

November 29, 2022

Alberta Transportation  
4<sup>th</sup> Floor, Provincial Building  
4920 – 51<sup>st</sup> Street  
Red Deer, Alberta  
T4N 6K8

**Tony Penney, P.Eng.**  
**Construction Engineer**

Dear Mr. Penney:

**CON0022160 Central Region GRMP Instrumentation Monitoring**  
**Site C067; H21:14, km 12.988 Kneehill Creek Slide**  
**Section C – 2022 Fall Readings**

## **1 GENERAL**

Six slope inclinometers (SIs) (SI16-02, SI17-C67-01 through SI17-C67-05) and one standpipe piezometer (SP) (SP16-01) were read at the C067 site in the Central Region on September 9, 2022 by Ms. Katrina Cereno of Klohn Crippen Berger Ltd. (KCB). SI17-C67-03 through SI17-C67-05 were re-read by Mr. Guerin White, E.I.T. of KCB on October 7, 2022. These instruments were read as part of the Central Region Geohazard Risk Management Program (GRMP). The site is located on Hwy 21:14, km 12.988, approximately 1 km south of the Hwy 21:13 and Hwy 575:02/04 intersection, and 5 km west of Carbon, Alberta. The approximate site coordinates are 5707671 N, 344892 E (UTM Zone 12, NAD 83). A site plan is presented in Figure 1.

The geohazard at the C067 site consists of two slope failures along the west slope (southbound lane) of Hwy 21:14. The two slope failures are referred to as Site A, which is at the north extent of the site, and Site B, which is at the south extent of the site. In April 2017, a 15-m deep, 80-m long H-pile wall (H360X132) consisting of 112 piles was installed at Site A, and a 16-m deep, 42.5-m long H-pile wall (H360X132) consisting of 60 piles were installed at Site B. The location and extents of the H-pile walls are depicted in Figure 1. Additional remedial actions include regular pavement patching.

In February and November 2016, KCB conducted two geotechnical site investigations at the C067 site to support design and construction work. Drilling in February and November 2016 was completed by Core Drilling Corp. and Mayfield Drilling, respectively. The encountered stratigraphy was as follows: fill (sand and gravel), overlying medium to high plastic clay till and silt.

## 1.1 Instrumentation

Instrumentation installation details are tabulated in Table 1.1. Instrument locations are shown in Figure 1.

In 2016, KCB installed one SI (SI16-02) and one SP (SP16-03) at Site A, and one SI (SI16-01) and two SPs (SP16-01 and SP16-02) at Site B to monitor depth of movement and groundwater conditions, respectively. The instruments were installed on the west shoulder (southbound lane) of Hwy 21:13 between the guardrail and H-pile walls. By May 2019, SI16-01 (sheared), SP16-02, and SP16-03 were inoperable.

In April 2017, five SIs (SI17-C67-01 through SI17-C67-05) were installed to monitor deflection of the H-pile walls. SI17-C67-01 and SI17-C67-02 were installed at Site A, and SI17-C67-03 through SI17-C67-05 were installed at Site B. Each SI was installed in the H-pile wall, in a rectangular opening created by tack-welding an L-shaped bracket (L102X102X6.4) to the web and flange of an H-pile. The space between the SI casing and rectangular opening was backfilled with sand.

All operable 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 they were re-initialized in July 2017, when the SI equipment was changed.

The operable standpipe was read using an RST Water Level Meter.

**Table 1.1 Instrumentation Installation Details**

Instrument ID	Instrument Type	Site	Date Installed	UTM Coordinates <sup>1</sup> (m)		Ground Surface Elevation <sup>1</sup> (m)	Stick Up (m)	Depth (mbgs <sup>2</sup> )	Condition
				Northing	Easting				
<del>SI16-01</del>	<del>SI</del>	<del>B</del>	<del>Feb. 9, 2016</del>	<del>5707640</del>	<del>344910</del>	<del>Unknown</del>	<del>1.0</del>	<del>15.2</del>	<del>Inoperable<sup>3</sup></del>
SI16-02	SI	A	Nov. 8, 2016	5708070	344700	Unknown	0.7	15.3	Operable
SI17-C67-01	SI	A	Apr. 27, 2017	5708082	344703	830.0	1.1	14.2	Operable
SI17-C67-02	SI	A	Apr. 27, 2017	5708064	344706	831.0	1.1	13.3	Operable
SI17-C67-03	SI	B	Apr. 27, 2017	5707651	344904	808.0	0.7	14.9	Operable
SI17-C67-04	SI	B	Apr. 27, 2017	5707634	344916	807.0	0.6	14.7	Operable
SI17-C67-05	SI	B	Apr. 28, 2017	5707619	344929	805.0	0.4	12.8	Operable
SP16-01	SP	B	Feb. 9, 2016	5707640	344910	808.2	0.7	15.2	Operable
<del>SP16-02</del>	<del>SP</del>	<del>B</del>	<del>Nov. 8, 2016</del>	<del>5707620</del>	<del>344930</del>	<del>Unknown</del>	<del>0.4</del>	<del>7.3</del>	<del>Inoperable</del>
<del>SP16-03</del>	<del>SP</del>	<del>A</del>	<del>Nov. 8, 2016</del>	<del>5708070</del>	<del>344700</del>	<del>Unknown</del>	<del>0.7</del>	<del>5.5</del>	<del>Inoperable</del>

**Notes:**

<sup>1</sup> Coordinates and ground surface elevations were obtained by KCB with a handheld GPS during installation with a horizontal accuracy of ± 5 m.

<sup>2</sup> Meters below ground surface (mbgs).

<sup>3</sup> SI16-01 is sheared at an approximate depth of 4.5 m below ground surface.

## 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). The A0-grooves of all the SIs are aligned approximately perpendicular to the highway in the direction of anticipated maximum movement (i.e., in the downslope direction).

Negative rates of movement are sometimes recorded, which indicate the readings are within the reading accuracy of the SI equipment.

For the operable SP, the recorded water levels were converted to an equivalent water/piezometric elevation and plotted relative to ground surface elevation and each instruments screen 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 2.1, respectively. 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.

### 2.2 Zones of Movement

#### 2.2.1 Site A (North, Higher Elevation)

Before installation of the H-pile wall, movement was being recorded in SI16-02 at an approximate depth of 9.1 m below ground surface.

Distributed movement is being recorded in the SIs installed in the H-pile wall (SI17-C67-01 and SI17-C67-02) from top of casing to an approximate depth of 11.3 m and 11.8 m, respectively. The H-pile wall is 15 m deep at Site A, and the SIs are approximately 13.3 m to 14.2 m deep.

#### 2.2.2 Site B (South, Lower Elevation)

Before installation of the H-pile wall, distributed movement was recorded in SI16-01 from ground surface to an approximate depth of 4.5 m below ground surface. However, between the fall 2016 and spring 2017 readings, SI16-01 sheared at this depth and is inoperable.

Distributed movement is being recorded in the SIs installed in the H-pile wall (SI17-C67-03 though and SI17-C67-05) from top of casing to an approximate depth of 8.7 m, 6.8 m, and 6.5 m, respectively. The H-pile wall is 15 m deep at Site B, and the SIs are approximately 12.8 m to 14.9 m deep.

**Table 2.1 Slope inclinometer Reading Summary**

Instrument ID <sup>2</sup>	Site	Date				Ground Surface Elevation (m)	Depth of Movement (mbgs <sup>1</sup> )	Direction of Movement <sup>3</sup>	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 <sup>3</sup>	After Re-Initialization <sup>3</sup>	Total				
SI16-02	A	Nov. 28, 2016 (Jul. 19, 2017) <sup>3</sup>	Sep. 18, 2021	Jun. 25, 2022	Sep. 09, 2022	Unknown	1.1 – 9.1	A-Direction	58.9	15.5	74.4	-0.2	345.1	0.4	0.7
SI17-C67-01	A	Apr. 28, 2017 (Jul. 19, 2017) <sup>3</sup>	Sep. 18, 2021	Jun. 25, 2022	Sep. 09, 2022	830.0	0.0 – 11.3	A-Direction	0.7	13.7	14.4	-0.4	48.6	4.2	5.8
SI17-C67-02	A	Apr. 28, 2017 (Jul. 19, 2017) <sup>3</sup>	Jun. 25, 2022	Jun. 25, 2022	Sep. 09, 2022	831.0	0.0 – 11.8	A-Direction	5.4	15.7	21.1	1.9	41.0	8.9	7.3
SI17-C67-03	B	Apr. 28, 2017 (Jul. 19, 2017) <sup>3</sup>	Sep. 18, 2021	Jun. 25, 2022	Oct. 07, 2022	808.0	0.0 – 8.7	A-Direction	7.0	18.1	25.1	1.9	115.5	6.6	6.6
SI17-C67-04	B	Apr. 28, 2017 (Jul. 19, 2017) <sup>3</sup>	Jun. 25, 2022	Jun. 25, 2022	Oct. 07, 2022	807.0	0.0 – 6.8	A-Direction	8.8	17.7	26.5	1.8	70.9	6.1	5.1
SI17-C67-05	B	Apr. 28, 2017 (Jul. 19, 2017) <sup>3</sup>	Sep. 18, 2021	Jun. 25, 2022	Oct. 07, 2022	805.0	0.0 – 6.5	A-Direction	6.4	10.2	16.6	-1.0	88.7	-0.4	0.7

**Notes:**

<sup>1</sup> Meters below ground surface (mbgs).

<sup>2</sup> SI16-02 was installed to monitor movement of the slide, whereas the remaining SIs were installed to monitor deflection of the H-pile walls.

<sup>3</sup> All SIs were re-initialized in July 2017 when the SI equipment was changed.

**Table 2.2 Standpipe Piezometer Reading Summary**

Instrument ID	Date			Ground Surface Elevation (m)	Screen Depth (mbgs <sup>1</sup> )	Water Level		
	Installed	Previous Reading	Most Recent Reading			Previous Reading (mbgs <sup>1</sup> )	Most Recent Reading (mbgs <sup>1</sup> )	Change from Previous Reading (m)
SP16-01	Feb. 09, 2016	Jun. 25, 2022	Sep. 09, 2022	808.2	13.3	11.6	12.4	-0.8

**Notes:**

<sup>1</sup> Meters below ground surface (mbgs).

## 2.3 Interpretation of Monitoring Results

### 2.3.1 Site A (North, Higher Elevation)

Data obtained from SI16-02 (installed upslope of the H-pile wall) indicates the active block upslope of the H-pile wall continues to creep as the H-pile wall stabilizes the sliding mass. Before the H-pile wall was installed, the maximum rate of movement recorded in SI16-02 was approximately 204 mm/year on February 21, 2017. Between April and May 2017, after installation of the H-pile wall, the rate of movement recorded in SI16-02 increased to approximately 345 mm/year. Since September 2018, the overall rate of movement recorded in this instrument has been slow (approximately 1 mm/year).

The lowest depth at which movement is being recorded in the pile-wall SIs (SI17-C67-01 and SI17-C67-02) appears to be occurring approximately 2 m to 3 m below the depth of movement recorded in SI16-02. This indicates the H-pile wall has intercepted the failure surface and is continuing to deflect, transferring load to depths below the failure plane as the piles stabilize the sliding mass.

The September 2022 data obtained from SI17-C67-01 and SI17-C67-02 indicates the top of the H-pile wall at Site A has deflected between approximately 14 mm and 21 mm since installation. The maximum rate of movement recorded in SI17-C67-01 and SI17-C67-02 was approximately 45 mm/year in May 2017, one month after the H-pile wall was installed. The rate of movement has since decreased and is now generally less than 10 mm/year.

Between June and September 2022, an increased rate of movement (between approximately 4 mm/year and 9 mm/year) was recorded in SI17-C67-01 and SI17-C67-02 likely in response to wet weather in June and July 2022. The previous year and the spring of 2022 were relatively dry.

### 2.3.2 Site B (South, Lower Elevation)

The depth of movement being recorded in the pile-wall SIs (SI17-C67-03 through SI17-C67-05) appears to be occurring 2 m to 4 m below the depth of movement previously recorded in SI16-01. This indicates the H-pile wall has intercepted the failure surface and is continuing to deflect, transferring load to depths below the failure plane as the piles stabilize the sliding mass.

The September 2022 data obtained from SI17-C67-03 through SI17-C67-05 indicates the top of the H-pile wall has deflected between approximately 17 mm and 27 mm since installation. The maximum rate of movement recorded in SI17-C67-03 through SI17-C67-05 was approximately 71 mm/year to 115 mm/year in May 2017, one month after the H-pile wall was installed. The rate of movement has since decreased and is now generally less than 10 mm/year.

Between June and September 2022, an increased rate of movement (between approximately 6 mm/year and 7 mm/year) was recorded in SI17-C67-03 and SI17-C67-04 likely in response to wet weather in June and July 2022. The previous year and the spring of 2022 were relatively dry.

The negative displacement recorded in SI21-C67-05 may be attributed to movement within the reading accuracy of the equipment or noisy data (KCB has previously observed the readings can sometimes take longer-than-usual to stabilize at the Site B SIs).

Since installation in February 2016, water levels recorded in SP16-01 have been relatively steady varying from 11.4 m to 12.7 m below ground surface. The September 2022 reading of 12.4 m below ground surface was consistent with historical trends observed in this instrument.

### 2.3.3 General

Before the instruments were re-initialized in July 2017, up to 10 mm of distributed movement (i.e., from top to bottom of casing) was recorded in the B-direction of the pile-wall SIs (SI17-C67-01 through SI17-C67-05). It is unknown if this movement was due to post-installation flexure or twist of the H-piles that occurred when the H-pile walls picked up load from the sliding mass. However, movements in the B-direction have attenuated and no additional movement has been recorded in the B-direction of these instruments since they were re-initialized, except in SI17-C67-03, but the movement has been attributed to poor backfill around the SI casing.

Based on KCB's 2017 design report, the top 8 m and 10 m of the H-pile walls at Site A and B, respectively, were expected to deflect up to 200 mm over the three to four years following installation (i.e., the estimated time for the H-pile wall to pick up the load and stabilize the sliding mass), respectively. However, since installation of the H-pile walls, only 27 mm of deflection has been recorded in the pile-wall SIs and pavement distress has been minimal indicating the H-pile walls are performing well.

It is anticipated that the H-pile walls will continue to deflect at what is expected to be a decreasing rate of movement until the slides are stabilized. Overall, the data obtained from the pile-wall SIs indicates that deflections of the H-pile walls at Site A and B are beginning to attenuate (now generally less than 10 mm/year). Similar to this year, movement rates may increase, or additional displacements of the H-pile walls may occur in response to periods of heavy or prolonged rainfall, resulting in higher groundwater conditions. The increased rate of movement recorded in 2022 is still relatively slow and similar to other short-term increases recorded after pile wall construction. Minor longitudinal pavement cracks were observed in the west (southbound) lane upslope of Site B confirm the recent movement recorded in the Site B SIs.

## 3 RECOMMENDATIONS

### 3.1 Future Work

The operable instruments should continue to be read twice per year (spring and fall) until movement rates attenuate.

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

### 3.2 Instrument Repairs and Maintenance

No 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.**



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

James Lyons, P.Eng.  
Civil Engineer

JL:bb

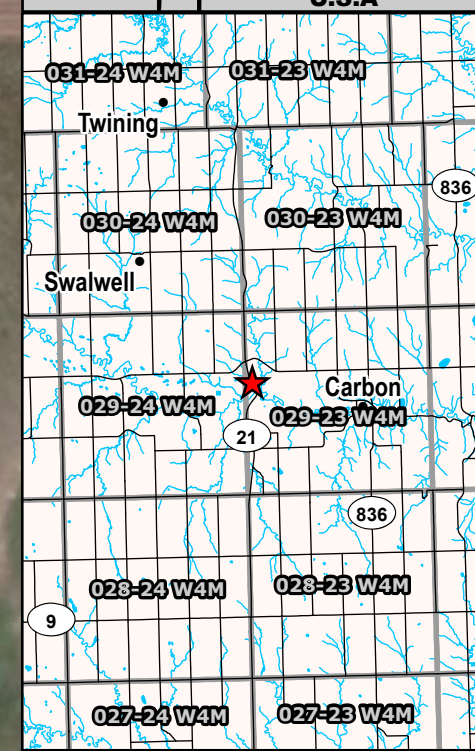
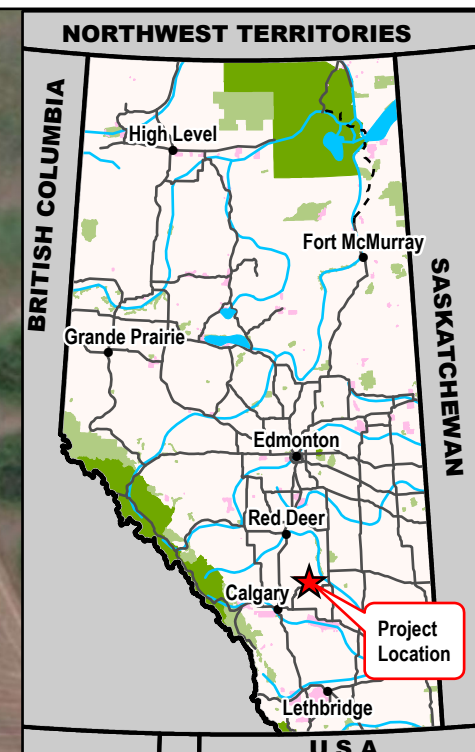
**ATTACHMENTS**

Figure  
Appendix I      Instrumentation Plots



## FIGURE

---



**Legend**

- Standpipe Piezometer (SP)
- Slope Inclinator (SI)
- H-Pile Wall



NOTES:  
 1. HORIZONTAL DATUM: NAD83  
 2. GRID ZONE: UTM Zone 12N  
 3. IMAGE SOURCE: World Imagery, ESRI ArcGIS Online  
 Source date July 22, 2019.  
 4. Instrument locations are approximate (not surveyed).  
 5. Strikethrough indicates the instrument is inoperable.

CLIENT

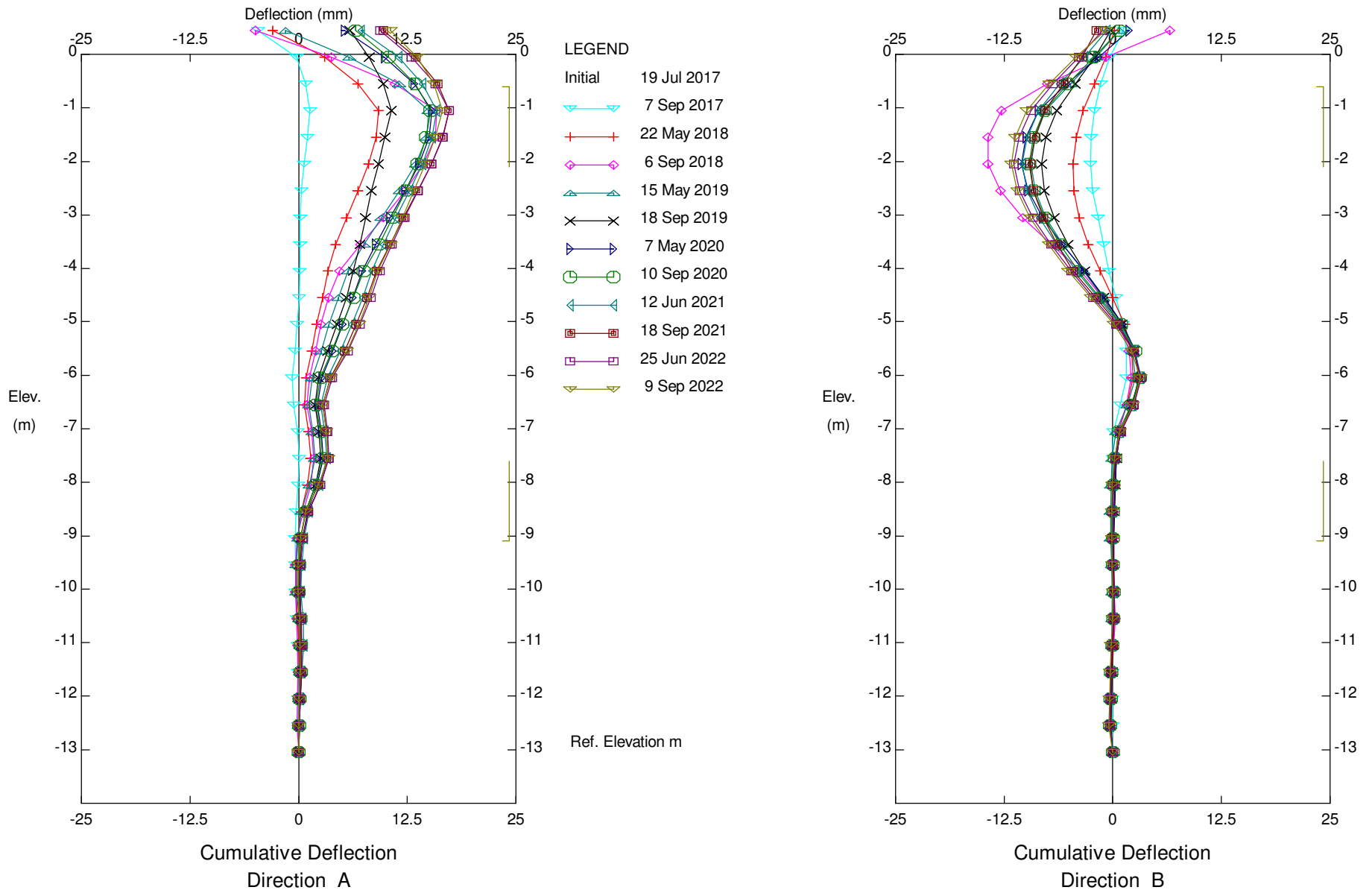
PROJECT CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM		
TITLE Site Plan C067 - Kneehill Creek Slide Hwy 21:14, km 12.988		
SCALE 1:3,000	PROJECT No. A05116A02	FIG No. 1

# APPENDIX I

## Instrumentation Plots

---

### Klohn Crippen Berger - Calgary

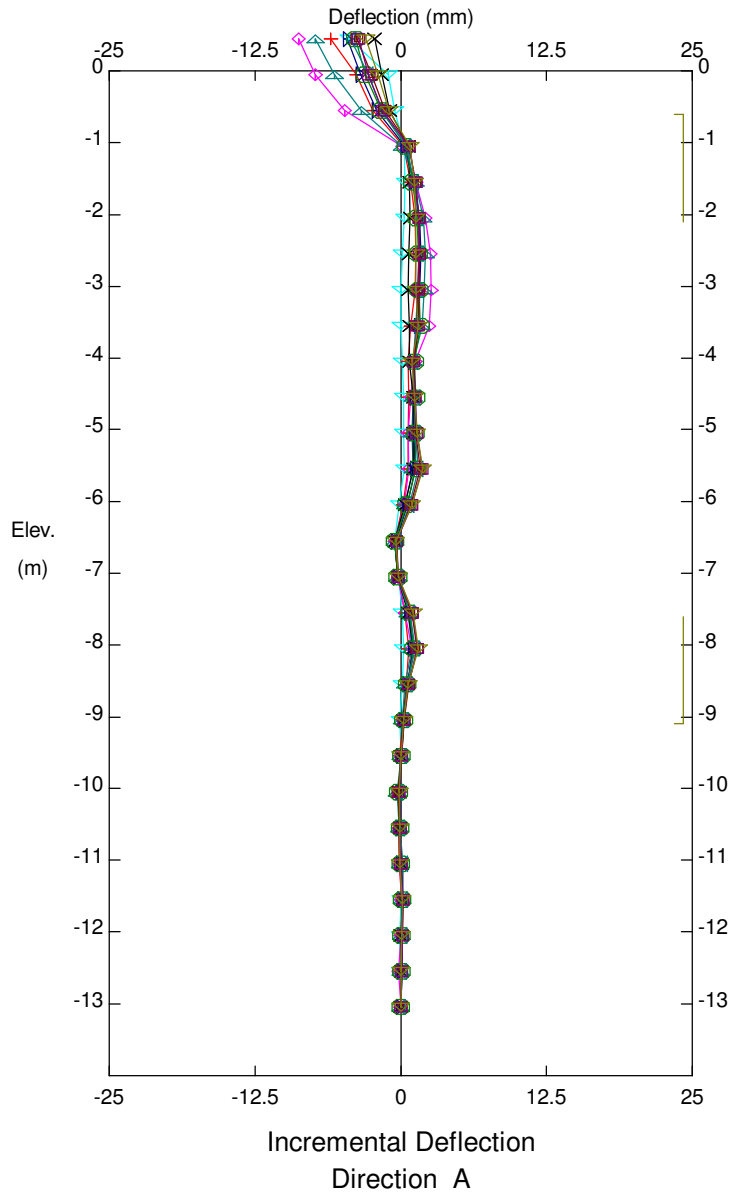


C067; H21:14, Kneehill Creek Slide, Inclinometer SI16-02

Alberta Transportation

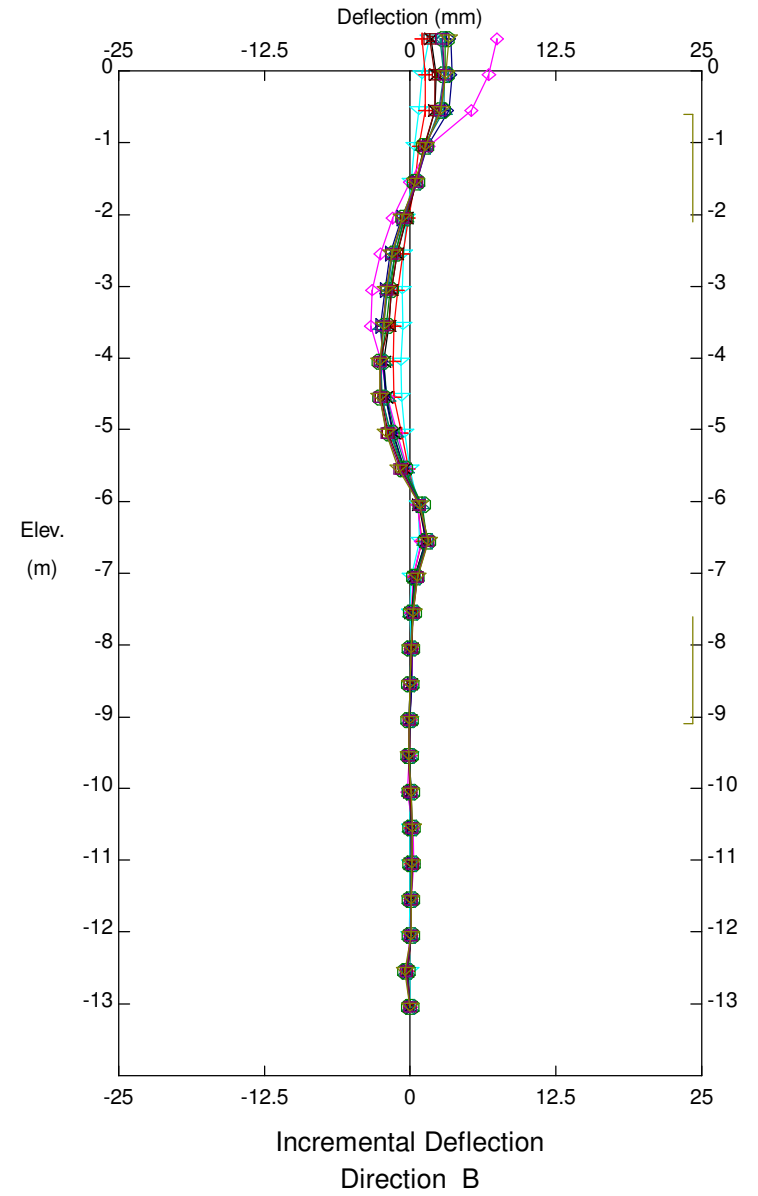
Instrument re-initialized in July 2017 when the SI equipment was changed.

### Klohn Crippen Berger - Calgary



- LEGEND**
- Initial 19 Jul 2017
  - ◁ 7 Sep 2017
  - + 22 May 2018
  - ◇ 6 Sep 2018
  - △ 15 May 2019
  - × 18 Sep 2019
  - ▷ 7 May 2020
  - ⊕ 10 Sep 2020
  - ◁ 12 Jun 2021
  - ⊞ 18 Sep 2021
  - ⊞ 25 Jun 2022
  - ▽ 9 Sep 2022

Ref. Elevation m

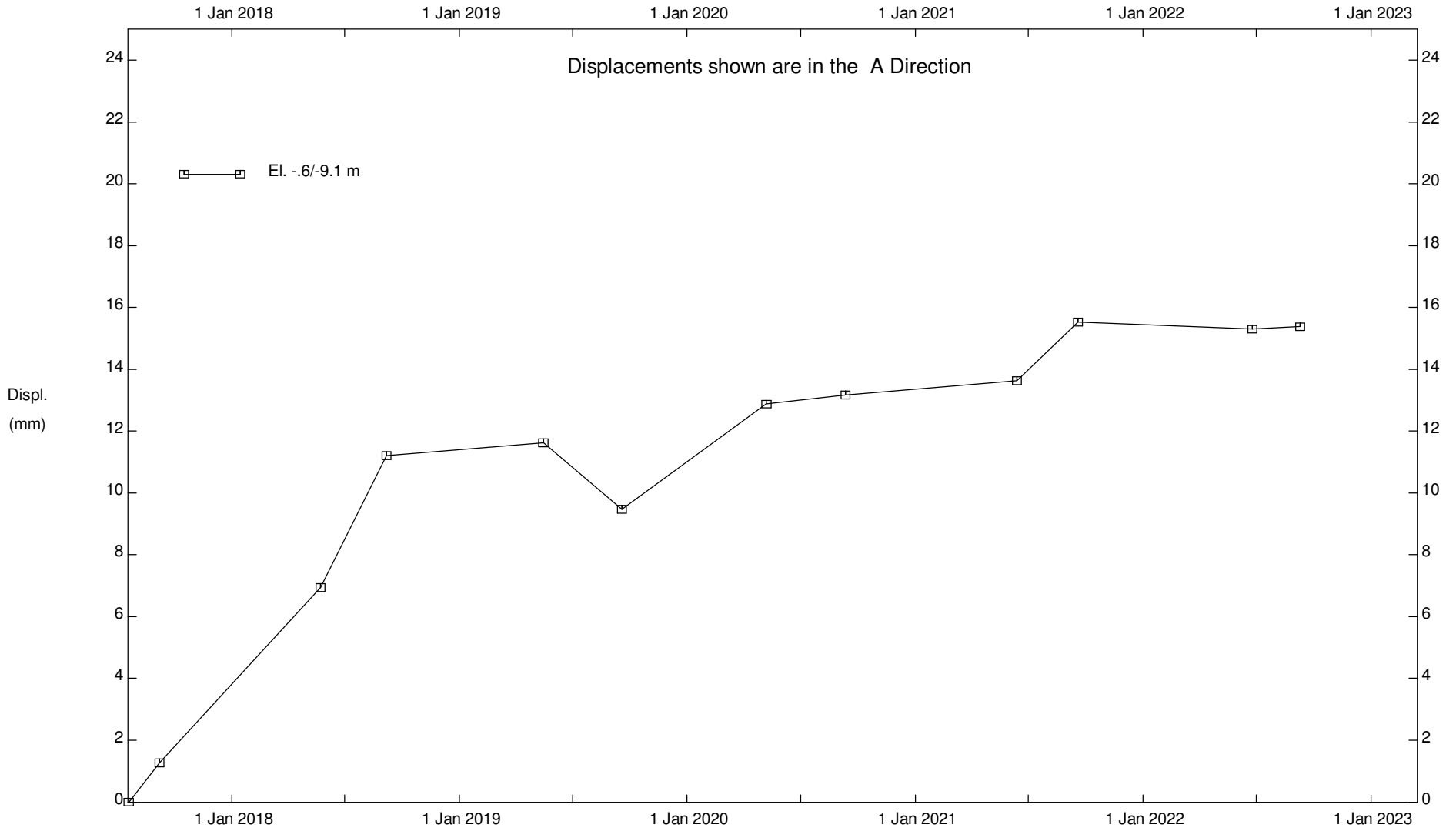


C067; H21:14, Kneehill Creek Slide, Inclinometer SI16-02

Alberta Transportation

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

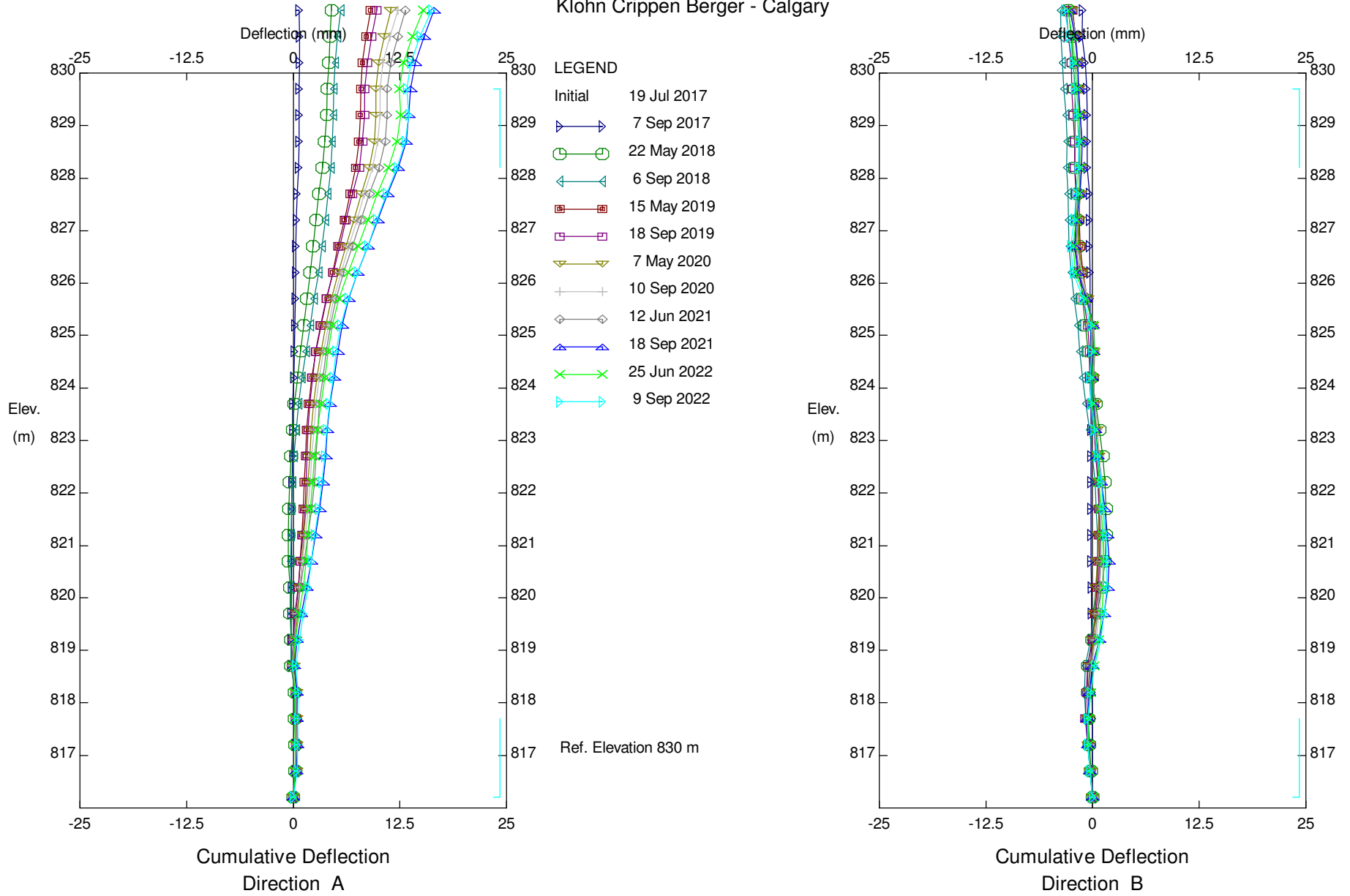
# Klohn Crippen Berger - Calgary



C067; H21:14, Kneehill Creek Slide, Inclinator S116-02

Alberta Transportation

# Klohn Crippen Berger - Calgary

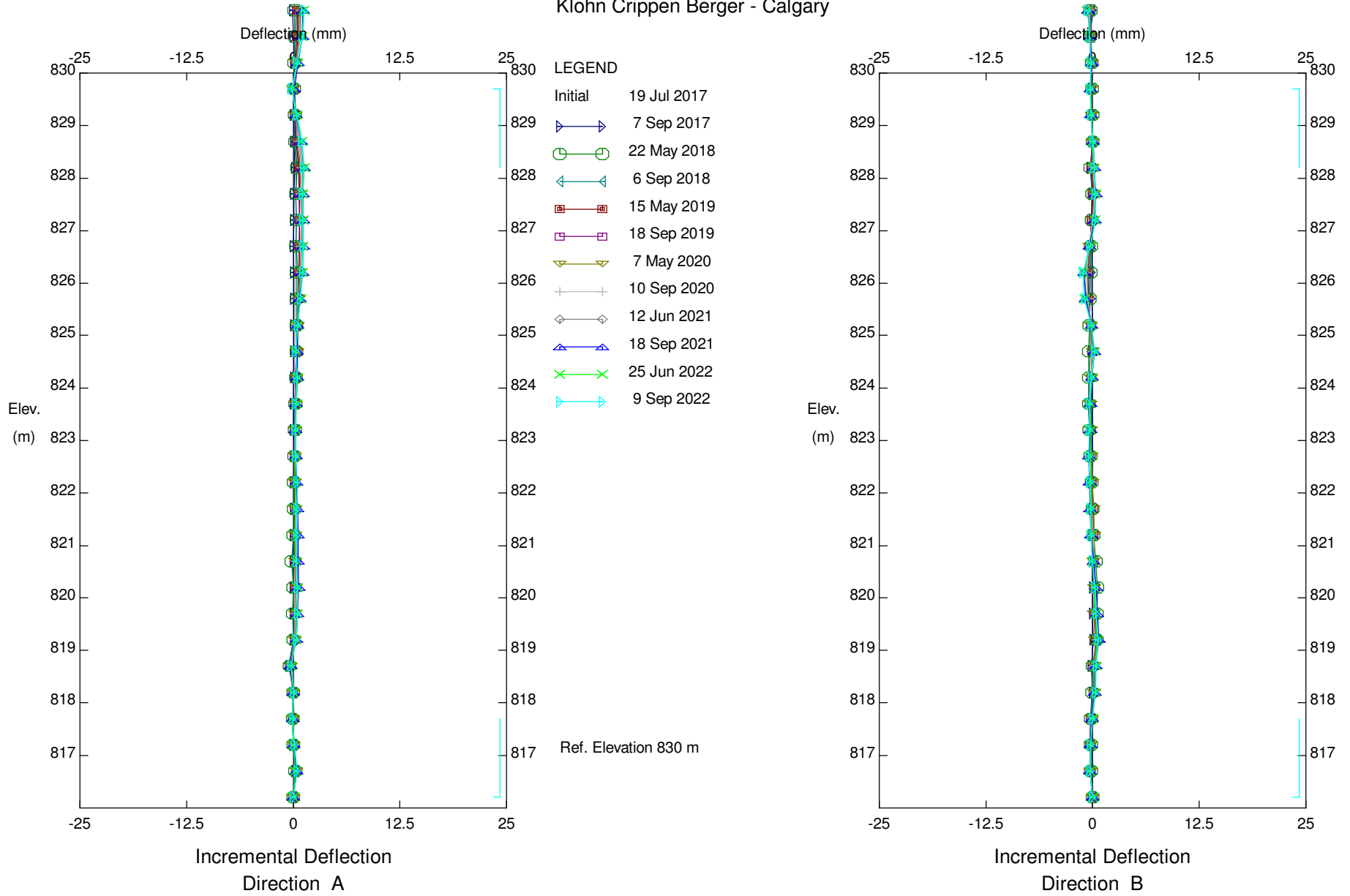


C067; H21:14, Kneehill Creek Slide, Inclinator SI17-C67-01

Alberta Transportation

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

# Klohn Crippen Berger - Calgary



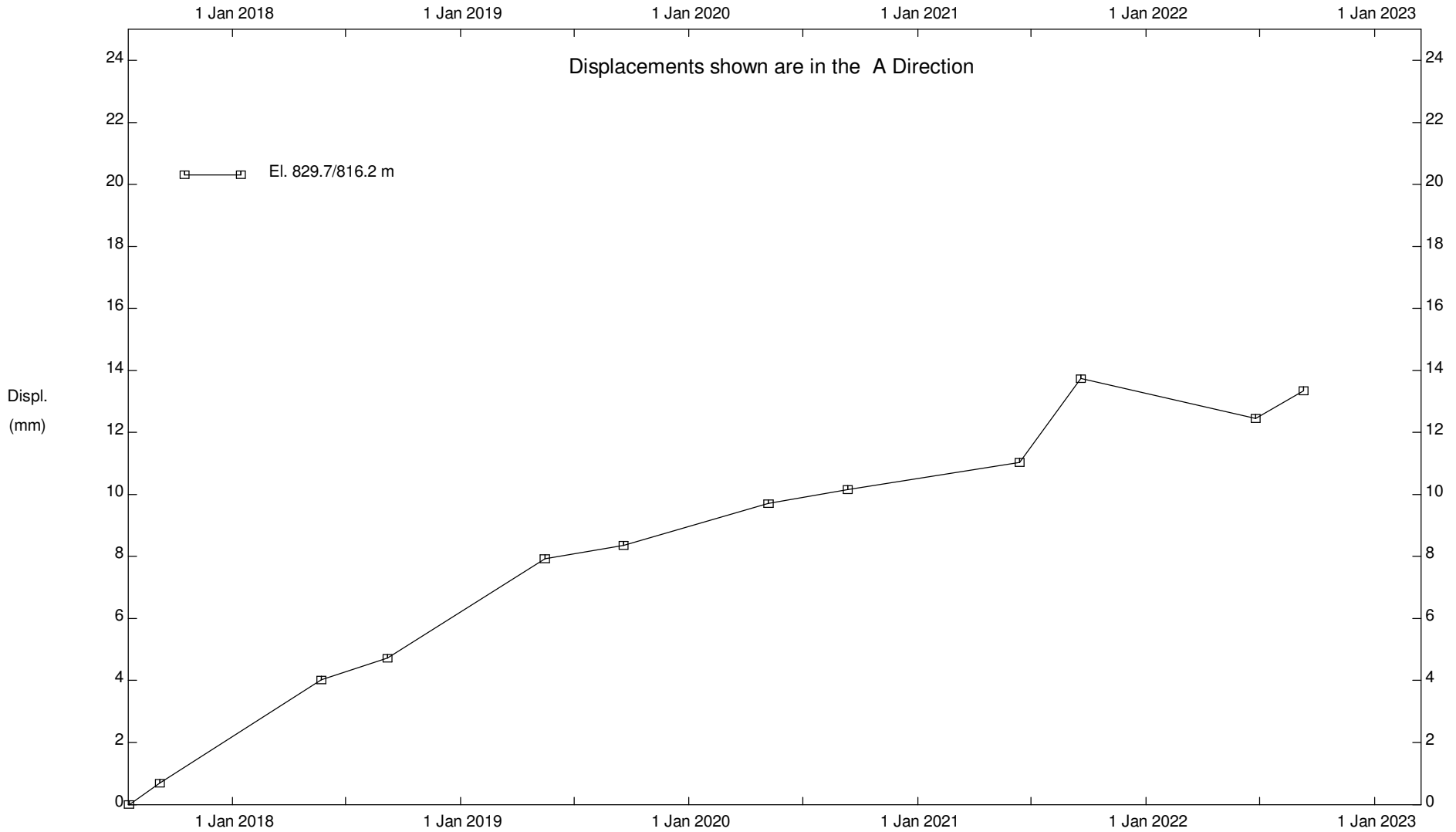
C067; H21:14, Kneehill Creek Slide, Inclinator SI17-C67-01

Alberta Transportation

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



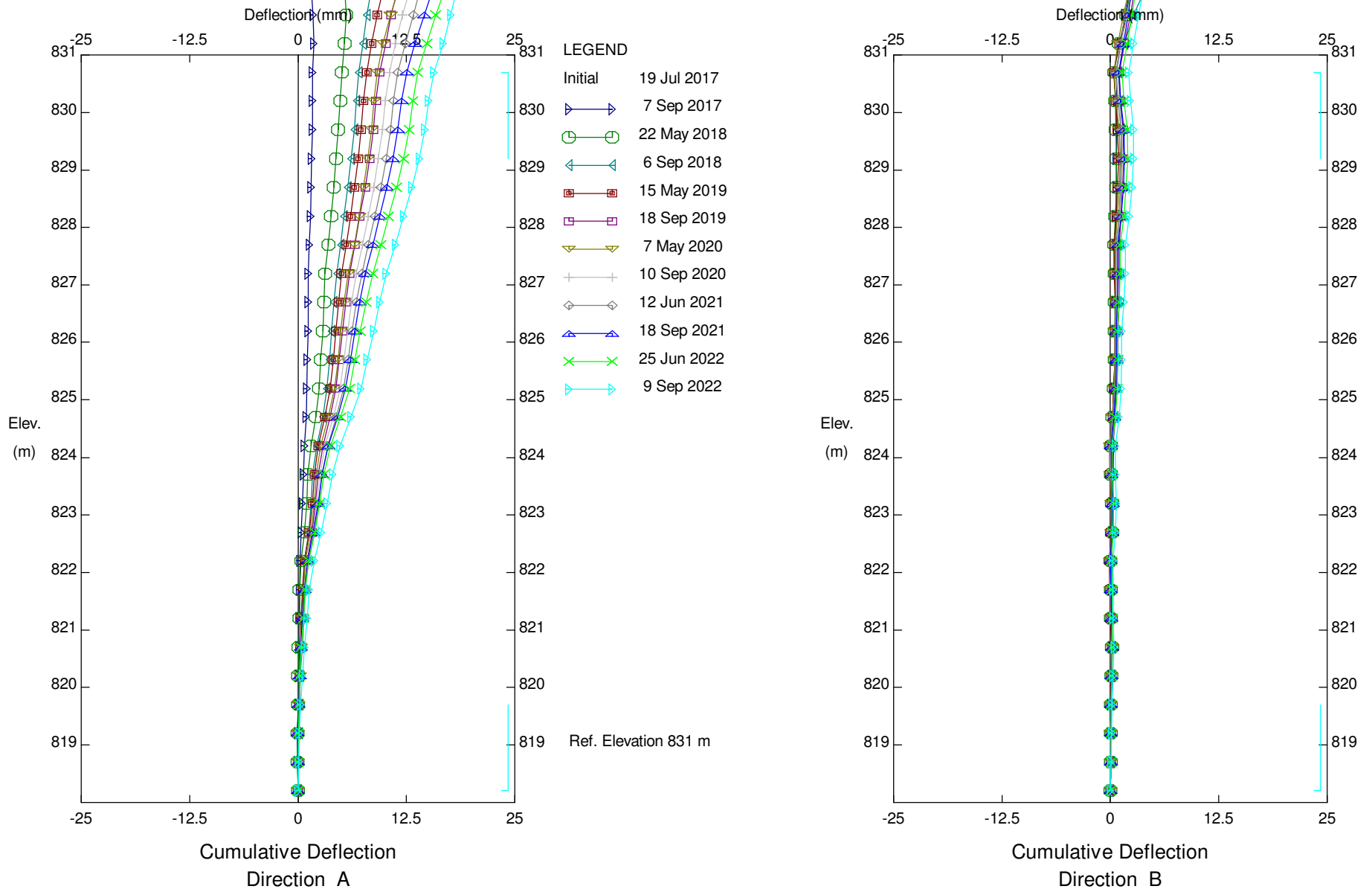
# Klohn Crippen Berger - Calgary



C067; H21:14, Kneehill Creek Slide, Inclinometer SI17-C67-01

Alberta Transportation

# Klohn Crippen Berger - Calgary

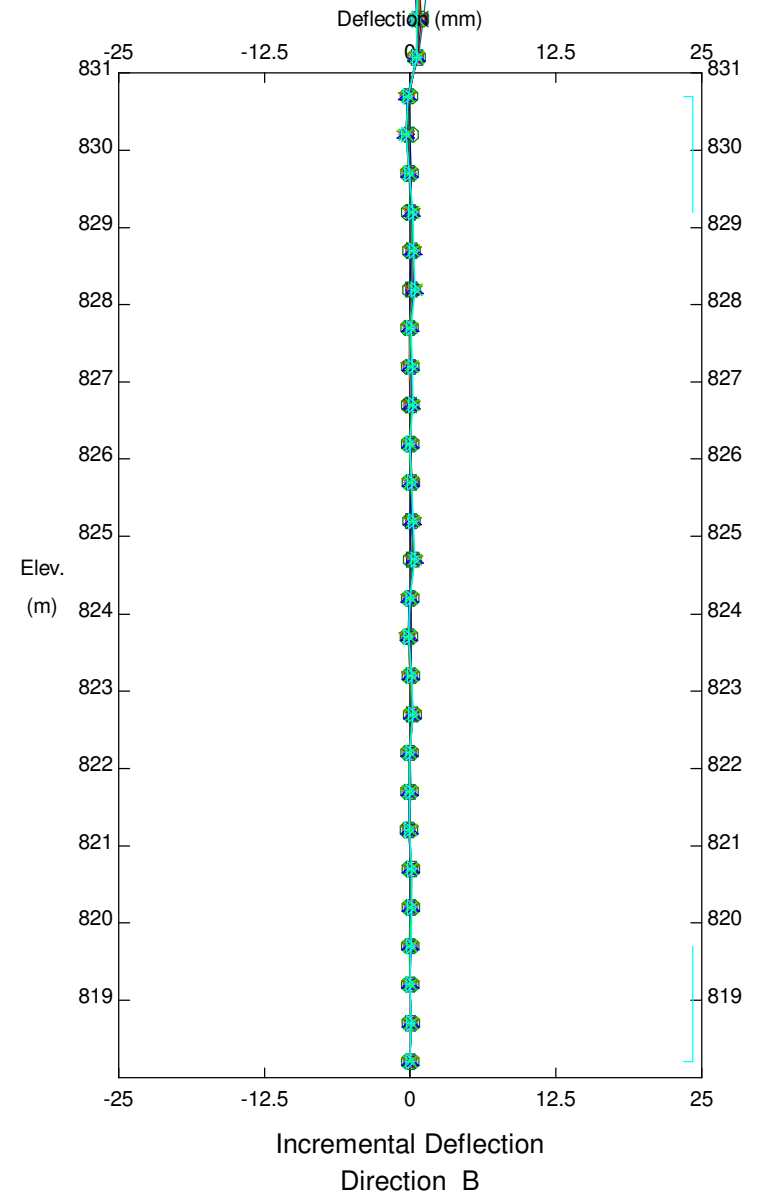
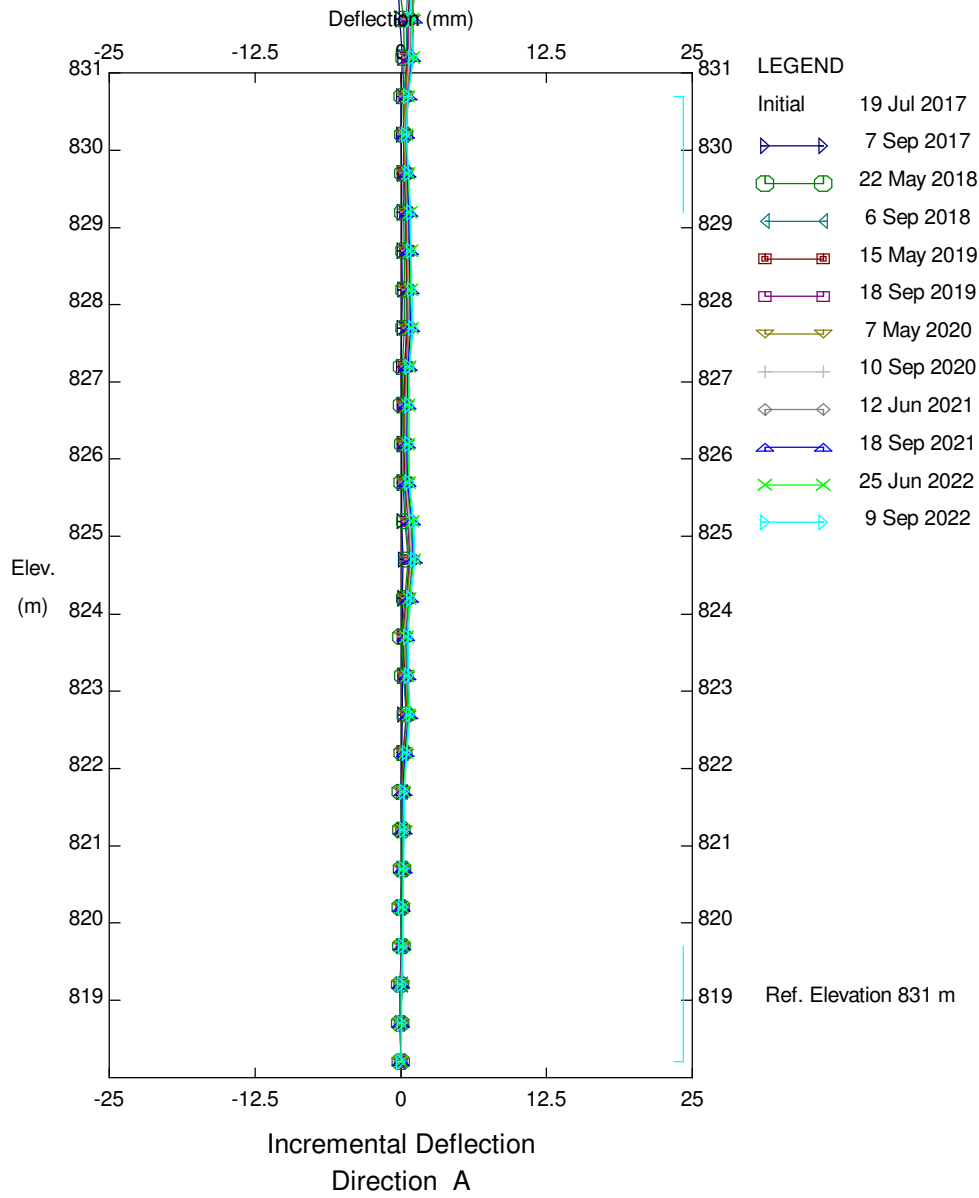


C067; H21:14, Kneehill Creek Slide, Inclinator SI17-C67-02

Alberta Transportation

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

# Klohn Crippen Berger - Calgary

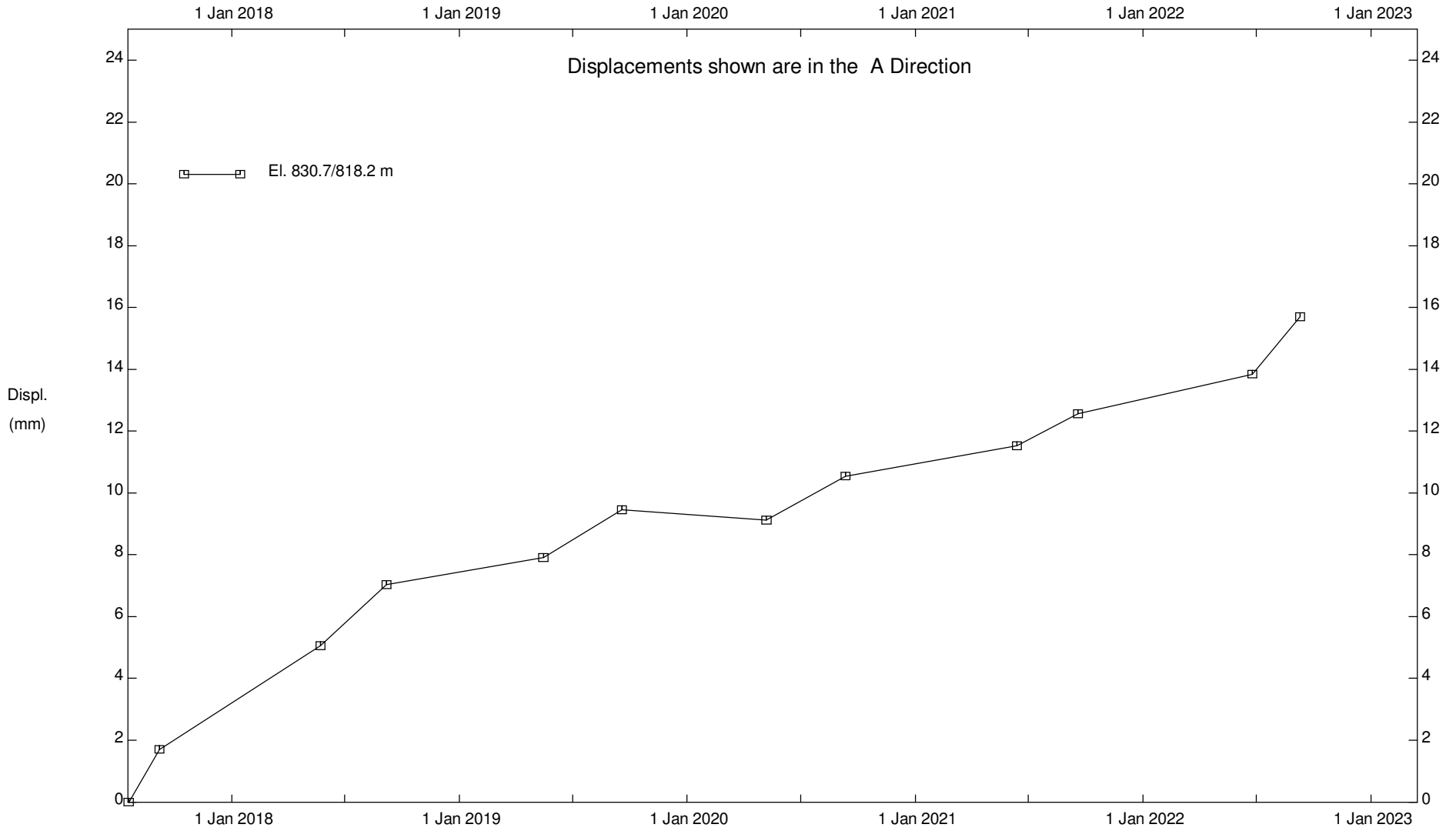


C067; H21:14, Kneehill Creek Slide, Inclinator SI17-C67-02

Alberta Transportation

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

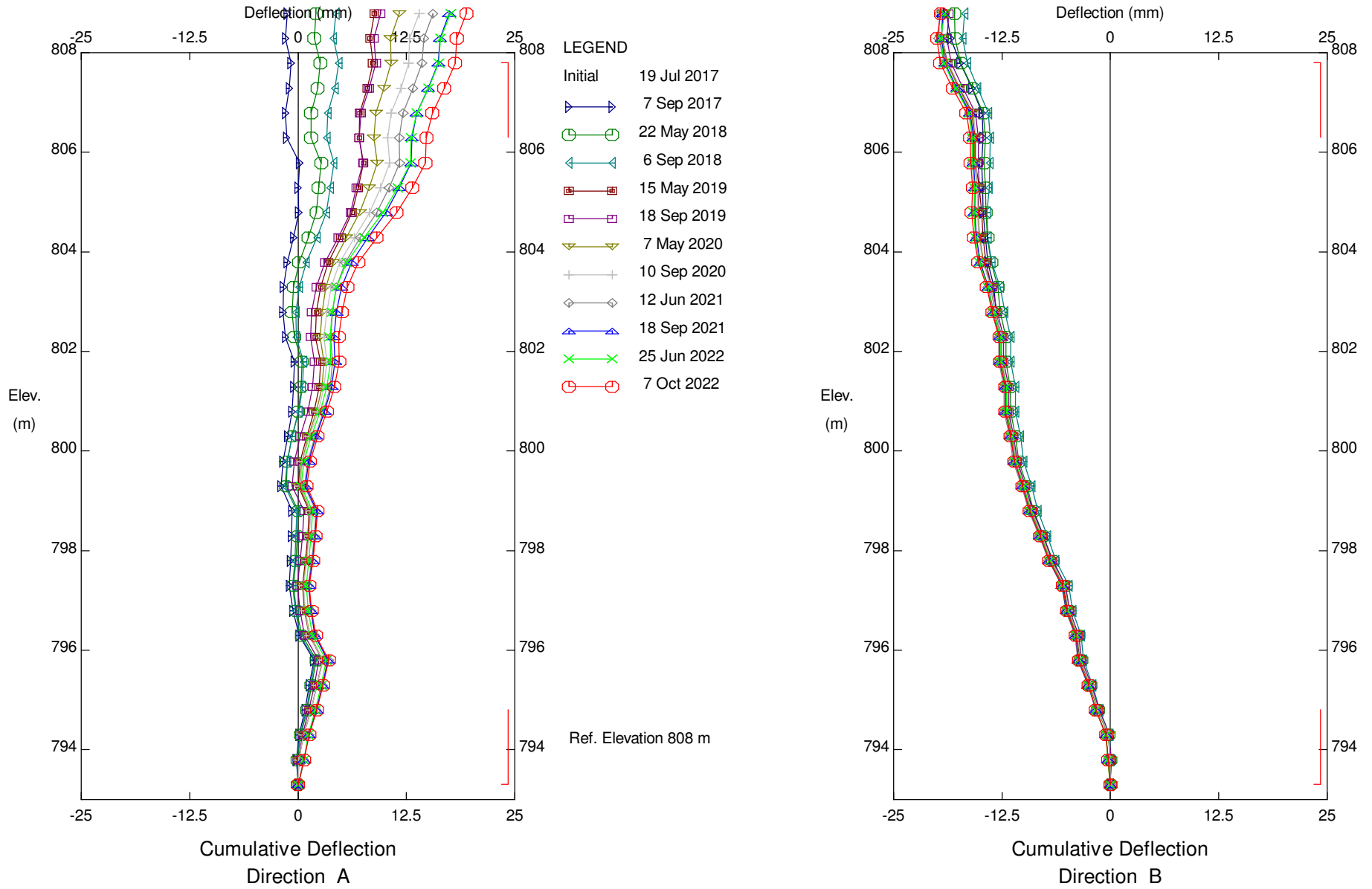
# Klohn Crippen Berger - Calgary



C067; H21:14, Kneehill Creek Slide, Inclinometer SI17-C67-02

Alberta Transportation

# Klohn Crippen Berger - Calgary

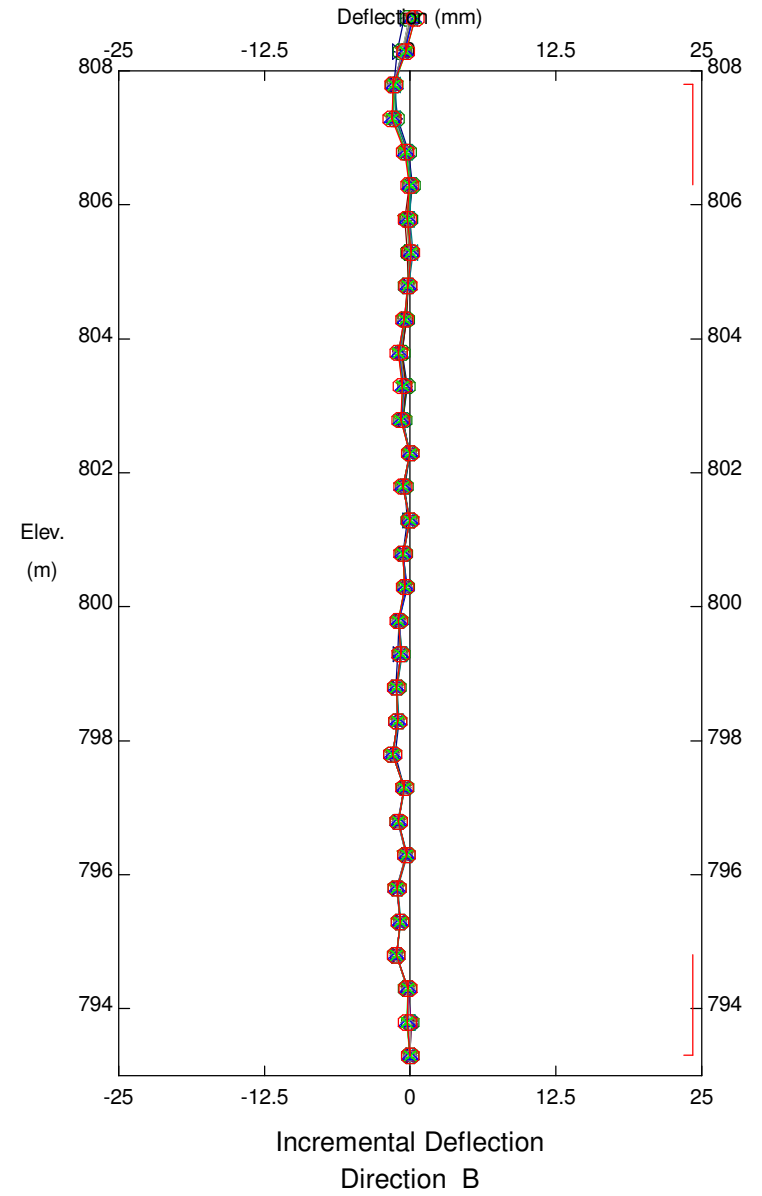
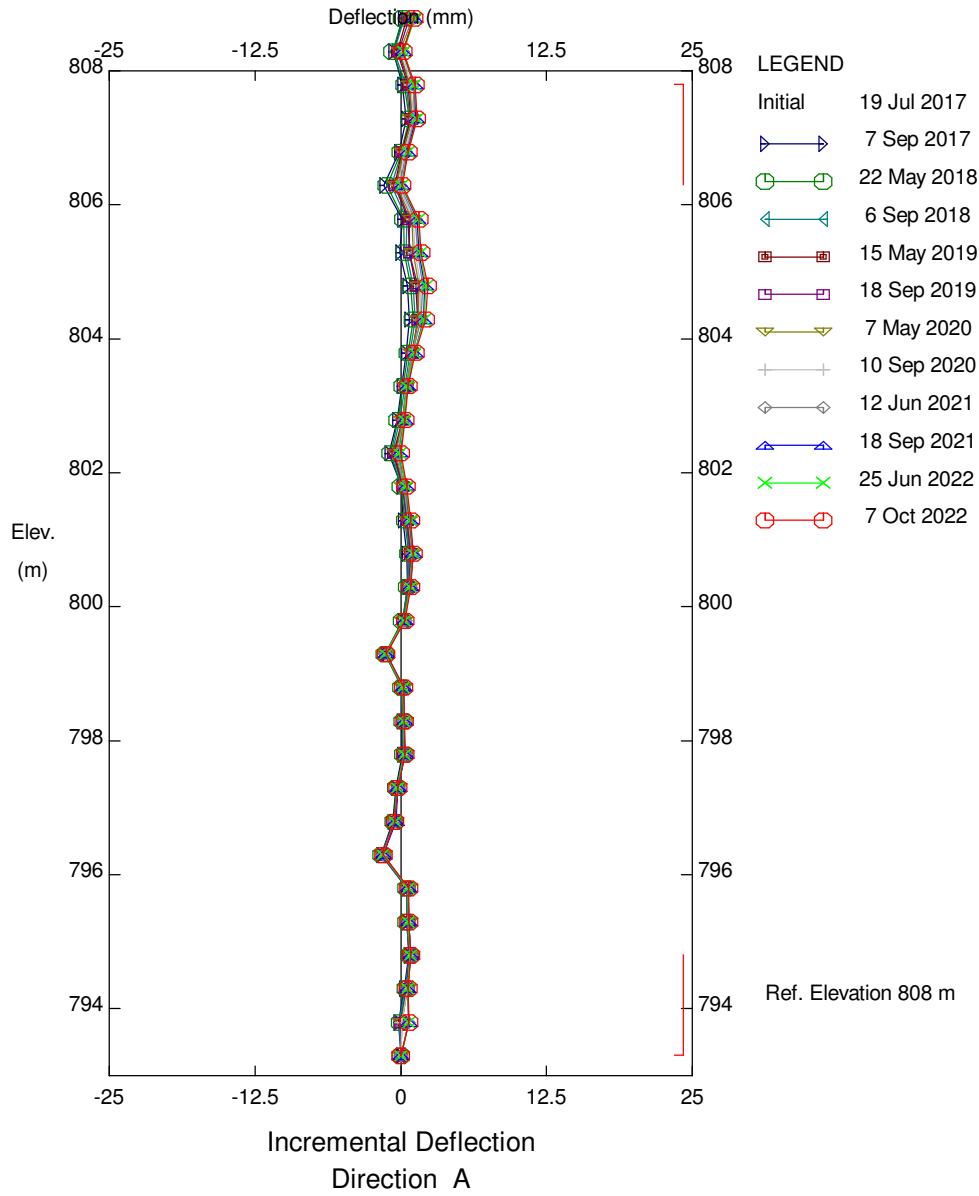


C067; H21:14, Kneehill Creek Slide, Inclinometer SI17-C67-03

Alberta Transportation

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

### Klohn Crippen Berger - Calgary

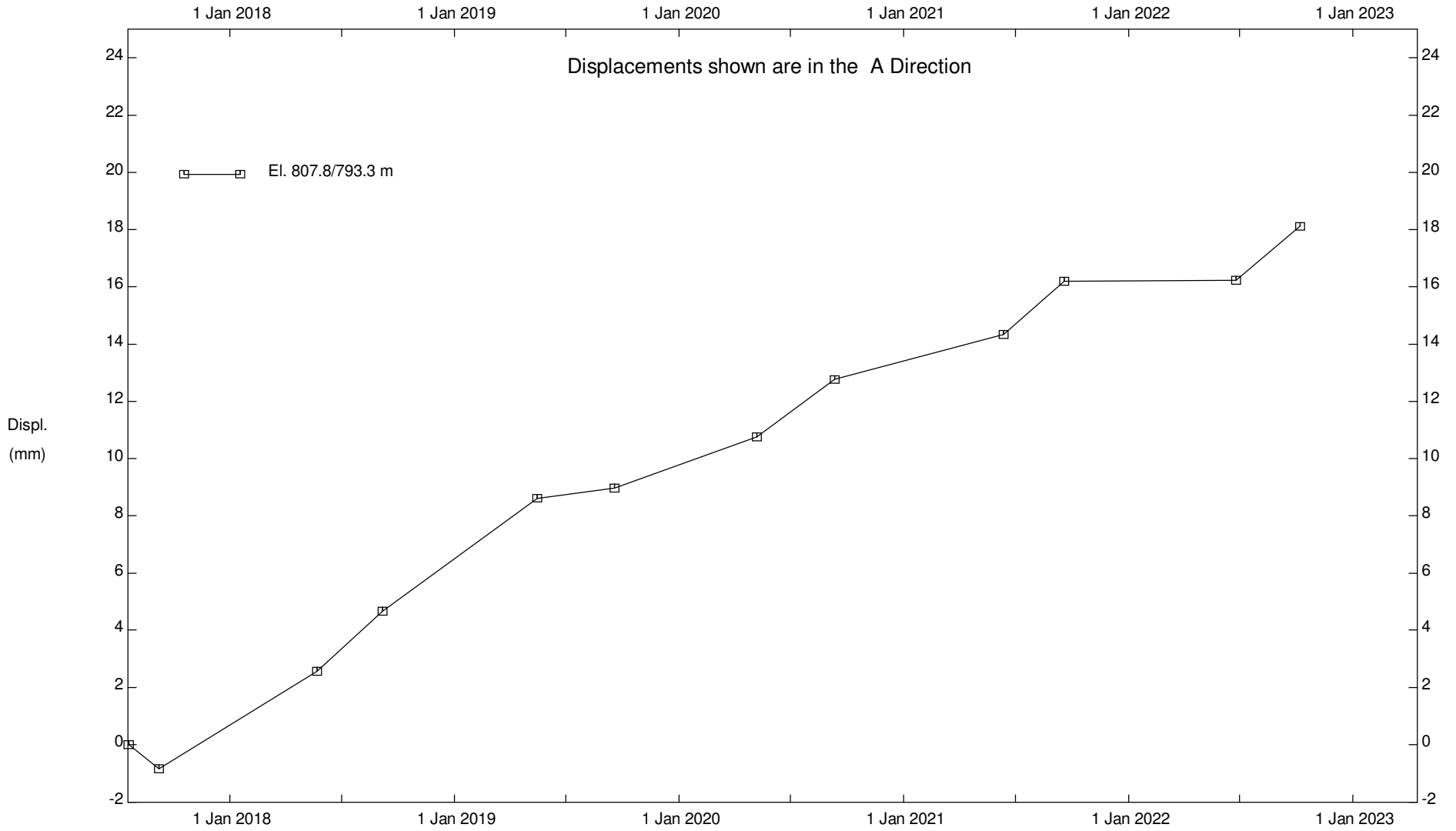


C067; H21:14, Kneehill Creek Slide, Inclinator SI17-C67-03

Alberta Transportation

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

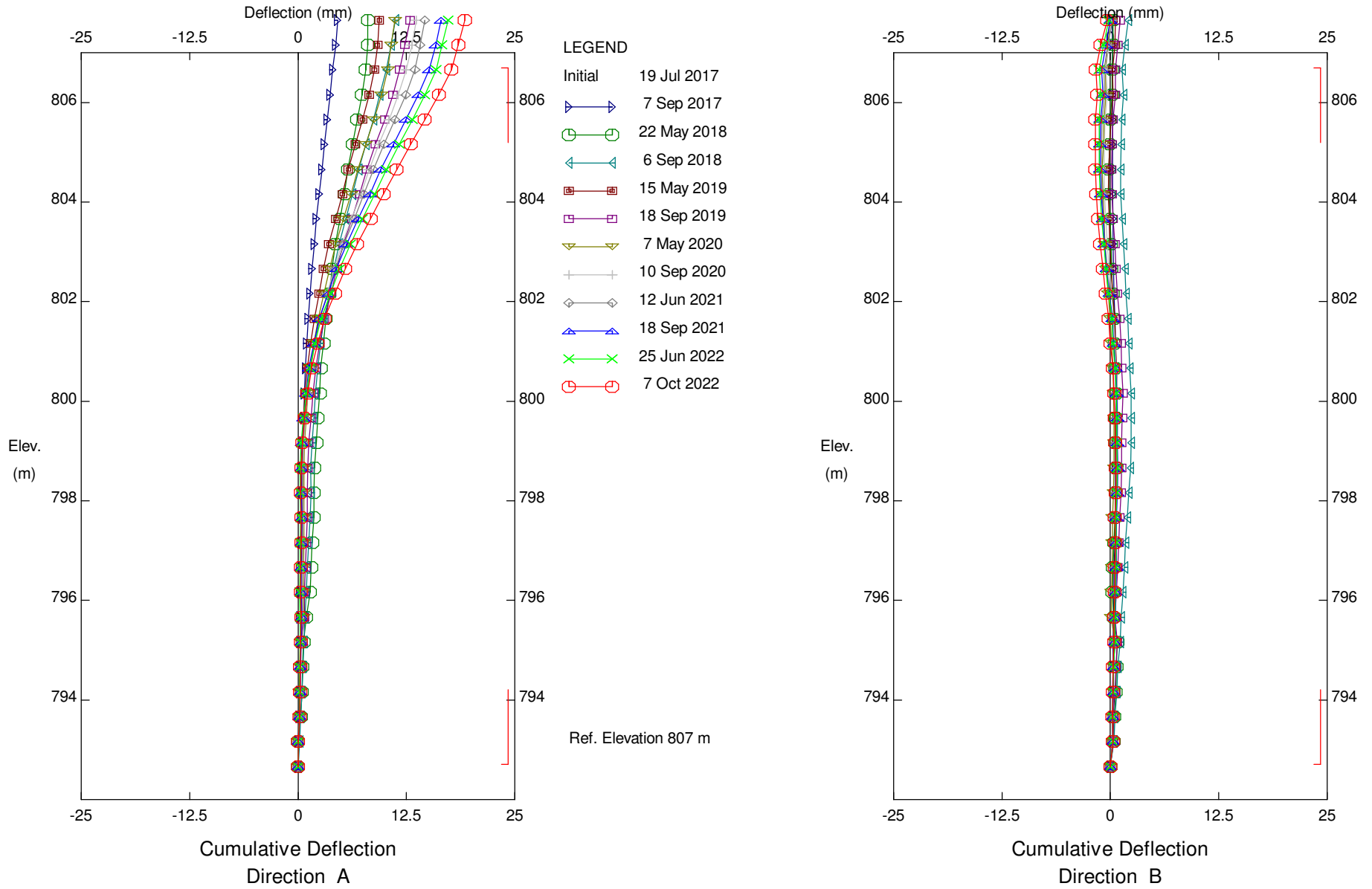
# Klohn Crippen Berger - Calgary



C067; H21:14, Kneehill Creek Slide, Inclinator SI17-C67-03

Alberta Transportation

# Klohn Crippen Berger - Calgary



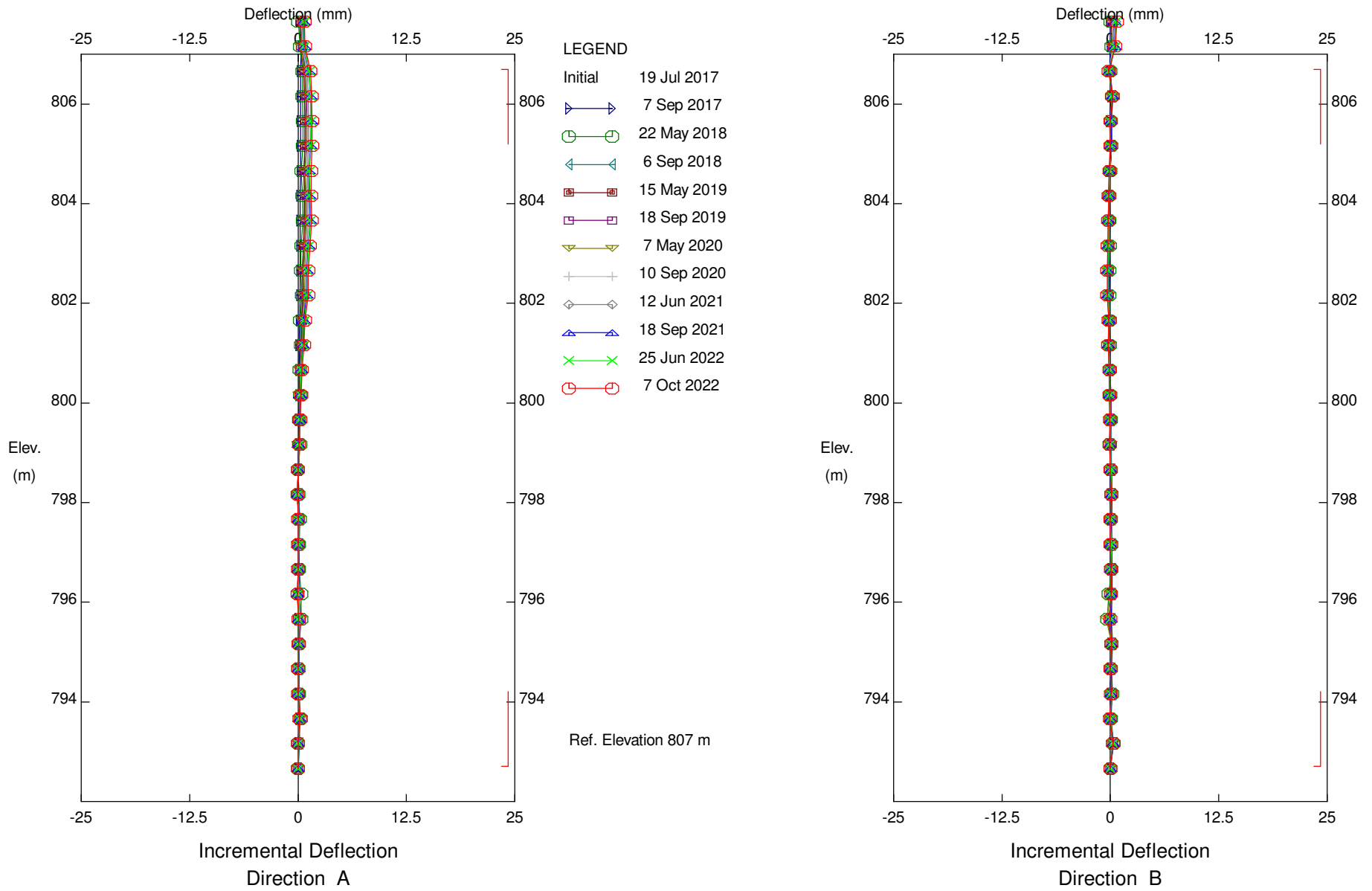
C067; H21:14, Kneehill Creek Slide, Inclinator SI17-C67-04

Alberta Transportation

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



# Klohn Crippen Berger - Calgary

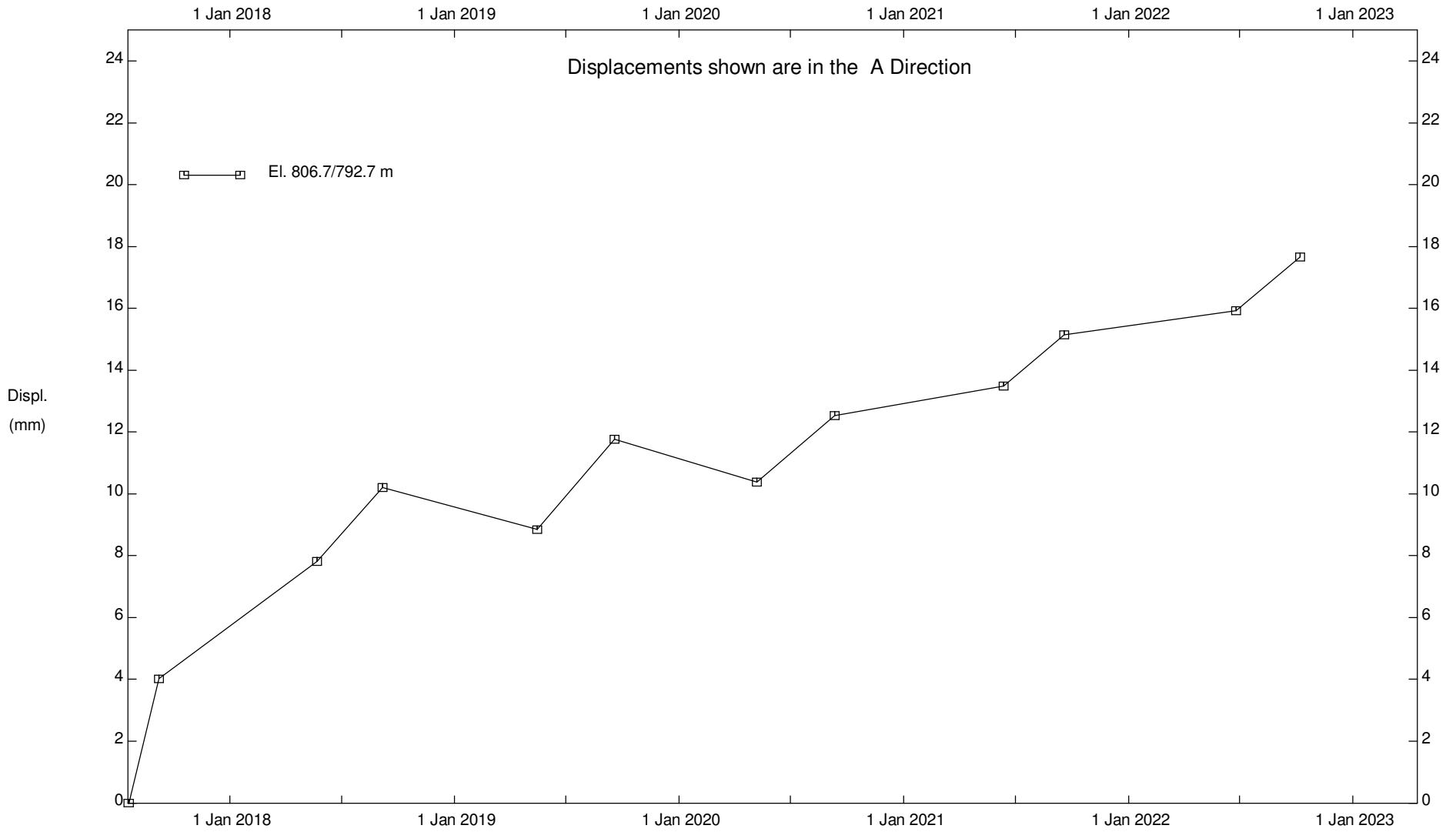


C067; H21:14, Kneehill Creek Slide, Inclinator SI17-C67-04

Alberta Transportation

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

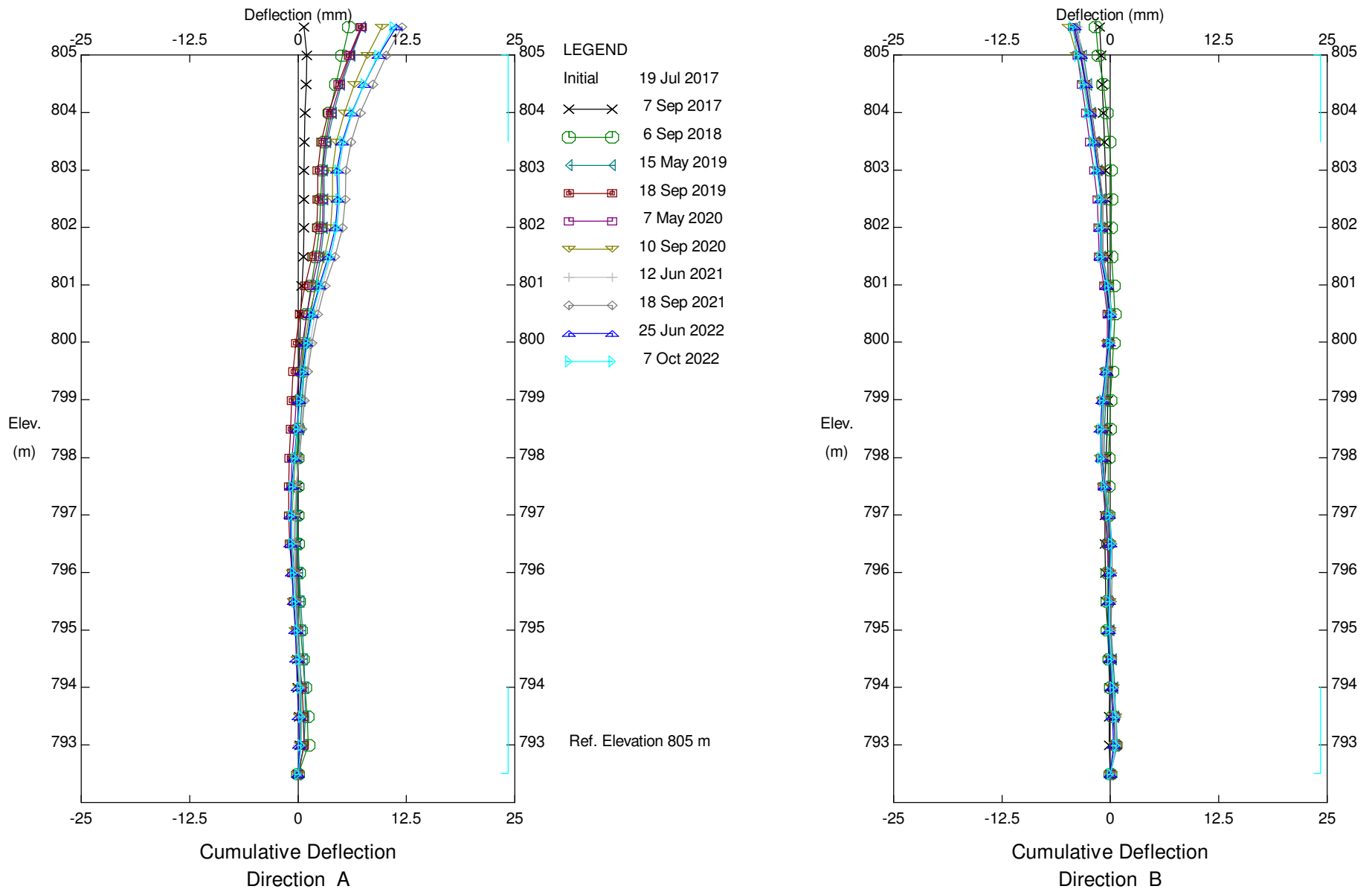
# Klohn Crippen Berger - Calgary



C067; H21:14, Kneehill Creek Slide, Inclinator SI17-C67-04

Alberta Transportation

### Klohn Crippen Berger - Calgary

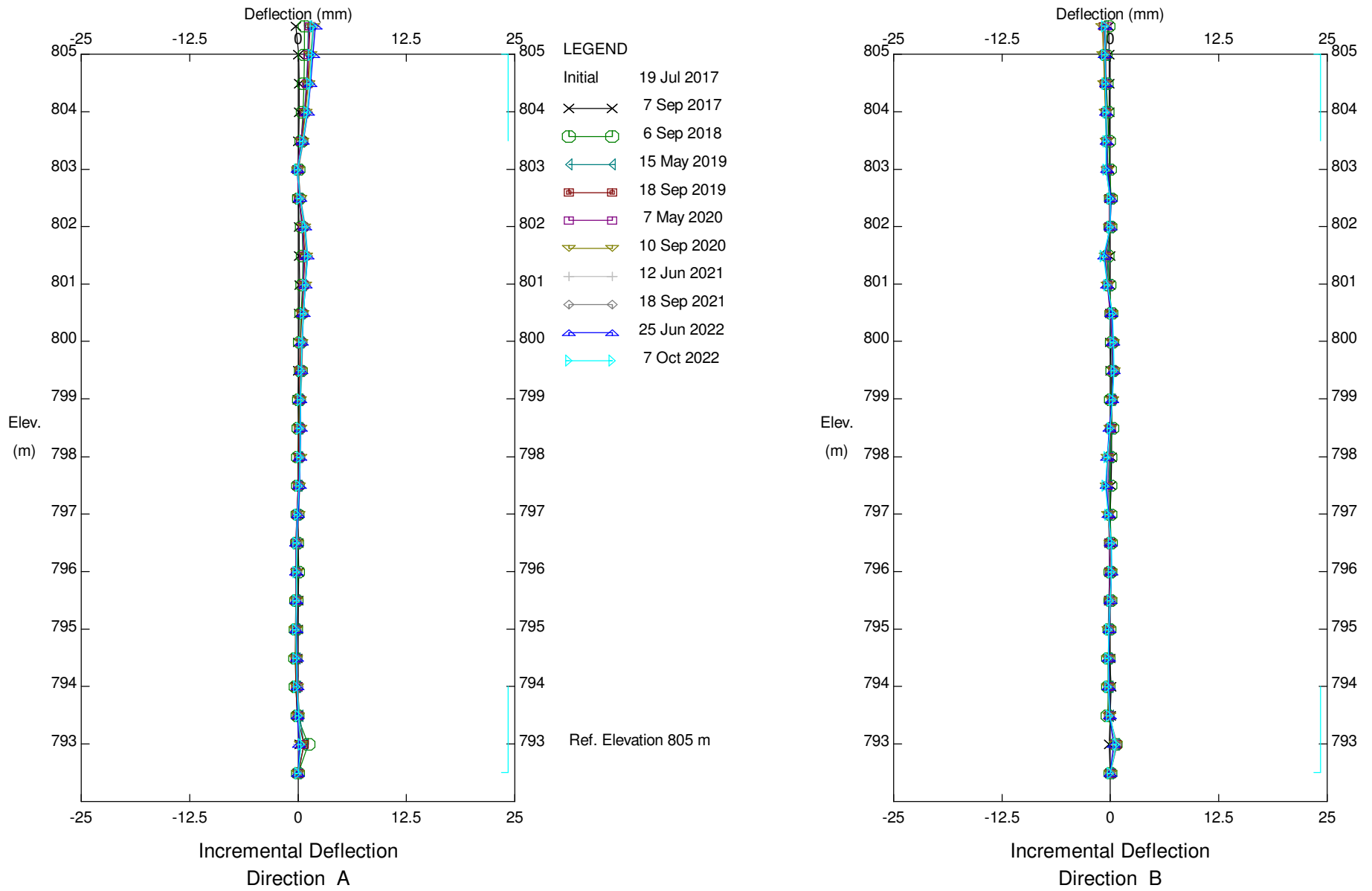


C067; H21:14, Kneehill Creek Slide, Inclinometer SI17-C67-05

Alberta Transportation

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

# Klohn Crippen Berger - Calgary

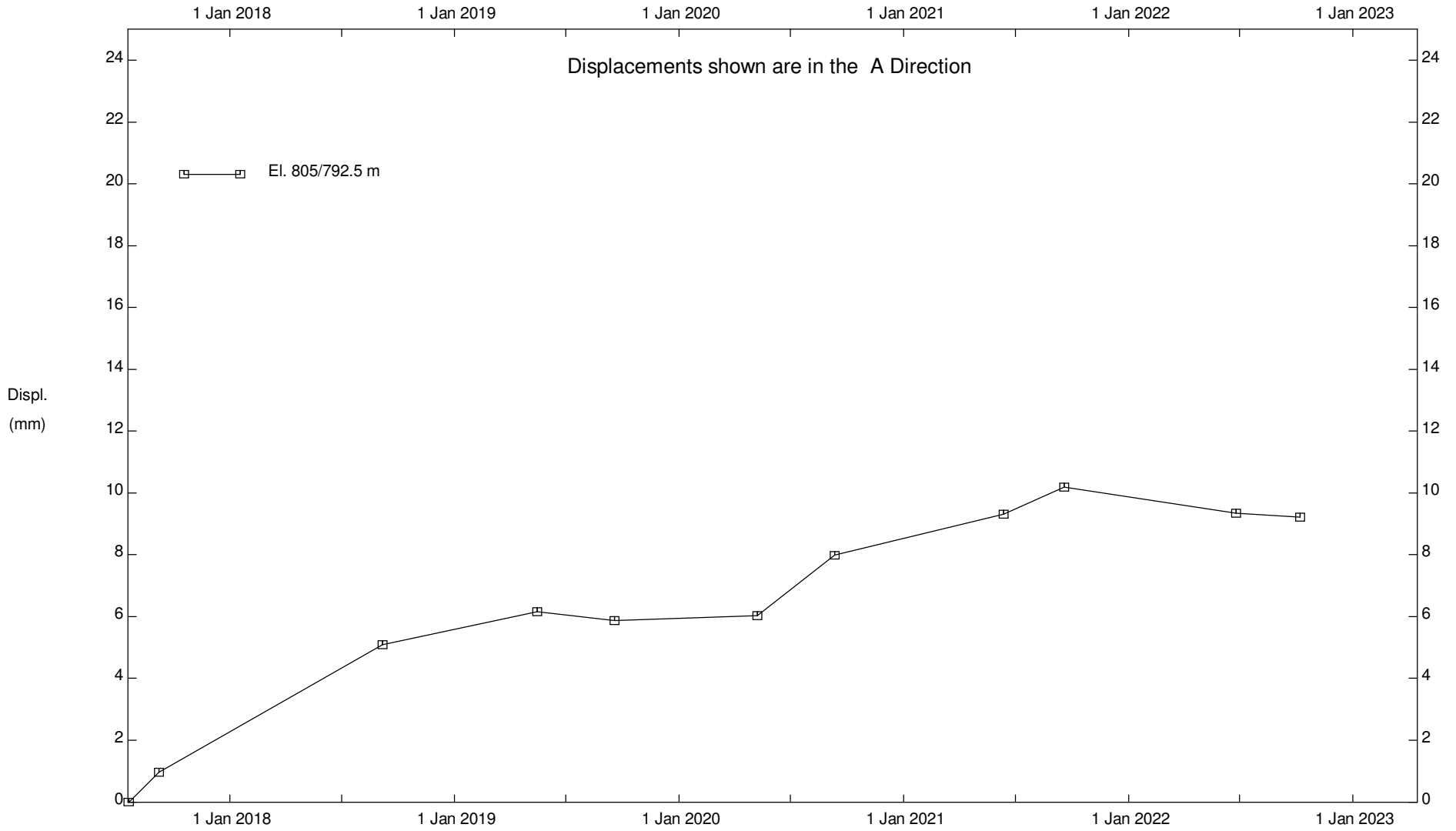


C067; H21:14, Kneehill Creek Slide, Inclinator SI17-C67-05

Alberta Transportation

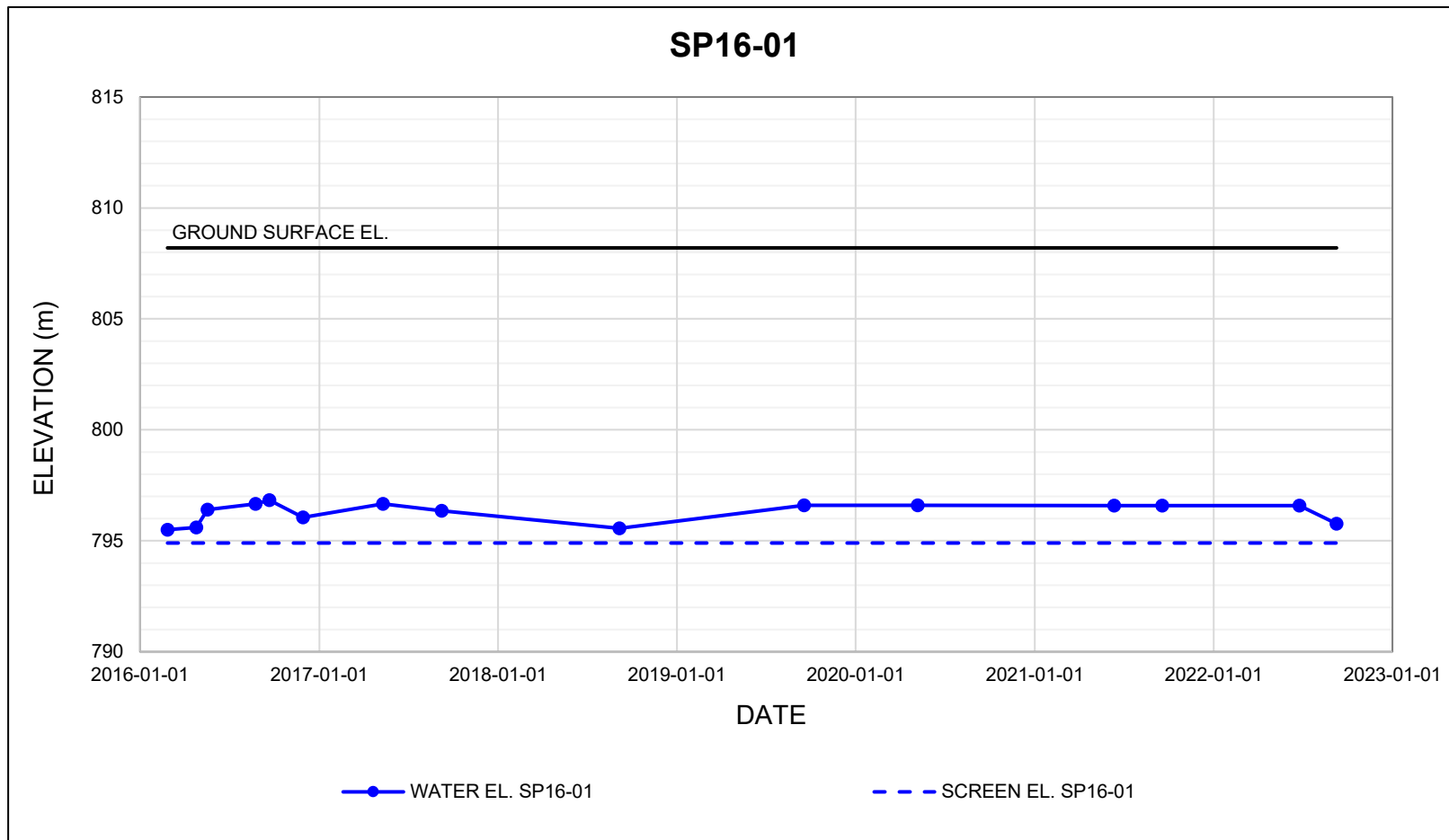
Instrument re-initialized in July 2017 when the SI equipment was changed.

Klohn Crippen Berger - Calgary





C067; H21:14, Kneehill Creek Slide, Inclinometer SI17-C67-05

Alberta Transportation



**NOTES:**

1. GROUND SURFACE ELEVATION OBTAINED WITH A HANDHELD GPS DURING 2017 INSTRUMENT INSTALLATION PROGRAM.

CLIENT 	PROJECT CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM	
	TITLE Piezometer Data C067 - Kneehill Creek Slide Hwy 21:14, km 12.988	
	SCALE	PROJECT No. A05116A02
	FIG No.	