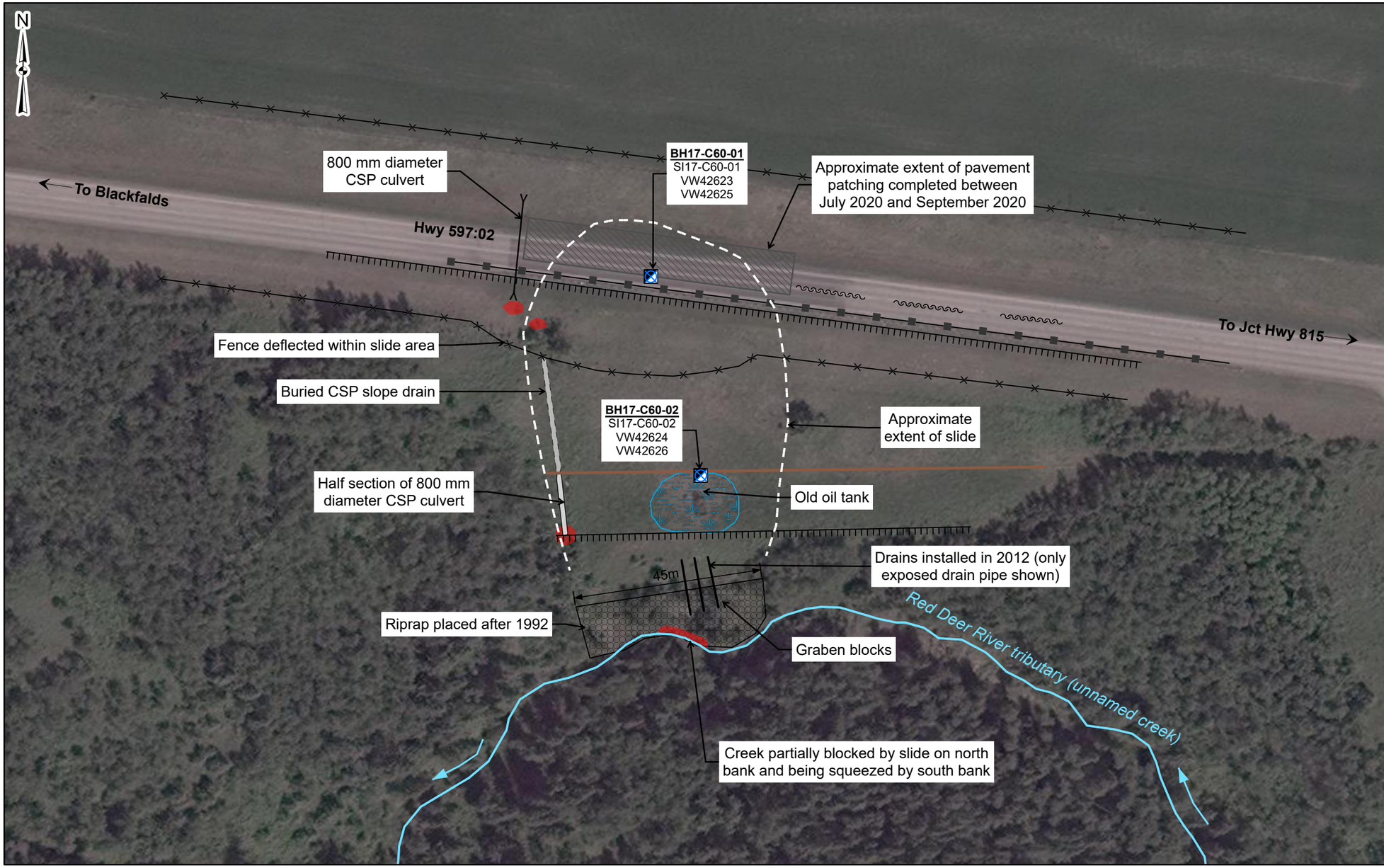
James Lyons, P.Eng.
Civil Engineer

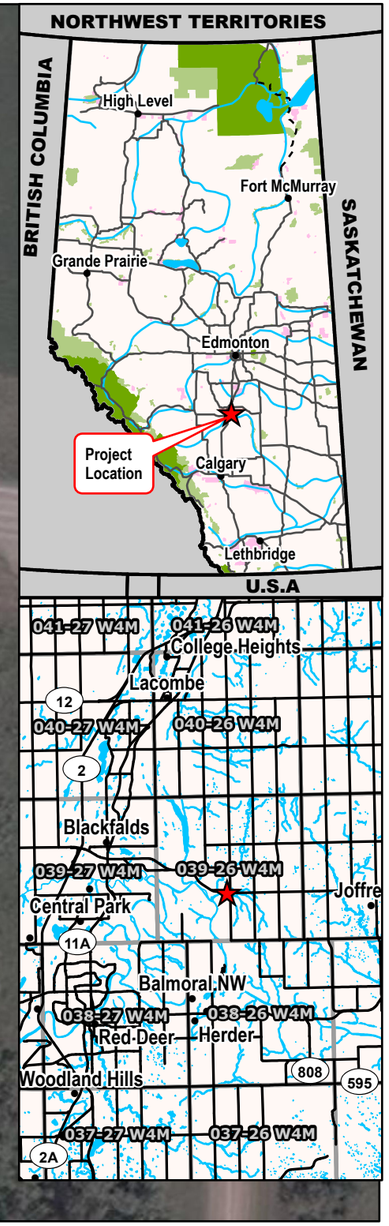
JL:bb

PERMIT TO PRACTICE
KLOHN CRIPPEN BERGER LTD.
RM SIGNATURE:
RM APEGA ID #: 187607
DATE: 13 Sep. 2022
PERMIT NUMBER: P009196
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

ATTACHMENTS
Figure
Appendix I Instrumentation Plots

FIGURE





0 50 Meters

Legend

- Vibrating Wire Piezometer (VW)
- Slope Inclinometer (SI)
- Fence
- Guardrail
- Culvert
- Crack
- Top of Slope
- Toe Berm Upslope Crest
- Creek
- Flow Direction
- Wet Area
- Erosion
- Riprap
- Pavement Patch

NOTES:
1. HORIZONTAL DATUM: NAD83
2. GRID ZONE: UTM ZONE 12N
3. IMAGE SOURCE: RED DEER COUNTY
4. LOCATION OF INSTRUMENTS IS APPROXIMATE (NOT SURVEYED)

CLIENT: Alberta

Klohn Crippen Berger

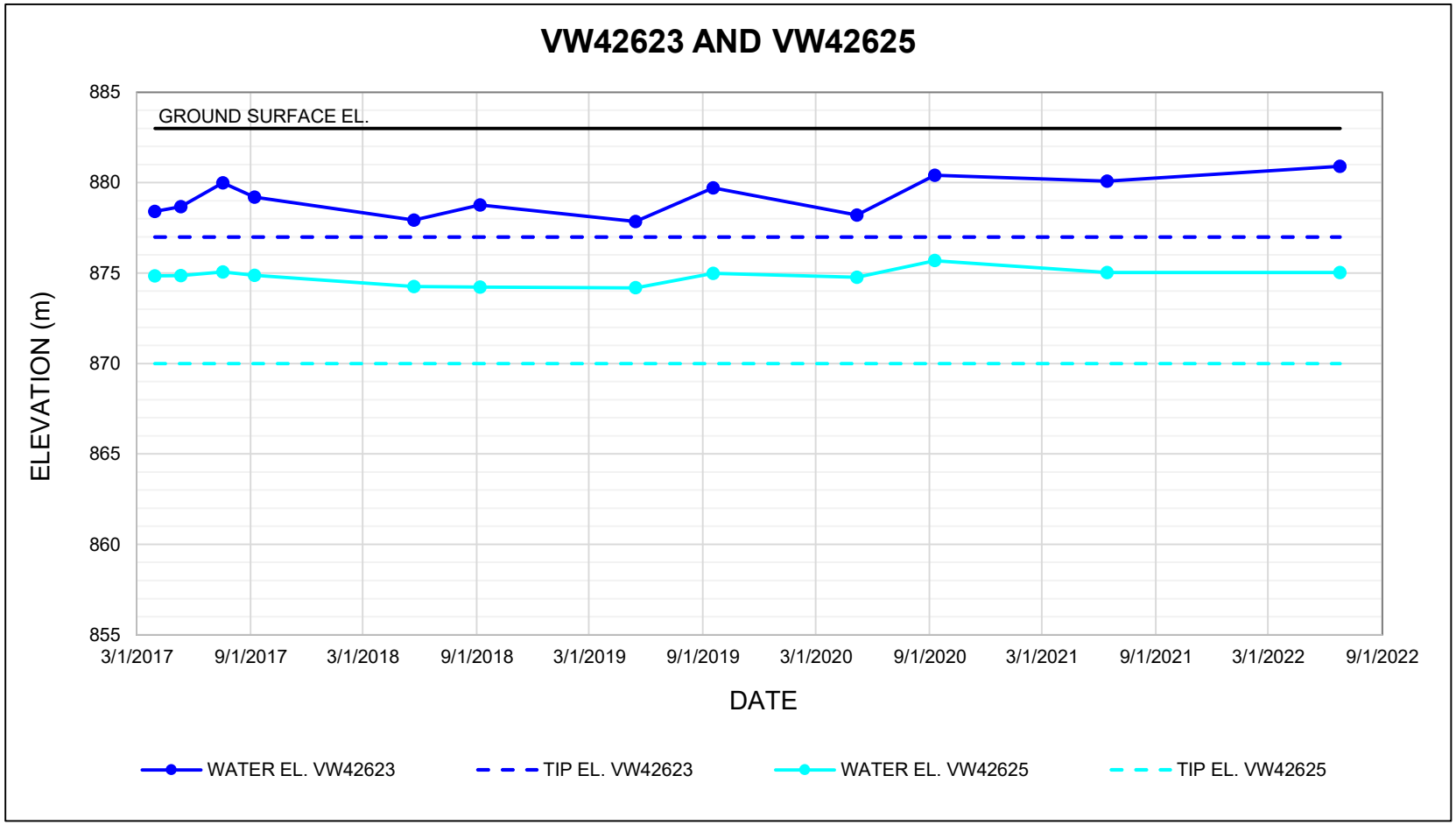
PROJECT: CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE: Site Plan
C060 - Slide East of Blackfalds
Hwy 597:02, km 11.299

SCALE	PROJECT No.	FIG No.
1:1,000	A05116A02	1

APPENDIX I

Instrumentation Plots



NOTES:
1. GROUND SURFACE ELEVATION OBTAINED WITH A HANDHELD GPS DURING INSTALLATION.

CLIENT
Alberta
Klohn Crippen Berger

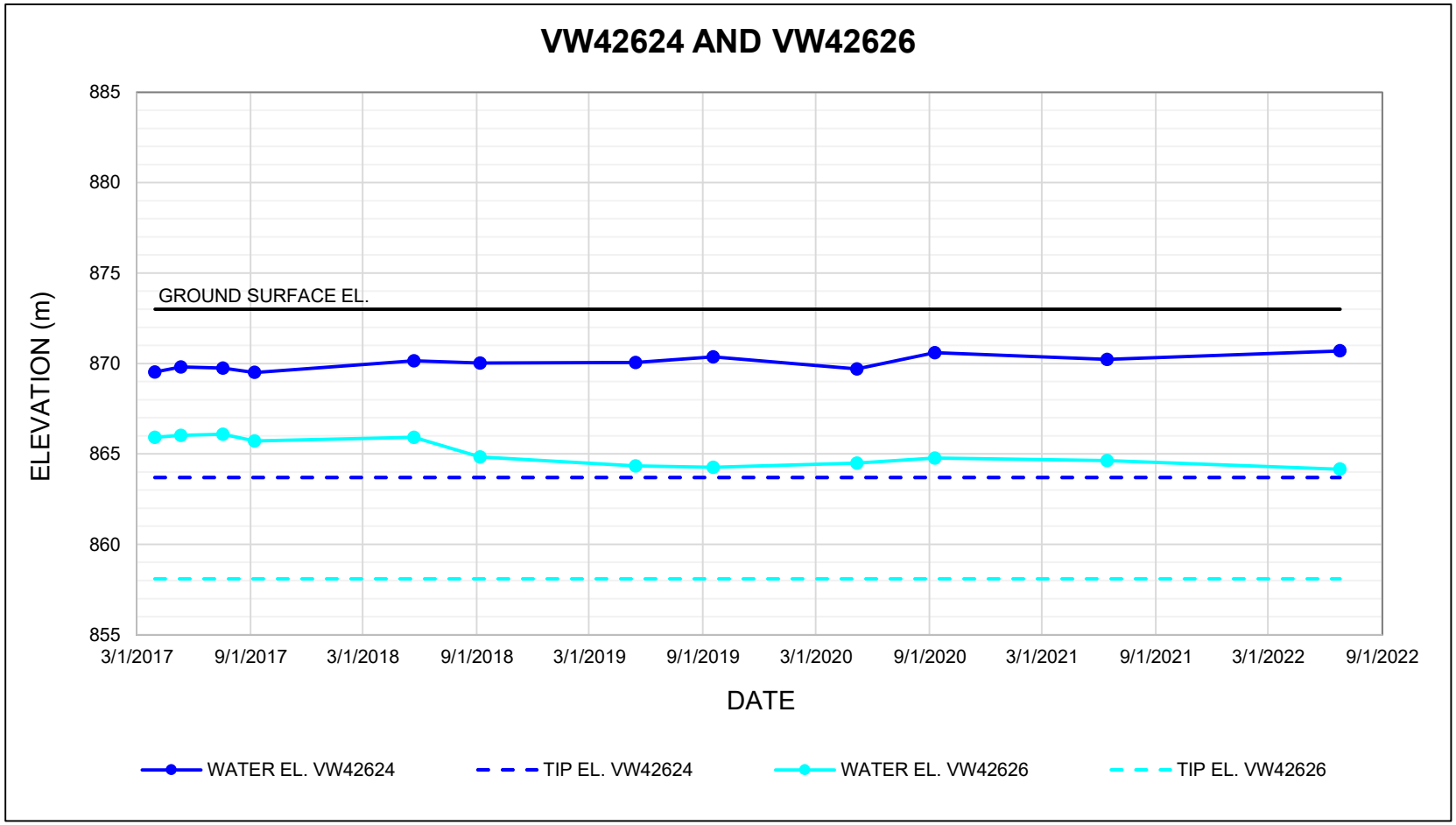
PROJECT
CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE
Piezometer Data
C060 - Slide East of Blackfalds
Hwy 597:02, km 11.299

SCALE

PROJECT No. A05116A02

FIG No.



NOTES:
1. GROUND SURFACE ELEVATION OBTAINED WITH A HANDHELD GPS DURING INSTALLATION.

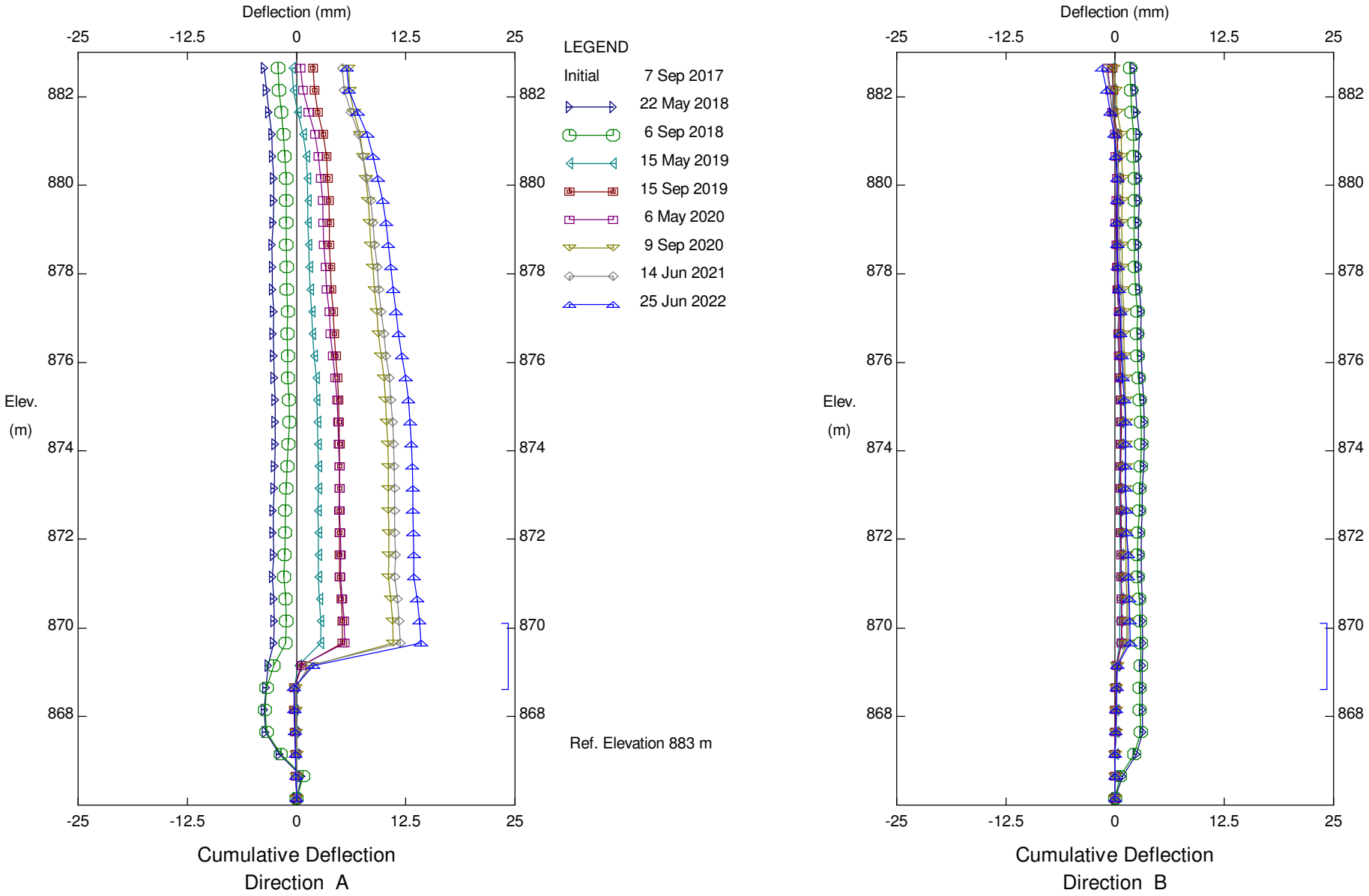
CLIENT
Alberta
Klohn Crippen Berger

PROJECT
CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE
Piezometer Data
C060 - Slide East of Blackfalds
Hwy 597:02, km 11.299

SCALE	PROJECT No.	FIG No.
	A05116A02	

Klohn Crippen Berger - Calgary

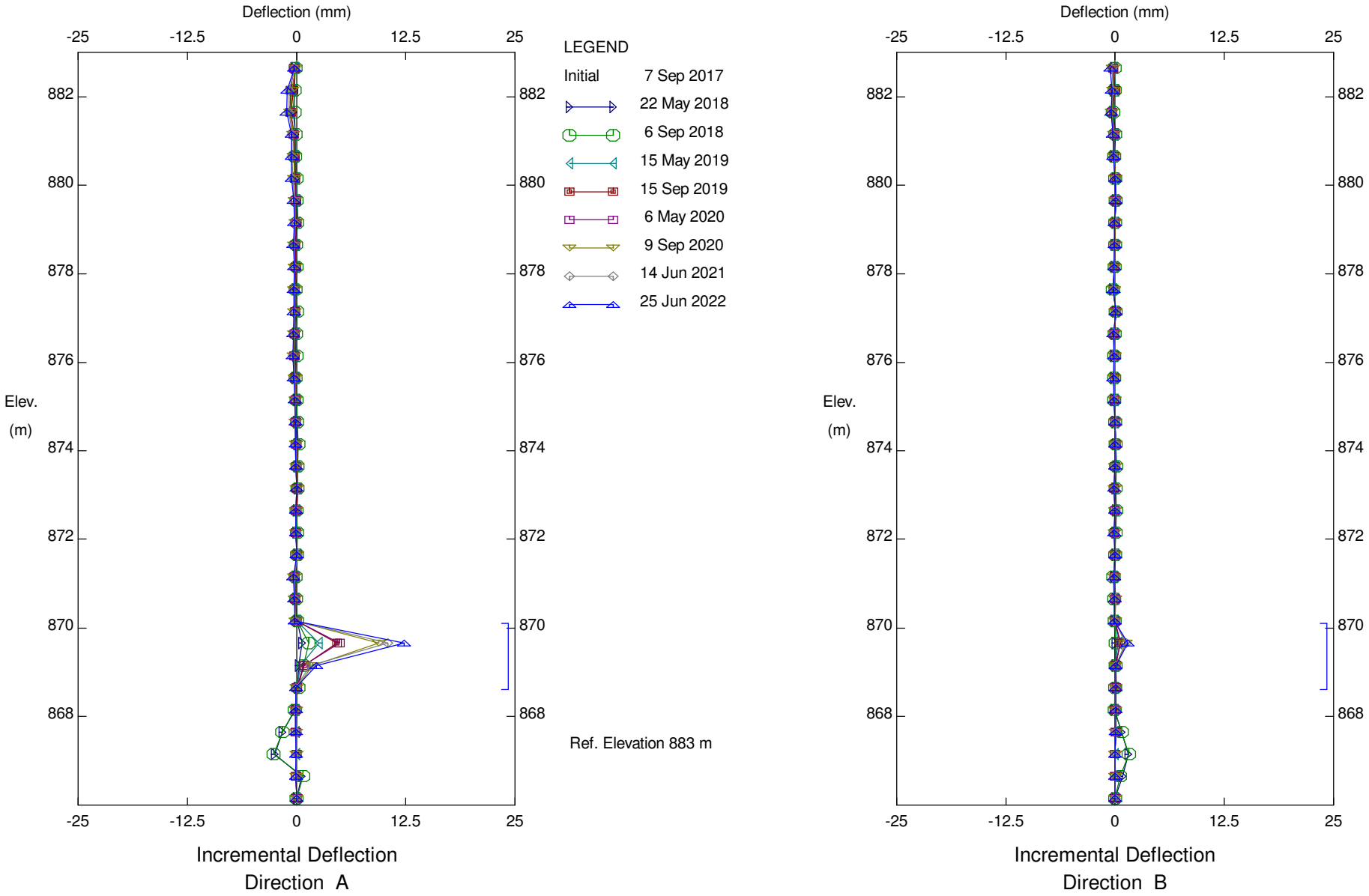


C060; H597:02, Slide East of Blackfalds, Inclinometer SI17-C60-01

Alberta Transportation

Instrument re-initialized in September 2017 when the SI equipment was changed.

Klohn Crippen Berger - Calgary

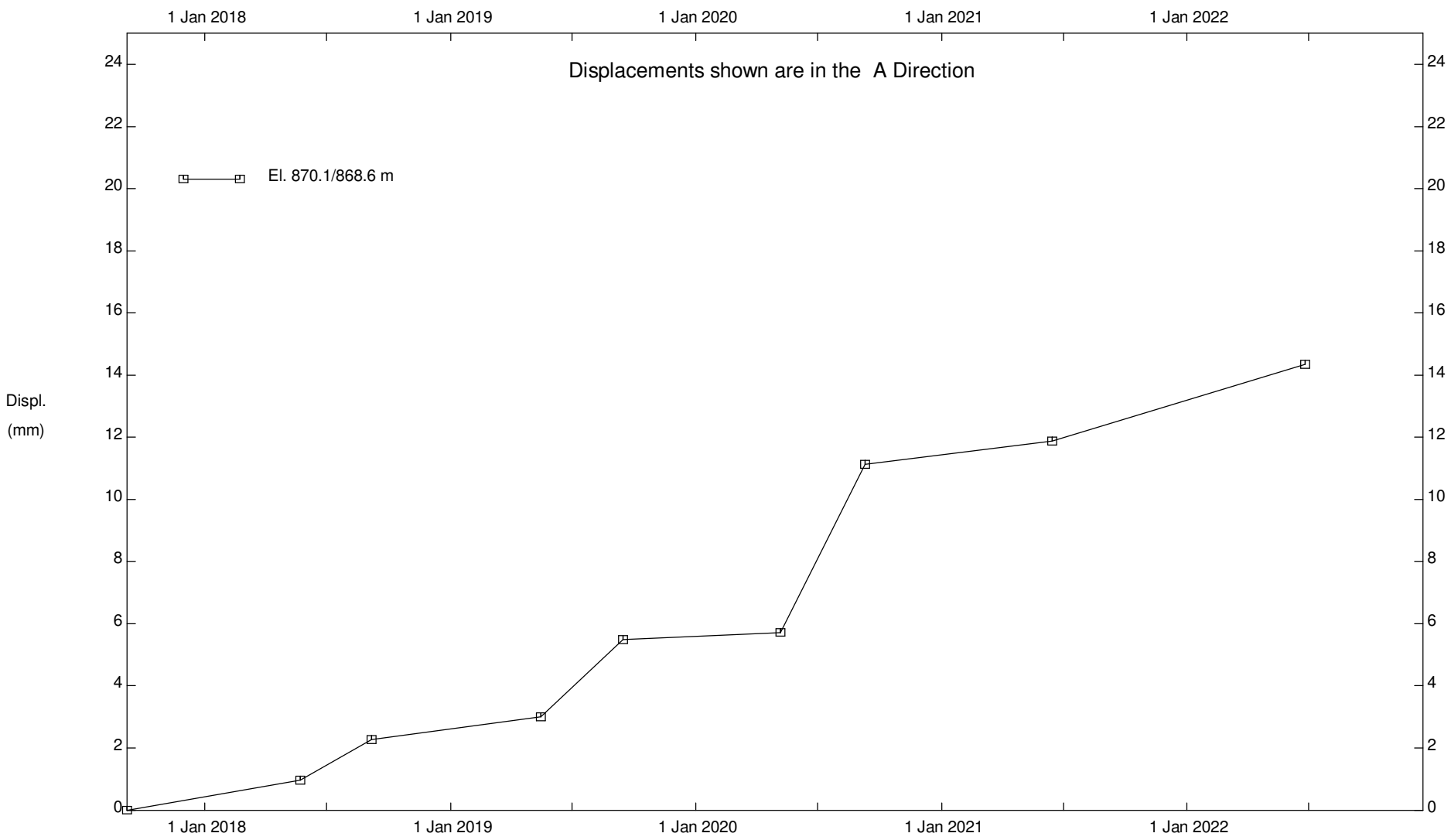


C060; H597:02, Slide East of Blackfalds, Inclinometer SI17-C60-01

Alberta Transportation

Instrument re-initialized in September 2017 when the SI equipment was changed.

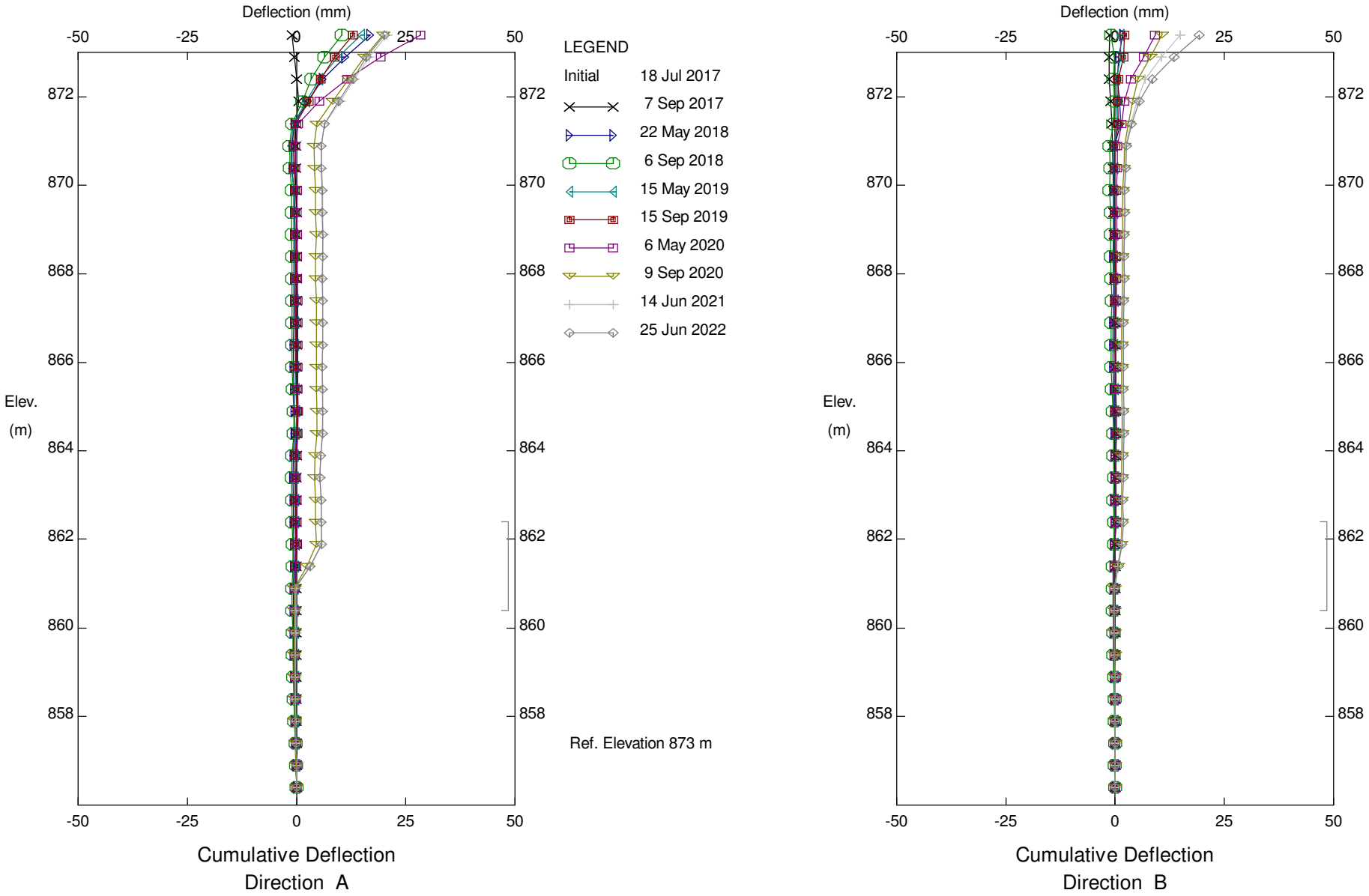
Klohn Crippen Berger - Calgary



C060; H597:02, Slide East of Blackfalds, Inclinometer SI17-C60-01

Alberta Transportation

Klohn Crippen Berger - Calgary

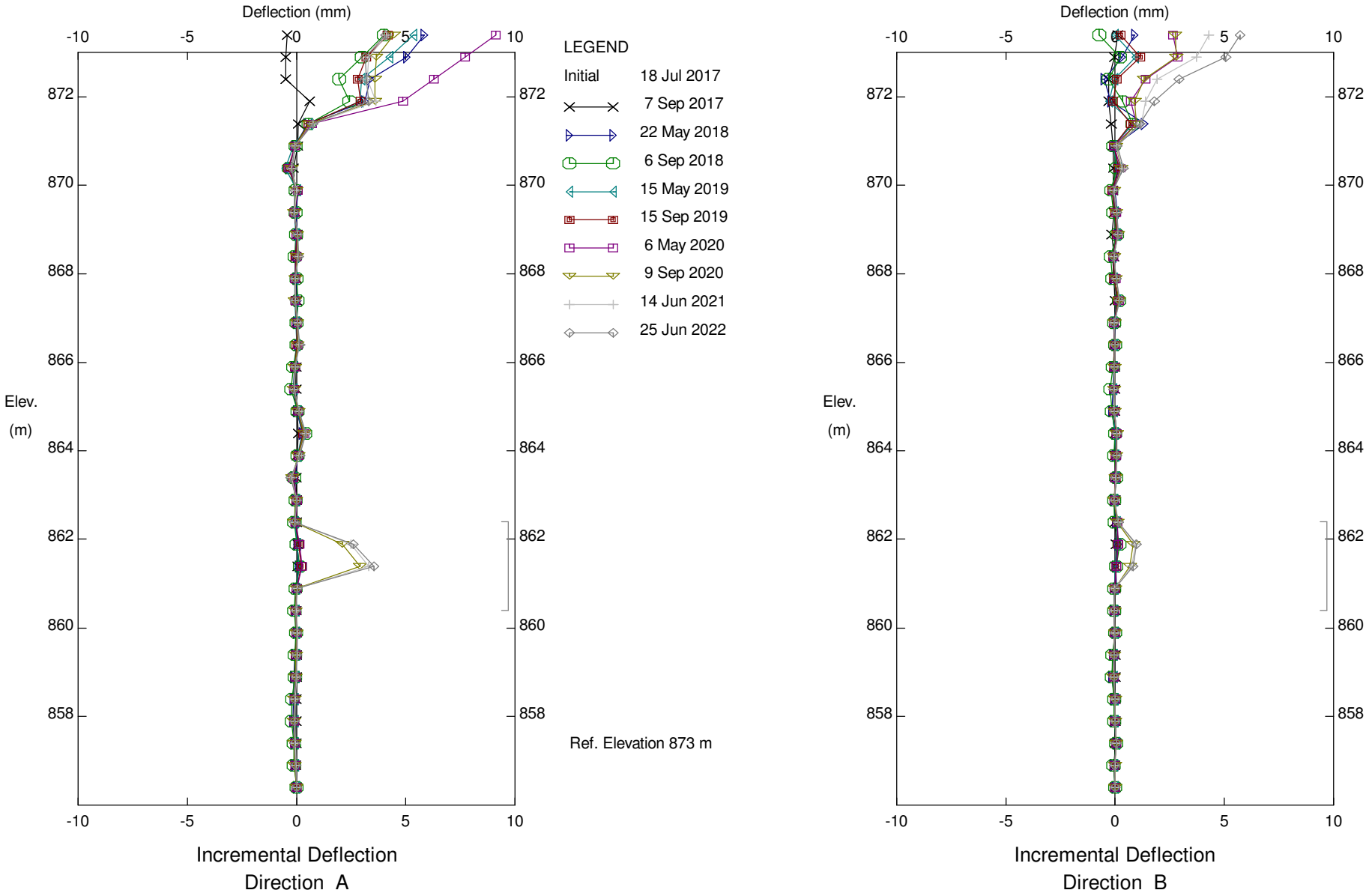


C060; H597:02, Slide East of Blackfalds, Inclinometer SI17-C60-02

Alberta Transportation

Instrument re-initialized in July 2017 when the SI equipment was changed.

Klohn Crippen Berger - Calgary

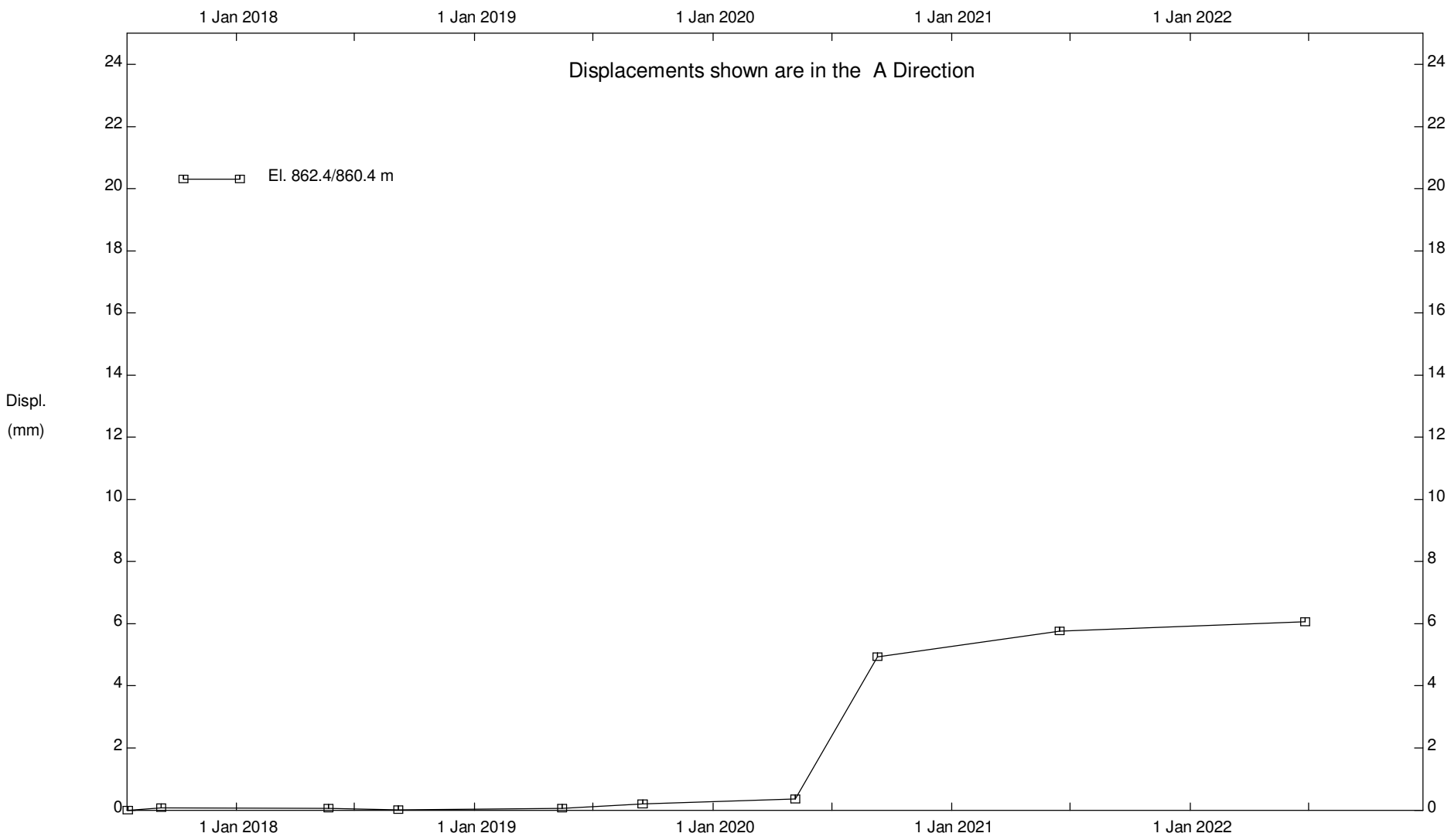


C060; H597:02, Slide East of Blackfalds, Inclinometer SI17-C60-02

Alberta Transportation

Instrument re-initialized in July 2017 when the SI equipment was changed.

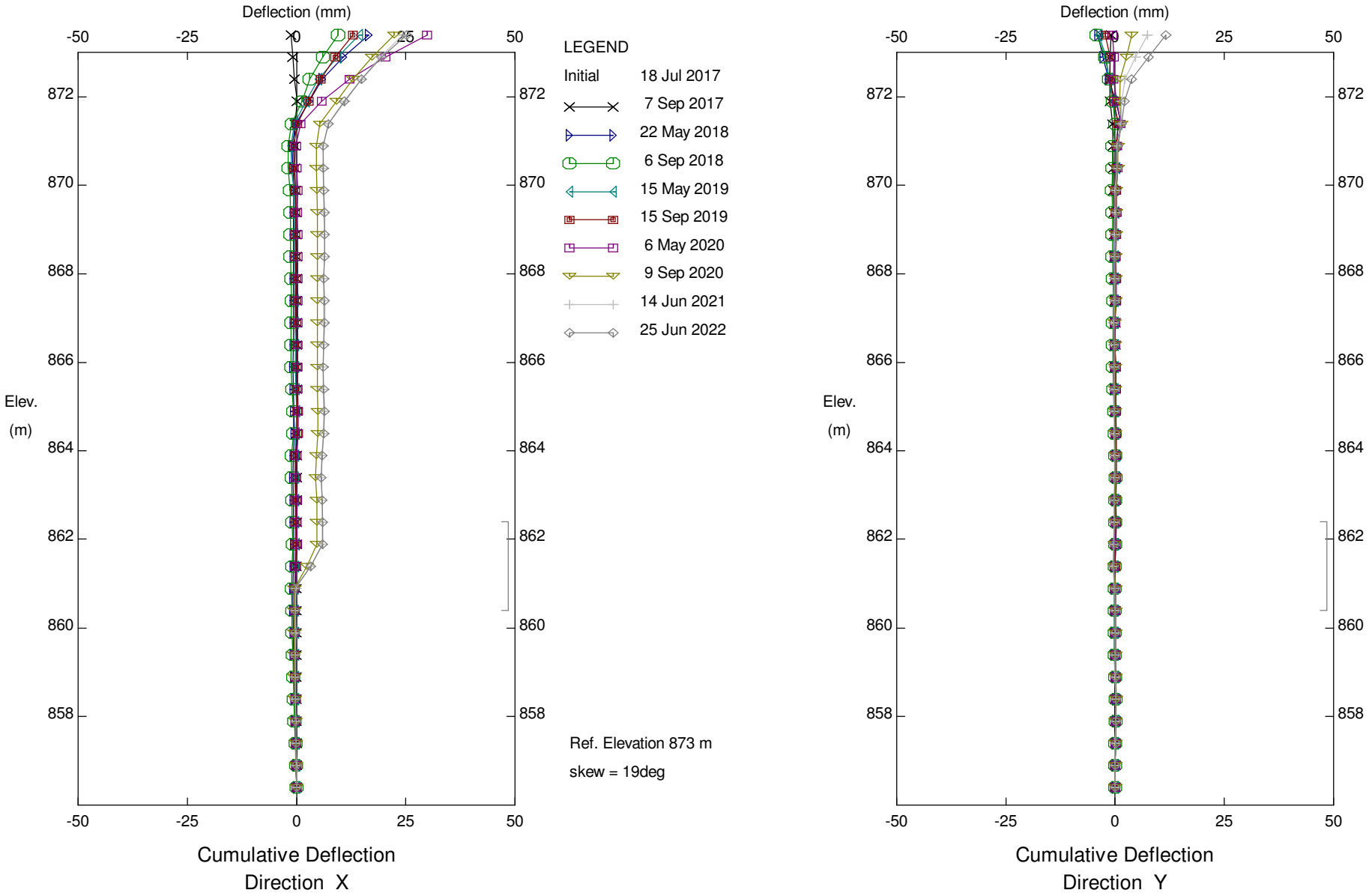
Klohn Crippen Berger - Calgary



C060; H597:02, Slide East of Blackfalds, Inclinometer SI17-C60-02

Alberta Transportation

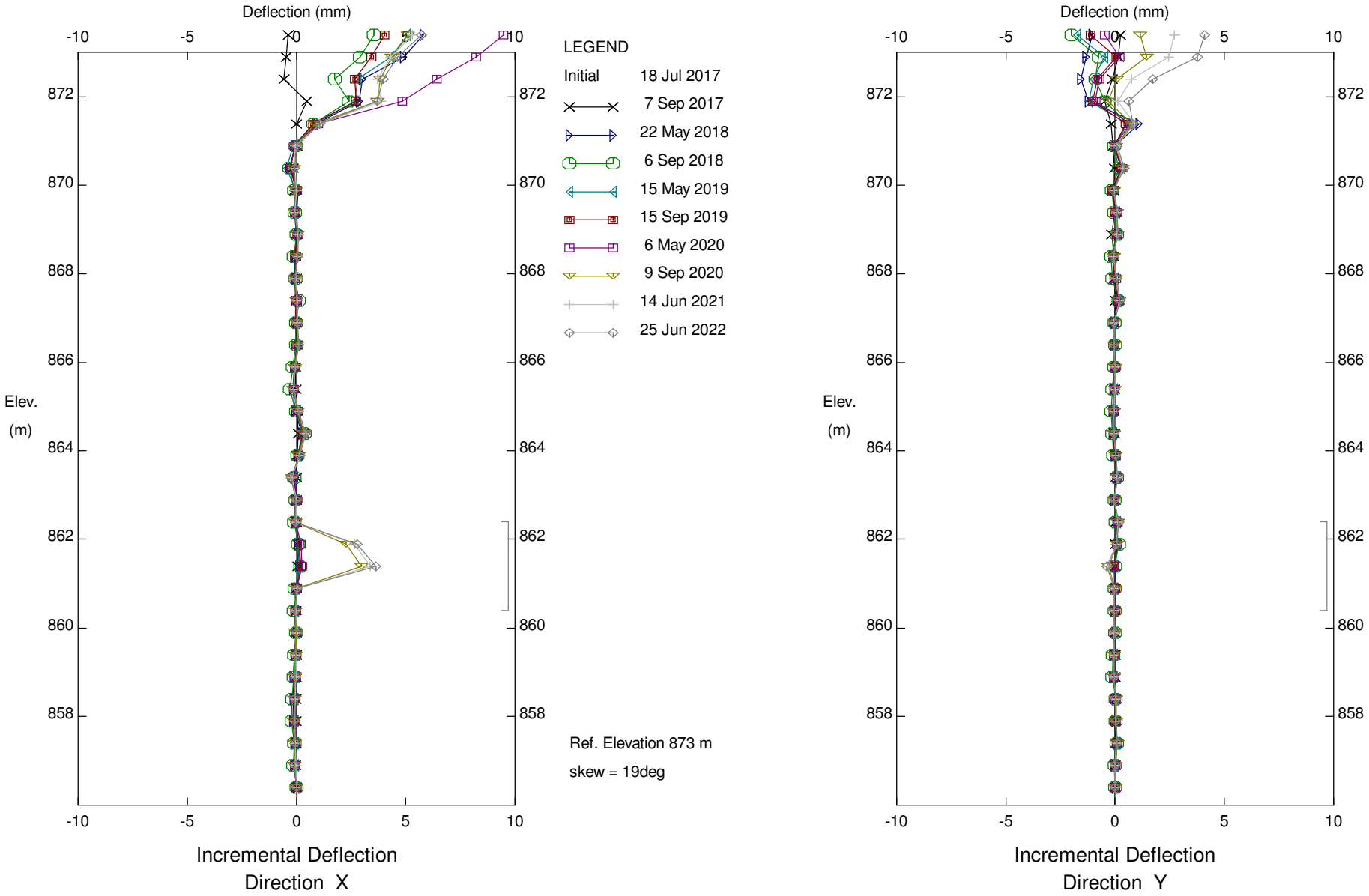
Klohn Crippen Berger - Calgary



C060; H597:02, Slide East of Blackfalds, Inclinometer SI17-C60-02

Alberta Transportation

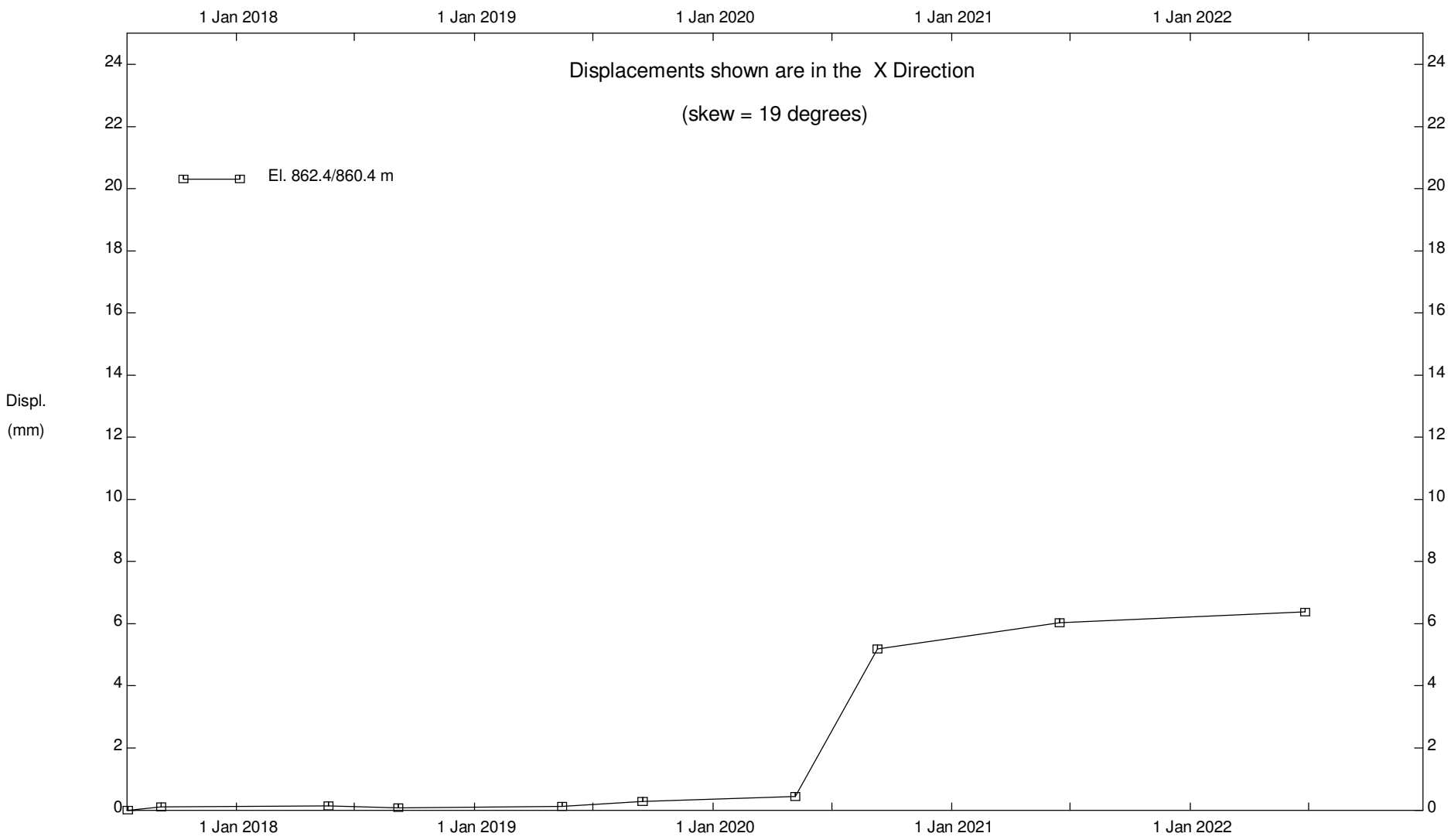
Klohn Crippen Berger - Calgary



C060; H597:02, Slide East of Blackfalds, Inclinometer SI17-C60-02

Alberta Transportation

Klohn Crippen Berger - Calgary



C060; H597:02, Slide East of Blackfalds, Inclinometer SI17-C60-02

Alberta Transportation