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 C065; H585:02, km 16.136 East of Trochu Slides
Section C – 2024 Spring Readings

1 GENERAL

Five slope inclinometers (SIs) (SI17-C65-01 and SI17-C65-02, and SI21-C65-01 through SI21-C65-03) and four vibrating wire piezometers (VWPs) (VW36843, VW42622, VW45895, and VW45897) were read at the C065 site in the Central Region on May 15, 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 585:02, km 16.136, approximately 13 km east of Trochu, Alberta and 2 km west of the Tolman Bridge, which crosses the Red Deer River. The approximate site coordinates are 5746288 N, 359329 E (UTM Zone 12, NAD 83). A site plan is presented in Figure 1.

The C065 site consists of several geohazard subsites along an approximate 1 km length of Hwy 585:02. The subsites include: C065-1 (Original Slide), C065-2 (Pavement Dips), C065-3 (Wasp Nest Slide), C065-4 (Upper Slide 1), and C065-5 (Upper Slide 2). The geohazards consist of valley slope and embankment fill slides, and subsidence features associated with dispersive soils beneath the highway. Ongoing asphalt patching paving and guardrail maintenance has been required at the site.

In October 2017, KCB conducted a geotechnical site investigation at the C065 site to support design and construction work. Drilling was completed by Mobile Augers & Research Ltd. The encountered stratigraphy was as follows: asphalt, overlying variable embankment fill, overlying variable foundation materials (e.g., dispersive soils or silty clay colluvium), overlying bedrock (e.g., coal, claystone, siltstone, and/or sandstone).

In 2021, the following remedial actions were completed:

- In March 2021, two H-pile walls (HP360x132) were installed at the C065-4 and C065-5 sites. The H-pile wall at the C065-4 (Upper Slide 1) site was 10-m-deep, 33-m-long, and consisted of

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56 piles. The H-pile wall at the C065-5 (Upper Slide 2) site was 10-m-deep, 16-m-long, and consisted of 27 piles.

- In August 2021, the highway embankment at the C065-1 site was reconstructed with geogrid-reinforced granular fill and a shear key. A 200-mm-diameter perforated drainpipe was also installed at the base of the shear key excavation to improve embankment drainage.
- Between August and October 2021, the upper 1 m of the highway embankment at the C065-2 site was excavated and reconstructed with geogrid-reinforced granular fill. Drainage improvements to the ditches were also made, including excavating and replacing material along the ditch bottom and installation of a 600-mm-diameter corrugated-steel-pipe (CSP) culvert below the highway.
- Between September and October 2021, the existing 1000-mm-diameter centre-line CSP culvert at the C065-3 site was replaced, and a gabion-basket inlet structure and riprap apron were constructed at the culvert inlet and outlet, respectively.

The H-pile walls installed in early-2021 were completed under TEC Contract No. CON0021394 and the C065-1 through C065-3 repairs were completed in late-2021 under TEC Contract No. CON0021408. Final details reports were issued to TEC on October 12, 2022 and August 22, 2022, respectively.

1.1 Instrumentation

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

In October 2017, KCB installed three SIs (SI17-C65-01 through SI17-C65-03) and six VWPs (VW45894 through VW45897, VW42622, and VW36843) at the C065-1, C065-3, and C065-4 subsites to monitor depth of movement and ground water conditions, respectively. The instruments were installed in boreholes located in the north (westbound) lane of Hwy 585:02 and are protected by flush-mounted casing protectors. In August 2021, instrumentation at the C065-1 site (SI17-C65-03, VW45894, and VW45896) was removed during 2021 construction.

In March 2021, three SIs (SI21-C65-01 through SI21-C65-03) were installed to monitor deflections of the H-pile walls at the C065-4 and C065-5 subsites. SI21-C65-01 and SI21-C65-02 are located approximately one-third (11 m) from either end of the H-pile wall at the C065-4 site. SI21-C65-03 is located approximately in the middle of the H-pile wall at the C065-5 site. Each SI was installed in the H-pile walls, 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 fine-grained sand.

The pile-wall SIs installed 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 installed.

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

Table 1.1 Instrumentation Installation Details

Instrument ID	Instrument Type	Site	Date Installed	UTM Coordinates[1] (m)		Ground Surface Elevation[1] (m)	Stick Up (m)	Depth (mbgs[2])	Condition
				Northing	Easting				
SI17-C65-01	SI	C065-4	Oct. 06, 2017	5746035	358741	823.0	-0.2	15.0	Operable
SI17-C65-02	SI	C065-3	Oct. 07, 2017	5746105	358828	816.5	-0.1	13.6	Operable
~~SI17-C65-03~~	~~SI~~	~~C065-1~~	~~Oct. 08, 2017~~	~~5746294~~	~~359524~~	~~765.5~~	~~-0.1~~	~~9.4~~	~~Inoperable~~[3]
SI21-C65-01	SI	C065-4	Mar. 30, 2021	5746041	358747	Unknown	1.1	9.6	Operable
SI21-C65-02	SI	C065-4	Mar. 30, 2021	5746033	358739	Unknown	0.8	9.4	Operable
SI21-C65-03	SI	C065-5	Mar. 30, 2021	5745789	358604	Unknown	0.7	10.0	Operable
~~VW45894~~	~~VWP~~	~~C065-1~~	~~Oct. 08, 2017~~	~~5746294~~	~~359524~~	~~765.5~~	~~N/A~~	~~4.8~~	~~Inoperable~~[3]
VW45895	VWP	C065-3	Oct. 07, 2017	5746105	358828	816.5	N/A	5.2	Operable
~~VW45896~~	~~VWP~~	~~C065-1~~	~~Oct. 08, 2017~~	~~5746294~~	~~359524~~	~~765.5~~	~~N/A~~	~~9.2~~	~~Inoperable~~[3]
VW45897	VWP	C065-3	Oct. 07, 2017	5746105	358828	816.5	N/A	13.4	Operable
VW42622	VWP	C065-4	Oct. 06, 2017	5746035	358741	823.0	N/A	2.7	Operable, but dry
VW36843	VWP	C065-4	Oct. 06, 2017	5746035	358741	823.0	N/A	14.8	Operable

Notes:
[1] Coordinates and ground surface elevations have not been surveyed and were estimated from September 2017 survey data.
[2] Meters below ground surface (mbgs).
[3] SI17-C65-03, VW45894, and VW45896 were removed during 2021 construction.

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, where applicable, the X-direction (i.e., the direction of maximum movement obtained at a skew angle from the A0-grooves). The A0-grooves of all the SIs are aligned approximately perpendicular to the highway. SI17-C65-02 has a skew angle of 285°, measured clockwise from the direction of the A0-grooves.

For the operable VWPs, 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 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.

Table 2.1 Slope Inclinometer Reading Summary

Instrument ID	Site No.	Date				Ground Surface Elevation (m)	Depth of Movement (mbgs[1])	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-C65-01	C065-4	Oct. 18, 2017	N/A – no discernible movement recorded	Sep. 20, 2023	May 15, 2024	823.0	N/A – no discernible movement recorded						
SI17-C65-02	C065-3	Oct. 18, 2017	Sep. 20, 2023	Sep. 20, 2023	May 15, 2024	816.5	4.9 – 7.9	X-Direction, 285°	86.3	3.2	69.0	4.9	4.2
~~SI17-C65-03[2]~~	~~C065-1~~	~~Oct. 18, 2017~~	~~May 22, 2018~~	~~May 15, 2019~~	~~N/A – inoperable[2]~~	~~765.5~~	~~1.9 – 3.4~~	~~X-Direction, 47°~~	~~7.1~~	~~N/A – inoperable[2]~~	~~25.1~~	~~N/A – inoperable[2]~~	
SI21-C65-01	C065-4	Apr. 21, 2021	N/A – no discernible movement recorded	Sep. 20, 2023	May 15, 2024	Unknown	N/A – no discernible movement recorded						
SI21-C65-02	C065-4	Apr. 21, 2021	Sep. 20, 2023	Sep. 20, 2023	May 15, 2024	Unknown	0.0 – 8.5	A-Direction	6.2	0.0	10.7	0.0	-5.7
SI21-C65-03	C065-5	Apr. 21, 2021	Sep. 20, 2023	Sep. 20, 2023	May 15, 2024	Unknown	0.5 – 9.0	A-Direction	11.040	1.4	9.5	2.1	-2.0

Notes:
[1] Meters below ground surface (mbgs).
[2] SI17-C65-03 was removed during 2021 construction.
[3] Skew angle of X-direction measured clockwise from the A-direction.

Table 2.2 Vibrating Wire Piezometer Reading Summary

Instrument ID	Site 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)
~~VW45894~~	~~C065-1~~	~~Oct. 08, 2017~~	~~May 15, 2019~~	~~N/A – inoperable[2]~~	~~765.5~~	~~4.8~~	~~N/A – inoperable[2]~~		
~~VW45896~~	~~C065-1~~	~~Oct. 08, 2017~~	~~May 15, 2019~~	~~N/A – inoperable[2]~~	~~765.5~~	~~9.2~~			
VW45895	C065-3	Oct. 07, 2017	Sep. 20, 2023	May 15, 2024	816.5	5.2	3.0	3.3	-0.3
VW45897	C065-3	Oct. 07, 2017	Sep. 20, 2023	May 15, 2024	816.5	13.4	4.2	4.2	0.0
VW42622	C065-4	Oct. 07, 2017	Sep. 20, 2023	May 15, 2024	823.0	2.7	4.3	4.4	-0.1
VW36843	C065-4	Oct. 07, 2017	Sep. 20, 2023	May 15, 2024	823.0	14.8	9.9	9.9	0.0

Notes:
[1] Meters below ground surface (mbgs).
[2] VW45894 and VW45896 were removed during 2021 construction.

2.2 Zones of Movement

2.2.1 C065-1 (Original Slide)

Before SI17-C65-03 was removed in August 2021 during construction, distributed movement was being recorded from ground surface to an approximate depth of 3.4 m below ground surface, in the fill and underlying high-plastic clay. There are currently no operable SIs at C065-1.

2.2.2 C065-3 (Wasp Nest Slide)

Prior to the start of construction at the C065-3 site in September 2021, signs of slope movement, including tension cracks, were noted just east of the culvert outlet channel, north of the highway. The slope was noted to have slumped partially into the culvert outlet channel and a series of tension cracks were observed at the crest of the slope. This area was graded to a flatter slope during 2021 construction.

Discrete movement (i.e., movement occurring on a defined failure plane) is being recorded in SI17-C65-02 between an approximate depth of 5.0 m to 7.5 m below ground surface, at the interface between clay colluvium and bedrock. Since June 2021, a pinch has been felt in the SI casing at this depth when reading the instrument.

2.2.3 C065-4 (Upper Slide 1)

No discernible movement has been recorded in SI17-C65-01 since installation, excluding shallow deflection in the upper 3 m of the instrument. No discernible movement has been recorded in SI21-C65-01.

Distributed movement has been recorded in SI21-C65-02 from ground surface approximately 1 m above the base of the instrument.

The H-pile wall is 10 m deep, and SI21-C65-01 and SI21-C65-02 are approximately 9.6 m and 9.4 m deep, respectively.

2.2.4 C065-5 (Upper Slide 2)

Distributed movement has been recorded in SI21-C65-03 from ground surface to approximately 2 m above the base of the instrument.

The H-pile wall and SI21-C65-03 are both 10 m deep.

2.3 Interpretation of Monitoring Results

2.3.1 C065-1 (Original Slide)

In August 2021, the C065-1 site was repaired, and all instrumentation was removed. No pavement distress (i.e., cracking and/or settlement) has been observed since 2021 construction, indicating that the repair is performing well.

2.3.2 C065-3 (Wasp Nest Slide)

In September 2020 and 2021, an increased rate of movement (approximately 69 mm/year and 45 mm/year, respectively) was recorded in SI17-C65-02. The increase is 2020 was most likely attributed to wet weather, while the 2021 increase was likely due to construction activities at the C065 site (e.g., heavy truck traffic, increased traffic in the north (westbound) lane during south (eastbound) lane closures, and channel excavation at the C065-3 site).

Since 2021 construction, the rate of movement has decreased (excluding an increased of a movement recorded in September 2022 of approximately 20 mm/year) and is currently less than approximately 5 mm/year. The increased rate of movement recorded in September 2022 was most likely attributed to wet weather in June and July 2022. Movement rates may increase, or additional displacements may occur in response to periods of heavy or prolonged rainfall, resulting in higher groundwater conditions.

Approximately 86 mm of movement has been recorded in SI17-C65-02 since installation. Since the spring of 2021, a zone of tightness (i.e., pinch) has been felt during readings of this instrument from approximately 5.0 m to 7.5 m below ground surface. This instrument may shear as overall displacement at this depth increases over time.

Since installation in October 2017, water levels recorded in VW45895 and VW45897 have been relatively steady varying from 2.5 m to 3.6 m below ground surface and 2.9 m to 4.2 m below ground surface, respectively. The May 2024 readings of W45895 and VW45897 were consistent with historical trends observed in these instruments. During the 2024 Section B inspection, no additional pavement distress (settlement and/or cracking) was observed.

2.3.3 C065-4 (Upper Slide 1)

No discernible movement has been recorded in SI17-C65-01 since installation, which indicates the slide is either inactive or moving at a very slow rate of movement (i.e., within the readings accuracy of the SI equipment).

No discernible movement has been recorded in SI21-C65-01, and distributed movement has been recorded in SI21-C65-02 from ground surface to near the base of the instrument. This indicates that 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 slide mass. As movement continues in the H-pile wall, it will be eventually reflected in SI21-C65-01.

The May 2024 data obtained from the pile-wall SIs indicates that the top of the H-pile wall has deflected up to approximately 6 mm since installation. Since installation, the overall rate of movement recorded in SI21-C65-02 has been slow (less than 3 mm/year) with minimal movement being recorded over the winter months (less than approximately 1 mm/year) and increased rates of movement recorded between spring and fall (up to approximately 11 mm/year). The May 2024 readings are consistent with historical trends for the instrument.

Since installation in October 2017, water levels recorded in VW36843 have been relatively steady varying from 9.4 m to 10.1 m below ground surface. VW42622 has been dry since October 2017. The May 2024 readings of VW42622 and VW36843 were consistent with historical trends observed in these instruments.

2.3.4 C065-5 (Upper Slide 2)

Distributed movement has been recorded in the pile-wall SI (SI21-C65-03) and appears to be from ground surface to near the base of the instrument. This indicates that 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 slide mass.

The May 2024 data obtained from the pile-wall SI indicates that the top of the H-pile wall has deflected up to approximately 11 mm since installation.

In the spring of 2021, shortly after construction of the H-pile wall, the maximum rate of movement recorded in this SI was approximately 10 mm/year. Since fall of 2021, the rate of movement has been relatively steady and is currently approximately 2 mm/year. KCB anticipated that the rate of movement shortly after installation would be highest and would decrease as the H-pile wall picked up load stabilizing the sliding mass.

Distributed movement (i.e., from top to bottom of casing) up to 8 mm has also been recorded in the B-direction of SI21-C65-03. It is unknown if this movement is due to post installation SI casing flexure, shifting in the steel pocket the SIs are installed in, or flexure/twist of the H-piles that is occurring due to the H-pile wall picking up load from the sliding mass. The rate of movement being recorded in the B-direction is slow (less than 5 mm/year).

2.3.5 Influence of Seasonal Precipitation on SI Data

The rate of movement recorded in the SIs (excluding SI21-C65-02) appear to fluctuate with precipitation (i.e., higher and lower rates of movement recorded after wet and dry weather, respectively). Additional movement may occur in response to increased precipitation (i.e., heavy or prolonged rainfall) or infiltration due to freshet resulting in higher groundwater conditions.

3 RECOMMENDATIONS

3.1 Future Work

KCB recommends reducing the reading frequency of all operable instruments from twice per year (spring and fall) to once per year (spring) unless movements increase and begin to impact the highway.

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

Periodic MCI site visits should continue to assess if voids are still opening between the web and flanges of the H-piles. During the 2022 and 2023 readings, several voids were observed at the top of the H-pile wall at the C065-4 site between SI21-C65-01 and SI21-C65-02. Additional sand backfill should be placed in the existing surface voids and any new surface voids that develop.

3.2 Instrument Repairs and Maintenance

The flush-mounted headbox at BH17-C65-01 (located at the C065-4 subsite) was replaced during the spring 2024 readings by sleeving the original headbox with a smaller-diameter RST headbox.

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.

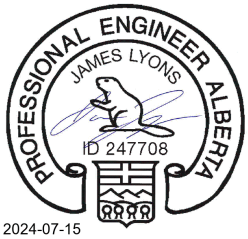
Use of or reliance upon this instrument of service by the Client is subject to the following conditions:

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.

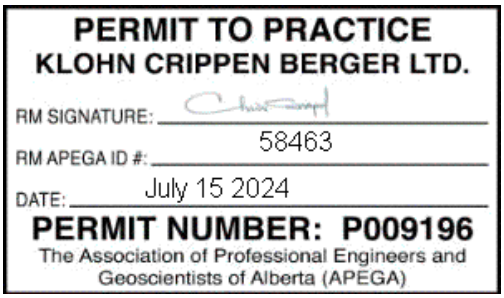


2024-07-15

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

- Vibrating Wire Piezometer (VW)
- Slope Inclinometer (SI)
- H-Pile Wall
- Scarp
- Culvert
- Crack
- Guardrail
- Erosion
- Dispersive soil void
- Possible dispersive soil void

0 200 Meters

NOTES:
1. HORIZONTAL DATUM: NAD83
2. GRID ZONE: UTM ZONE 12N
3. IMAGE SOURCE: MAXAR

CLIENT: Alberta

Klohn Crippen Berger

PROJECT: CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE: Site Plan
C065 - East of Trochu Slides
Hwy 585:02, km 16.136

SCALE	PROJECT No.	FIG No.
1:3,500	A05116A02	1

APPENDIX I

Instrumentation Plots

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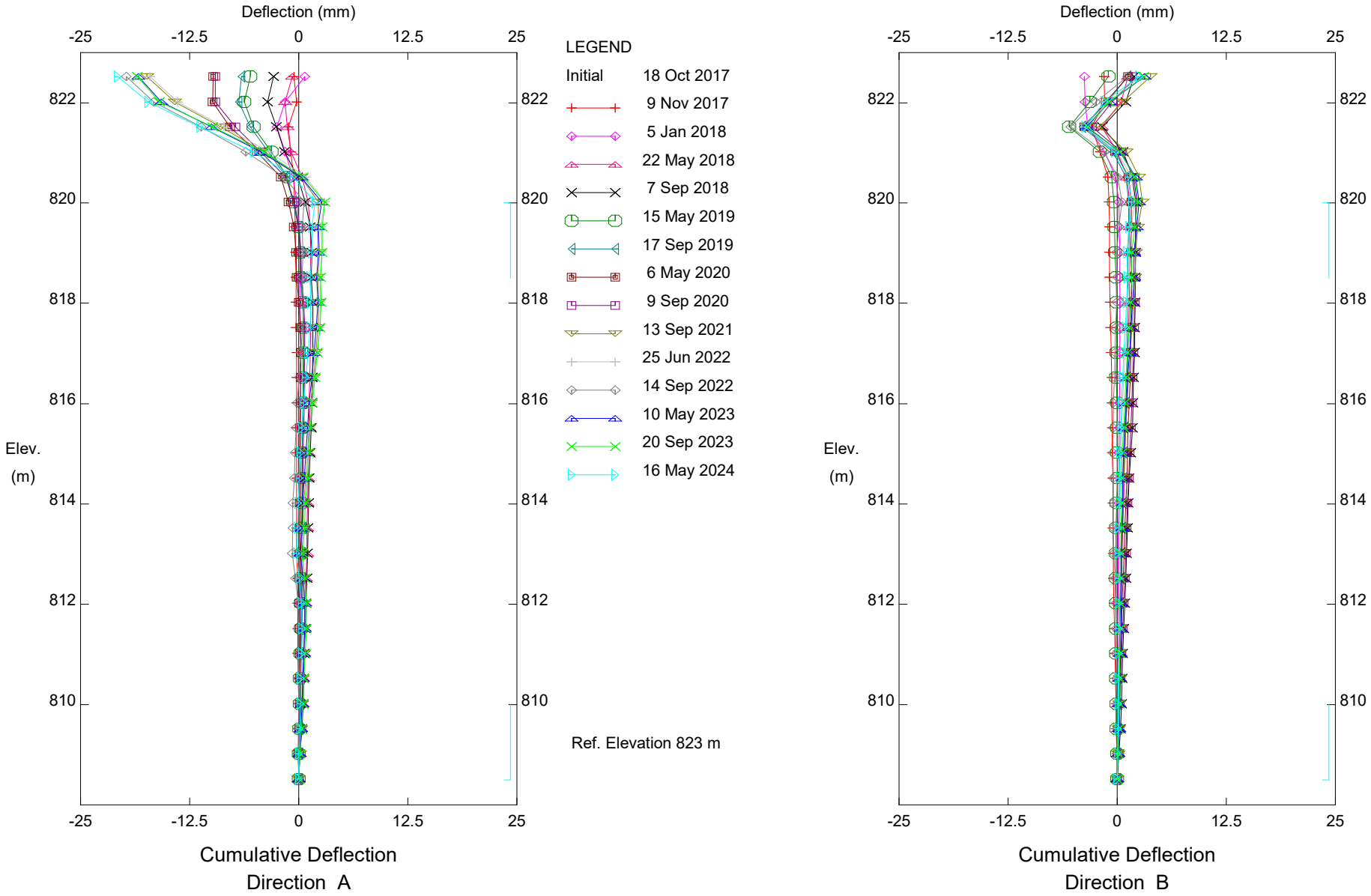

C065-IV; H585:02, East of Trochu, Inclinometer SI17-C65-01

Alberta Transportation

Read in A-Direction, Perpendicular to Highway

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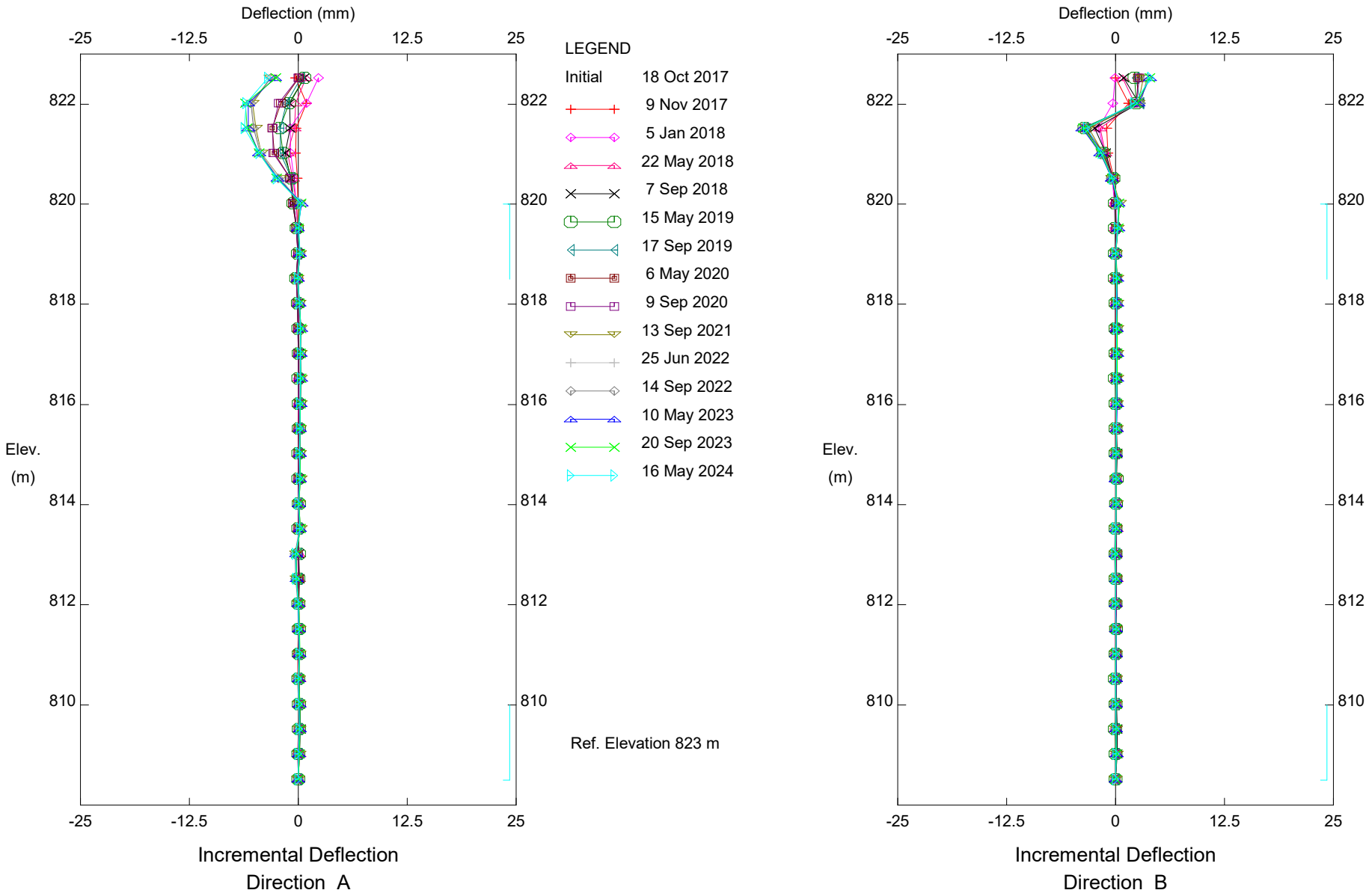
Klohn Crippen Berger - Calgary



C065-IV; H585:02, East of Trochu, Inclinometer SI17-C65-01

Alberta Transportation

Read in A-Direction, Perpendicular to Highway

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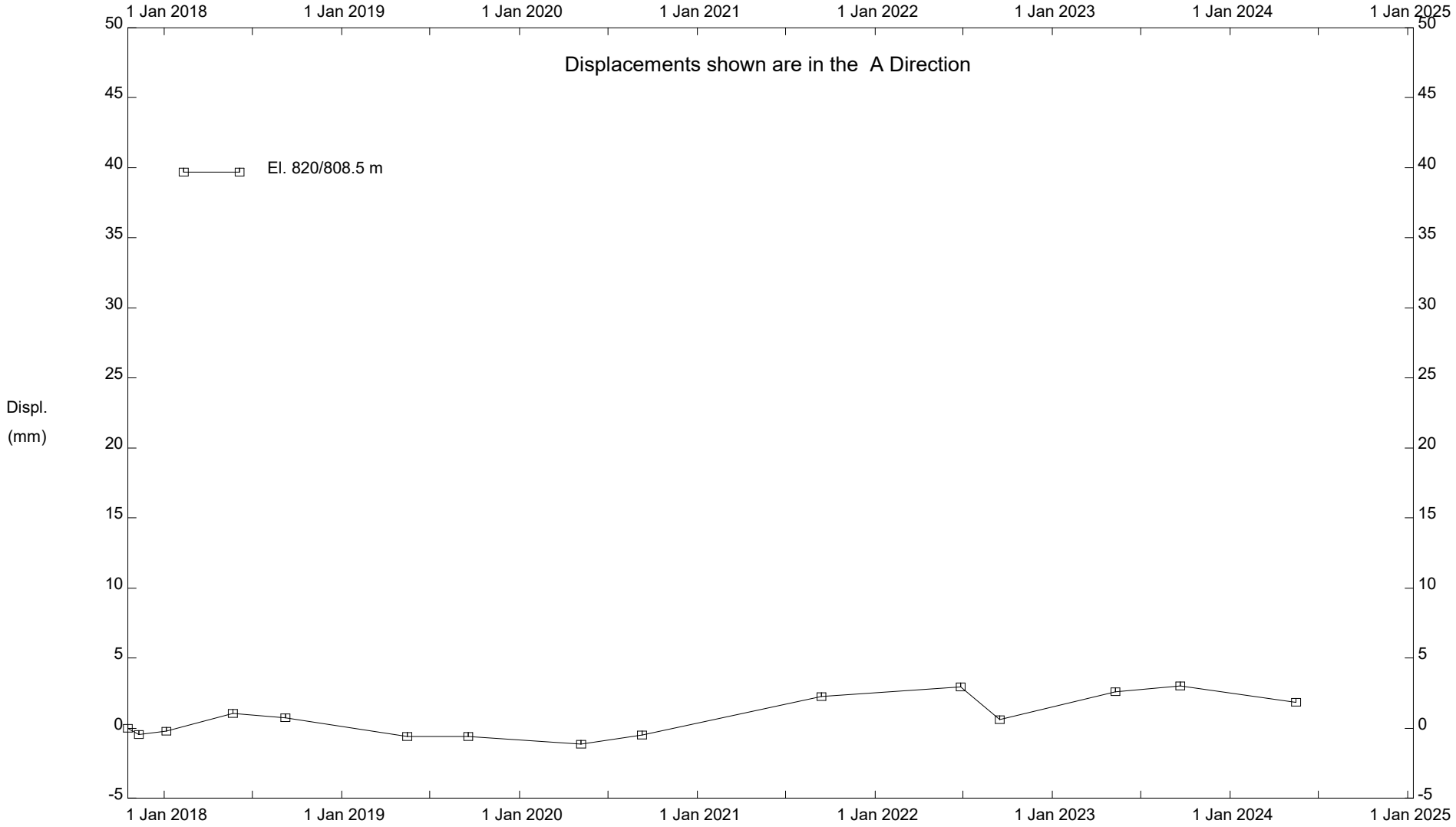
Klohn Crippen Berger - Calgary



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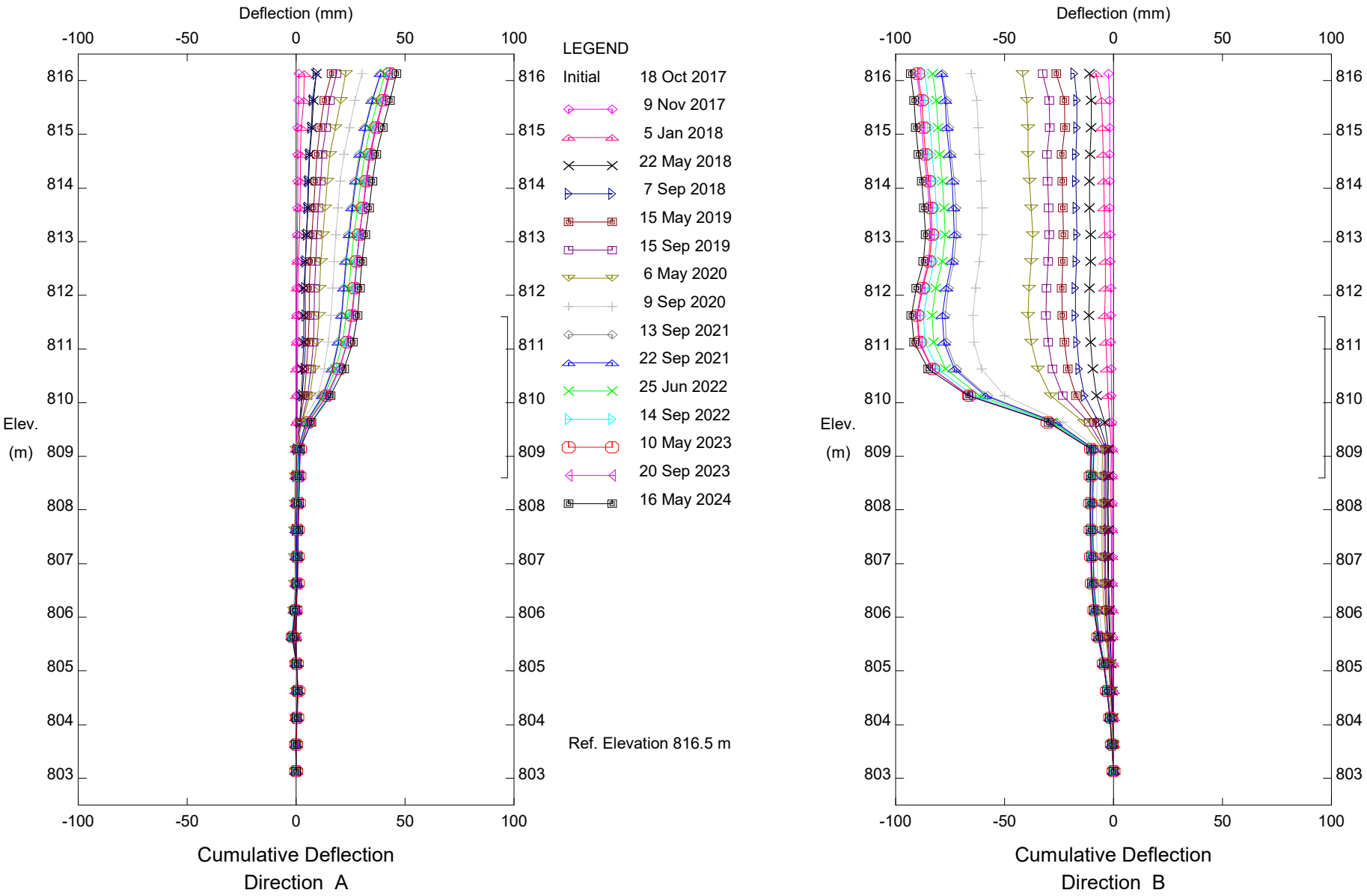

C065-III; H585:02, East of Trochu, Inclinometer SI17-C65-02

Alberta Transportation

Read in A-Direction, Perpendicular to Highway

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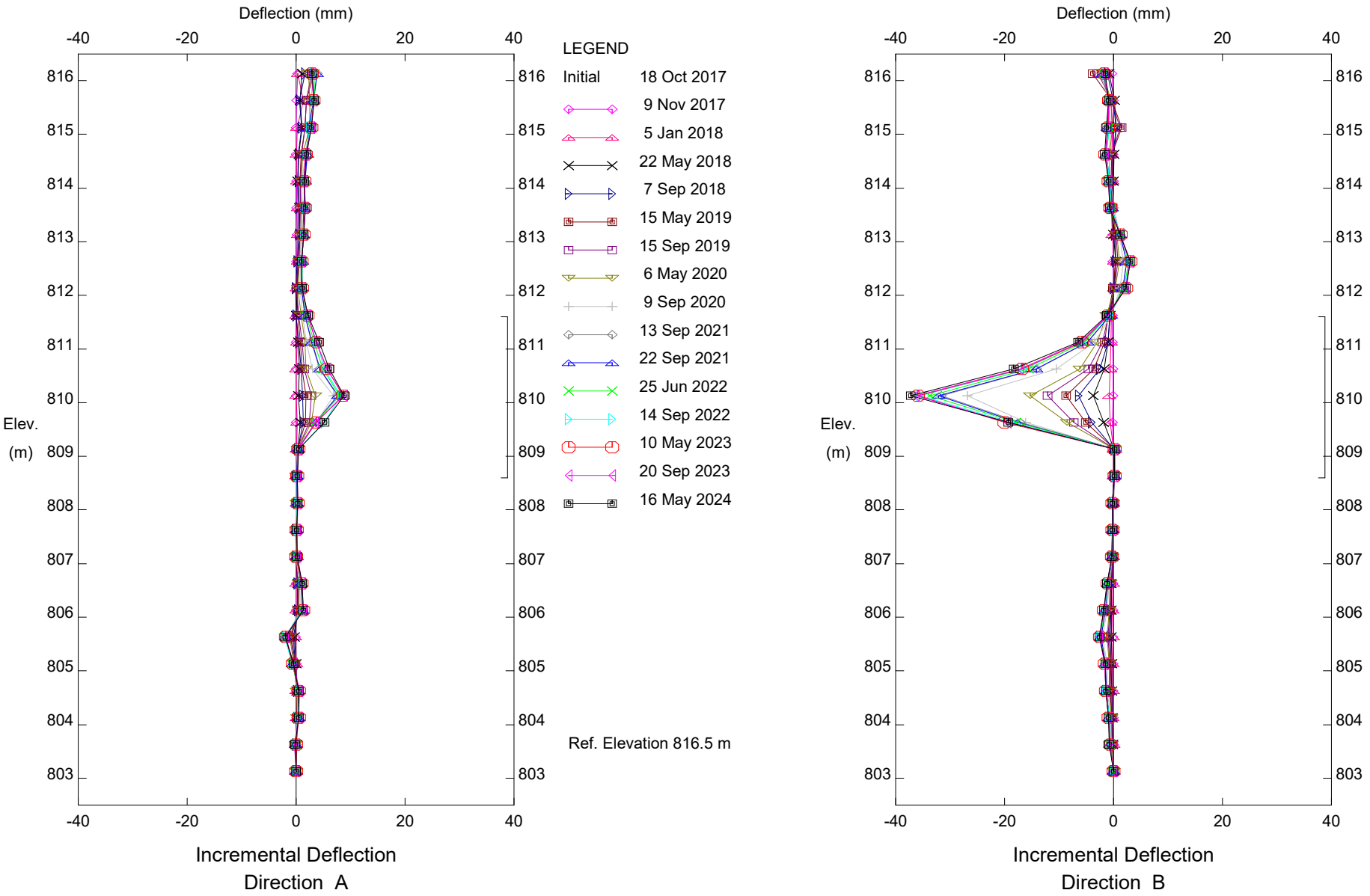
Klohn Crippen Berger - Calgary



C065-III; H585:02, East of Trochu, Inclinometer SI17-C65-02

Alberta Transportation

Read in A-Direction, Perpendicular to Highway

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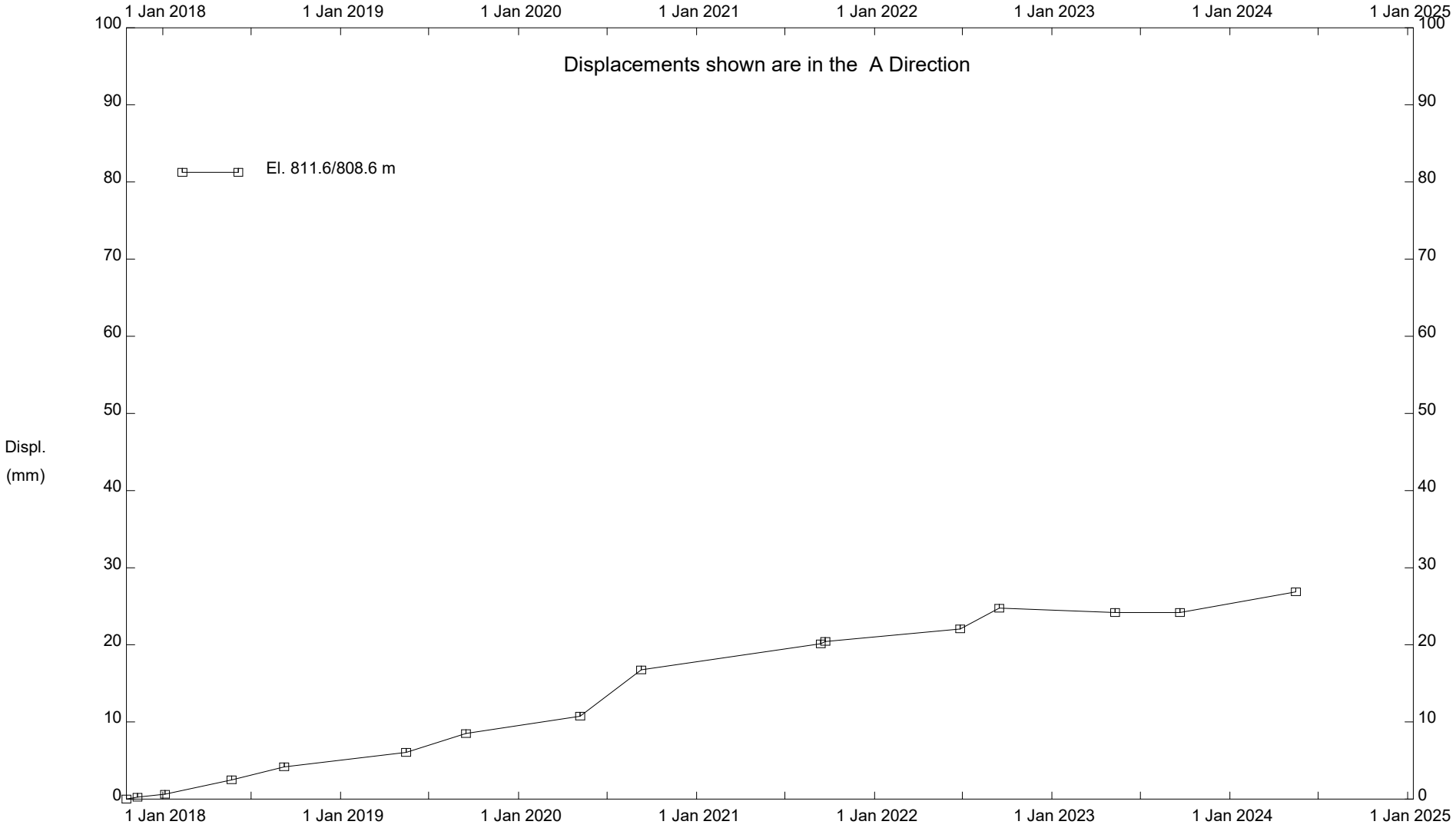

C065-III; H585:02, East of Trochu, Inclinometer SI17-C65-02

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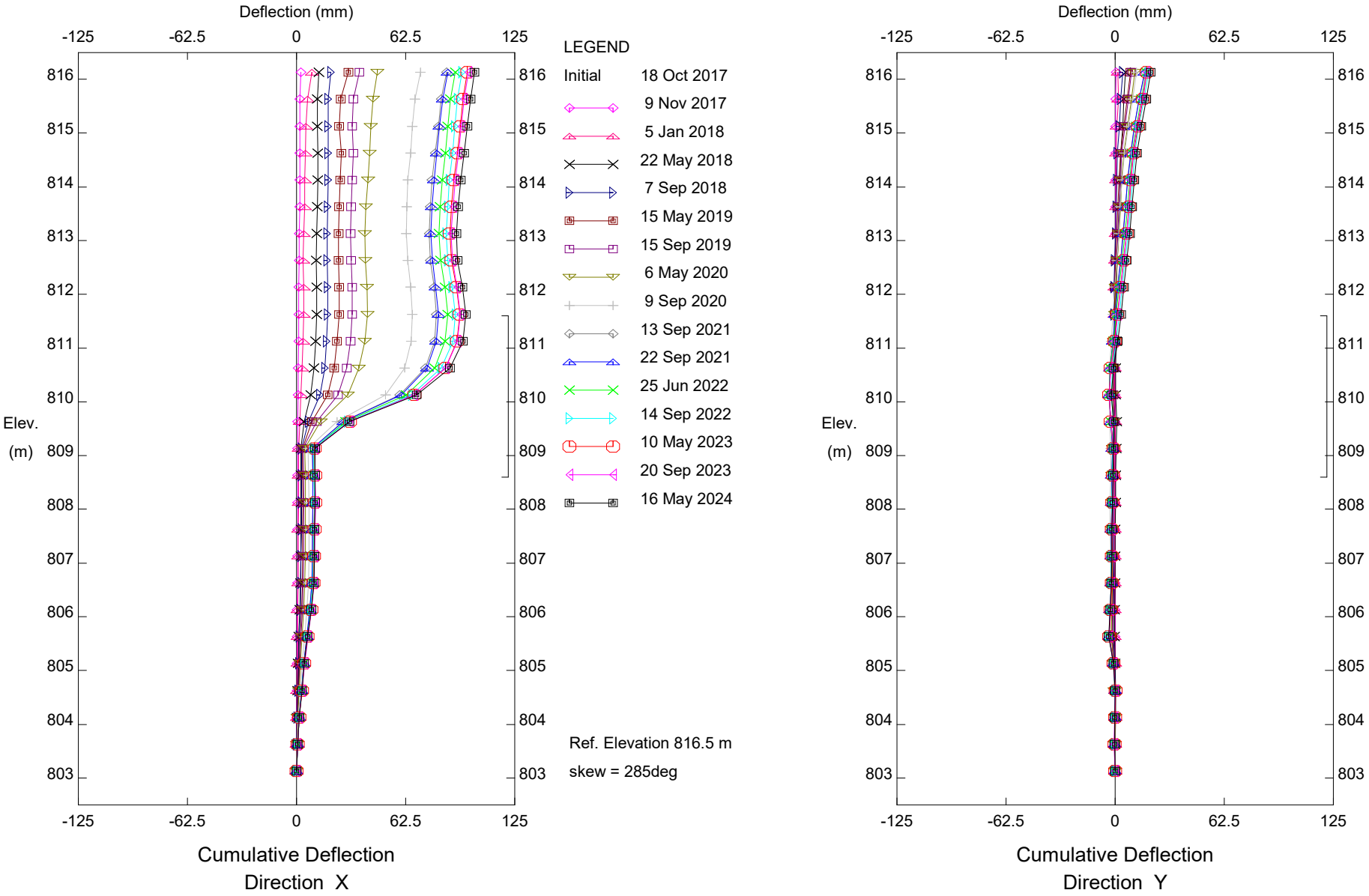

C065-III; H585:02, East of Trochu, Inclinometer SI17-C65-02

Alberta Transportation

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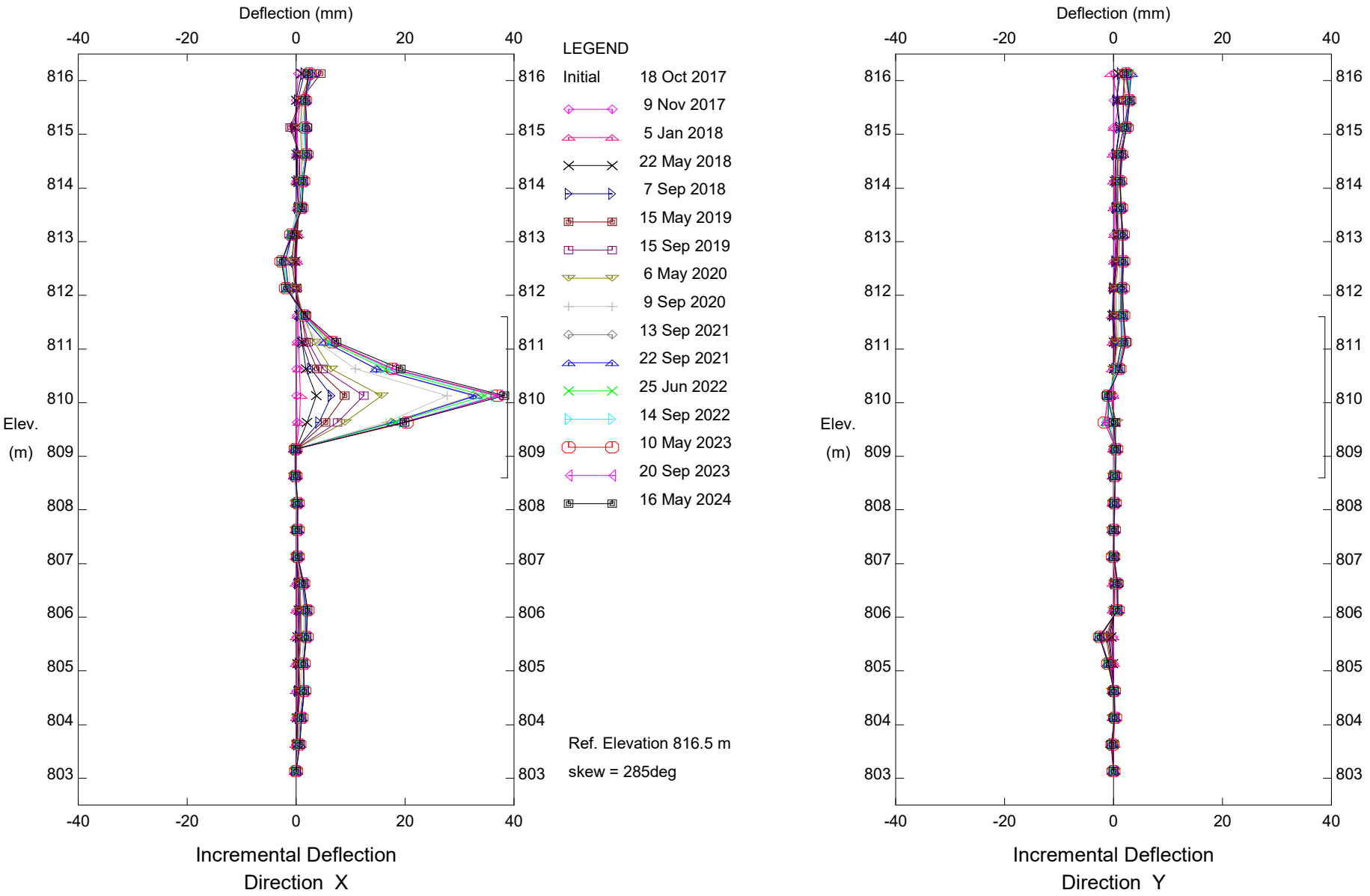
Klohn Crippen Berger - Calgary



C065-III; H585:02, East of Trochu, Inclinometer SI17-C65-02

Alberta Transportation

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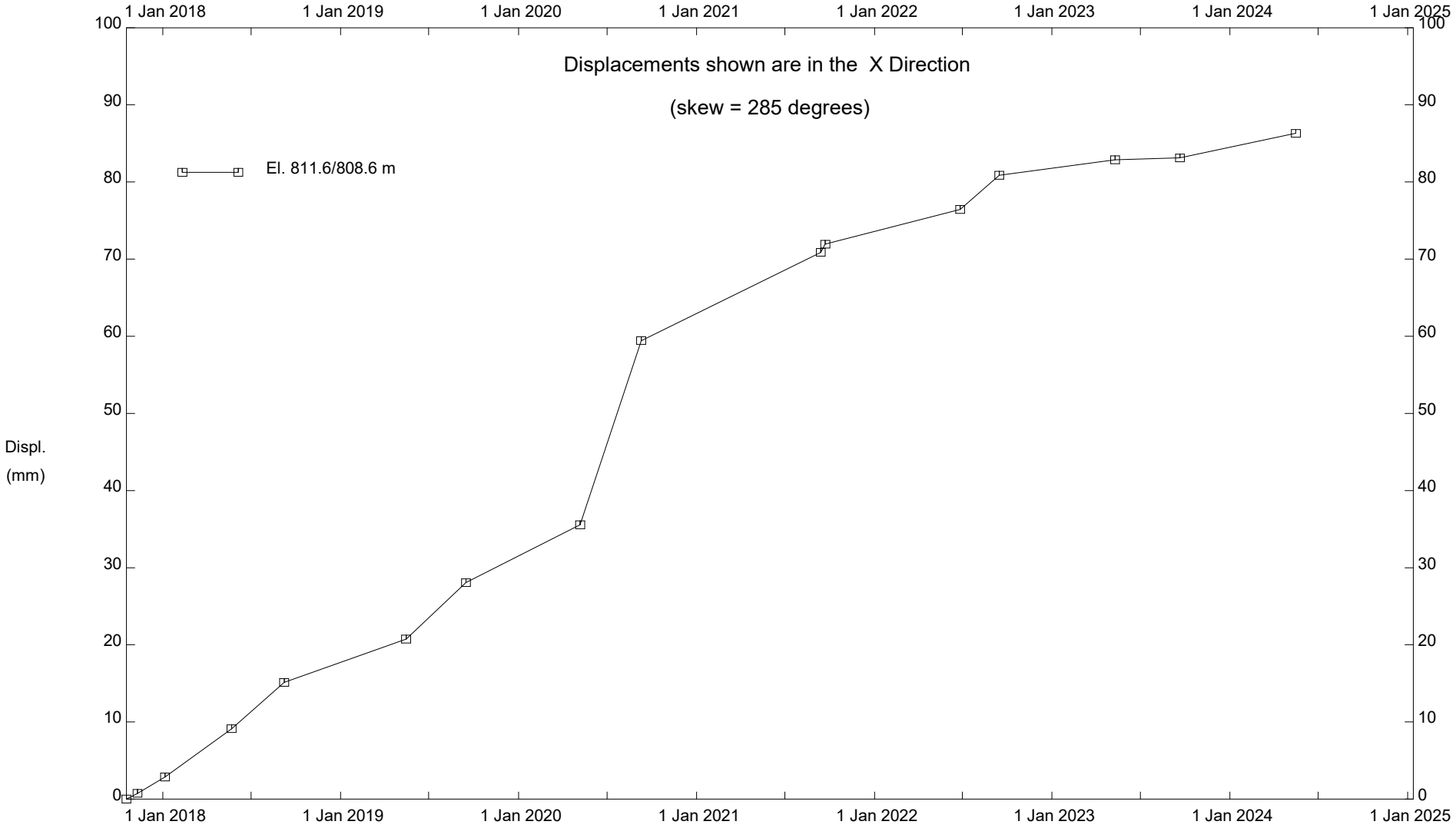
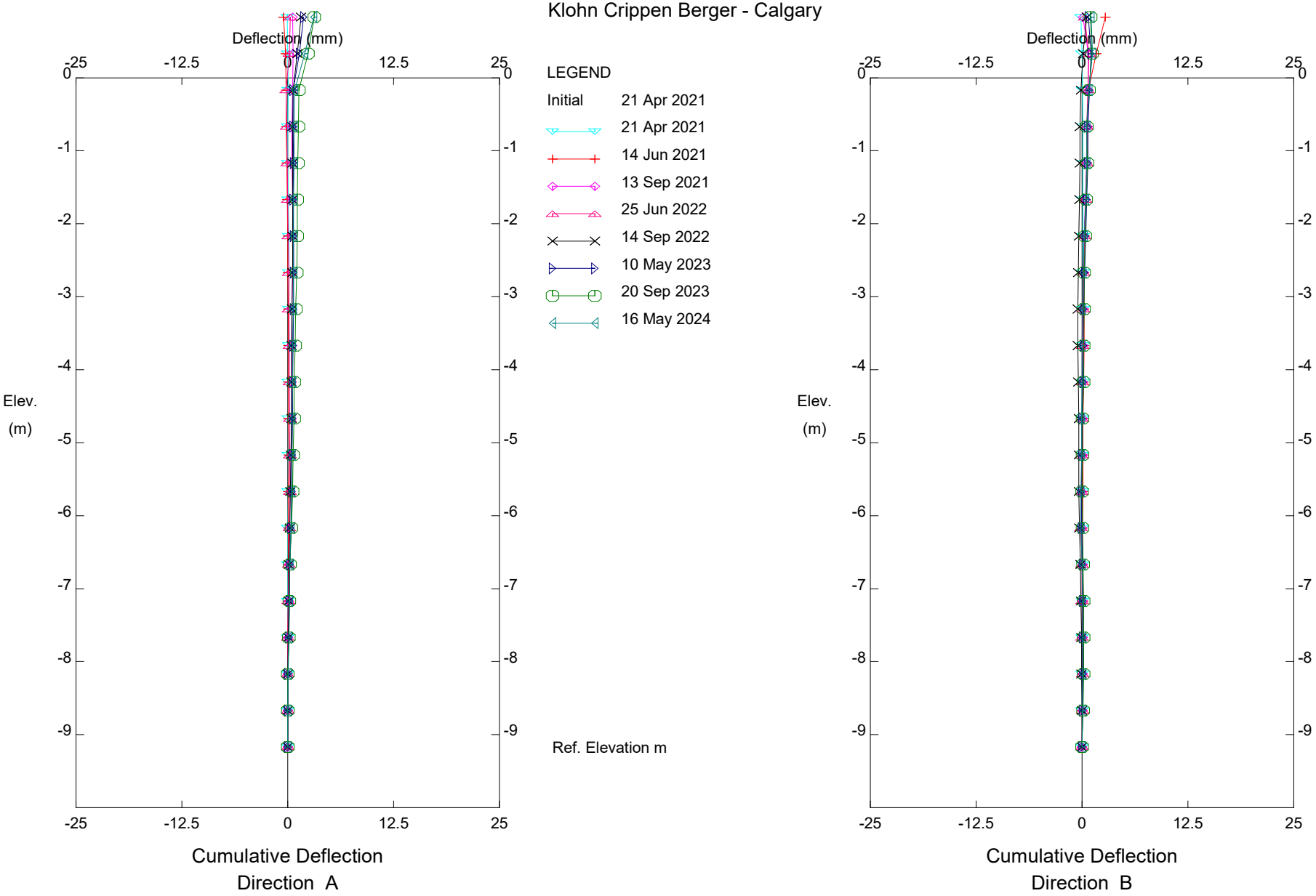
Klohn Crippen Berger - Calgary



C065-III; H585:02, East of Trochu, Inclinometer SI17-C65-02

Alberta Transportation

Klohn Crippen Berger - Calgary



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Alberta Transportation

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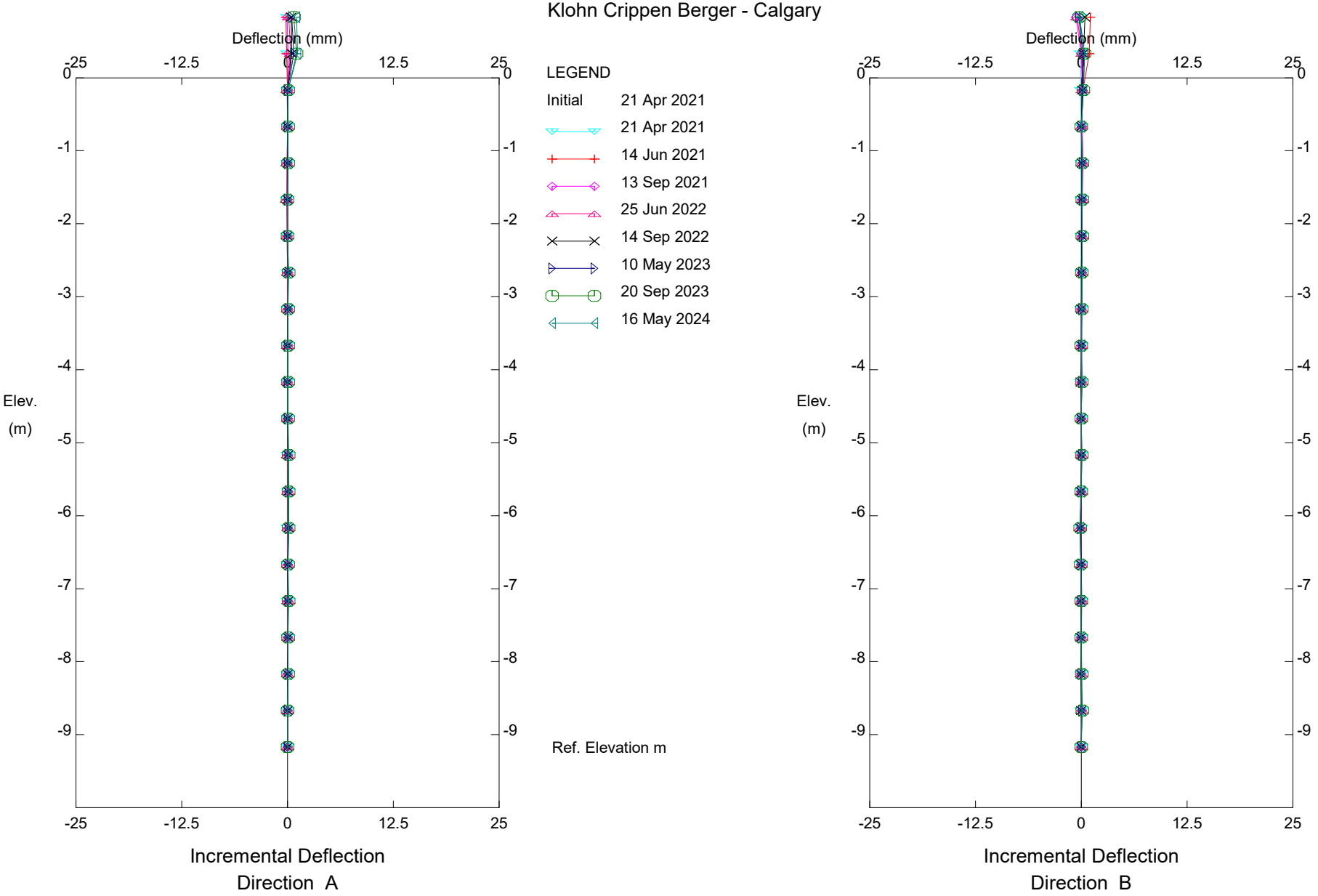
Klohn Crippen Berger - Calgary



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Alberta Transportation

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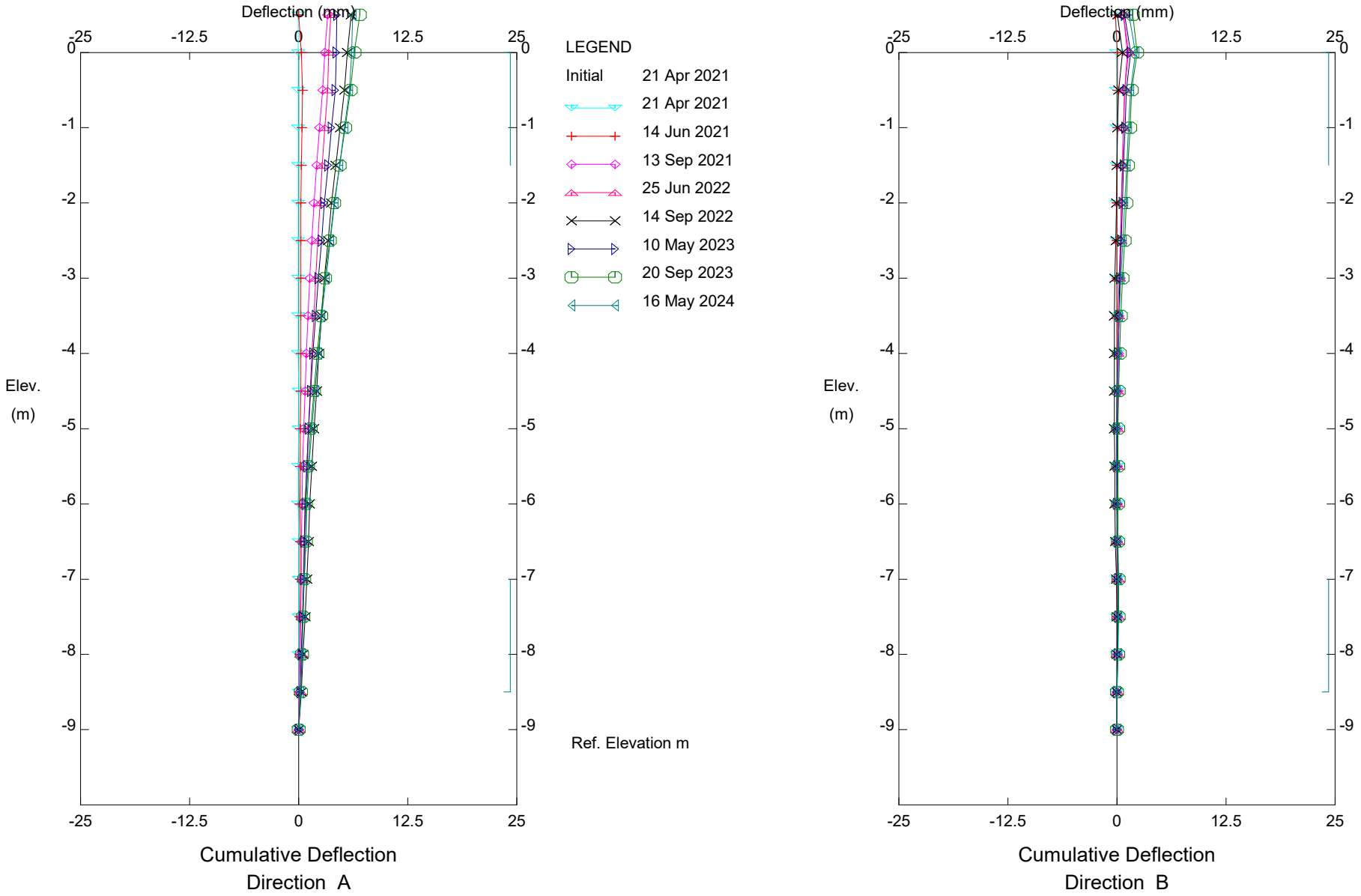
Klohn Crippen Berger - Calgary



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Alberta Transportation

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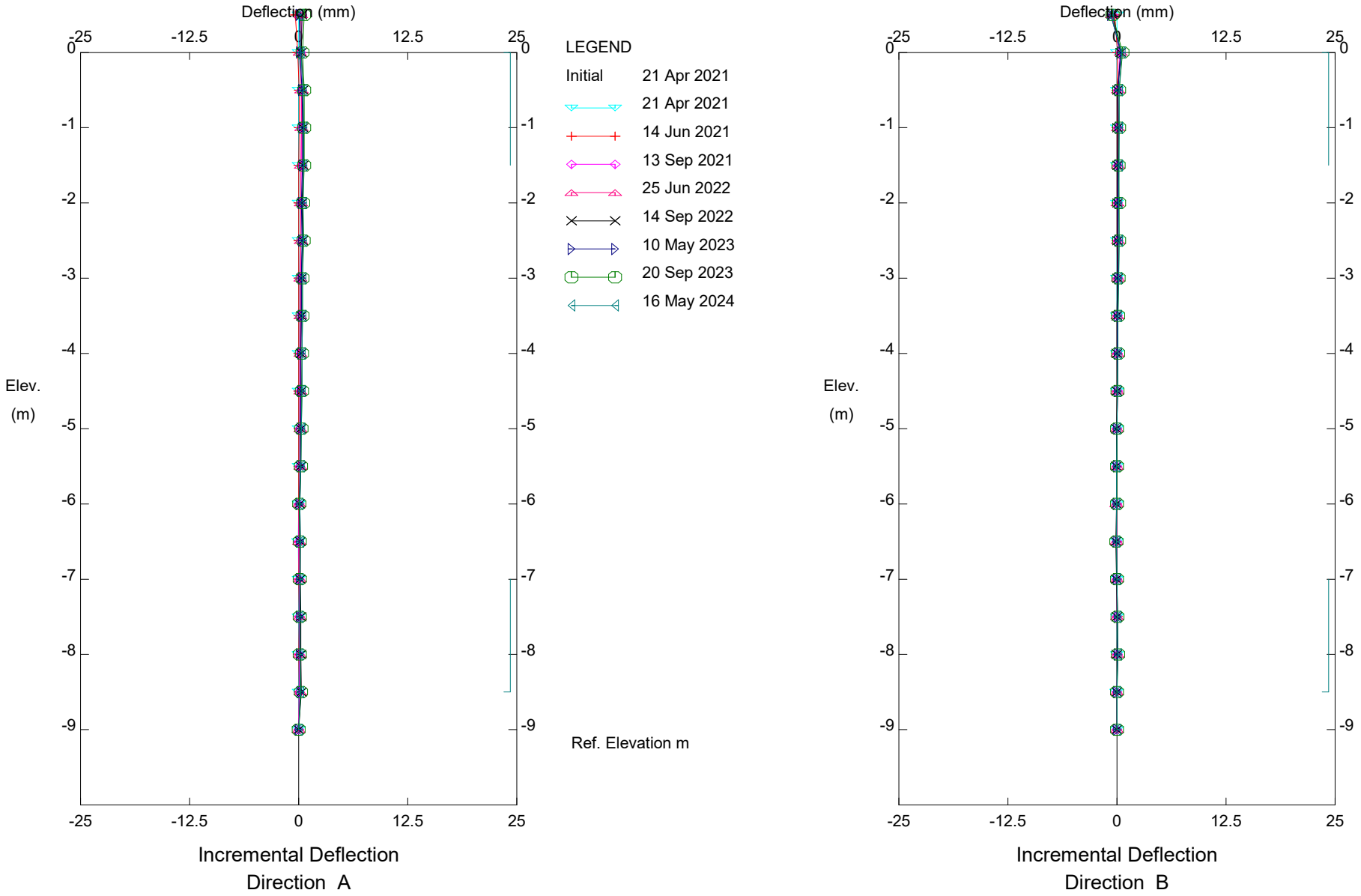
Klohn Crippen Berger - Calgary



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Alberta Transportation

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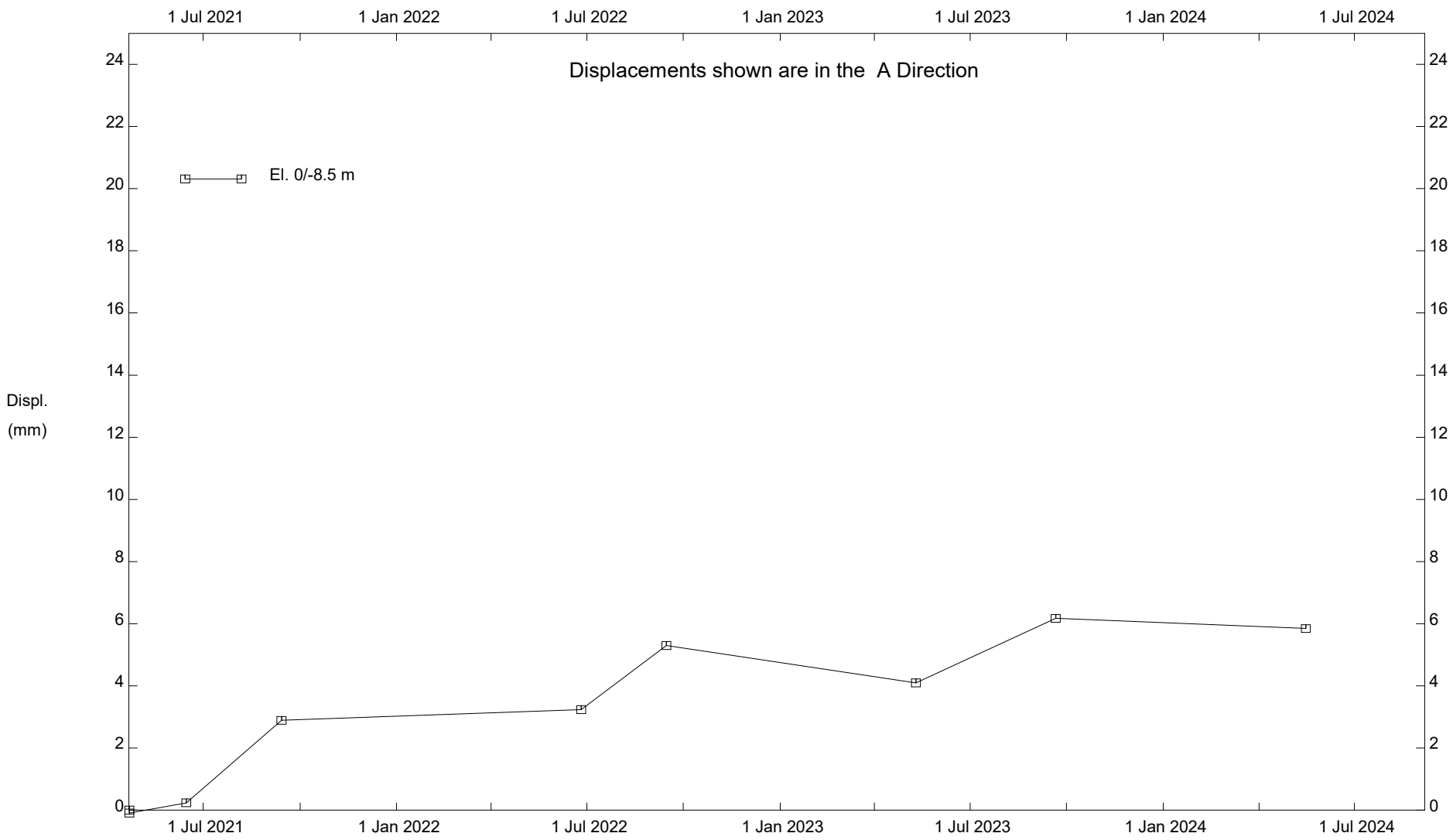
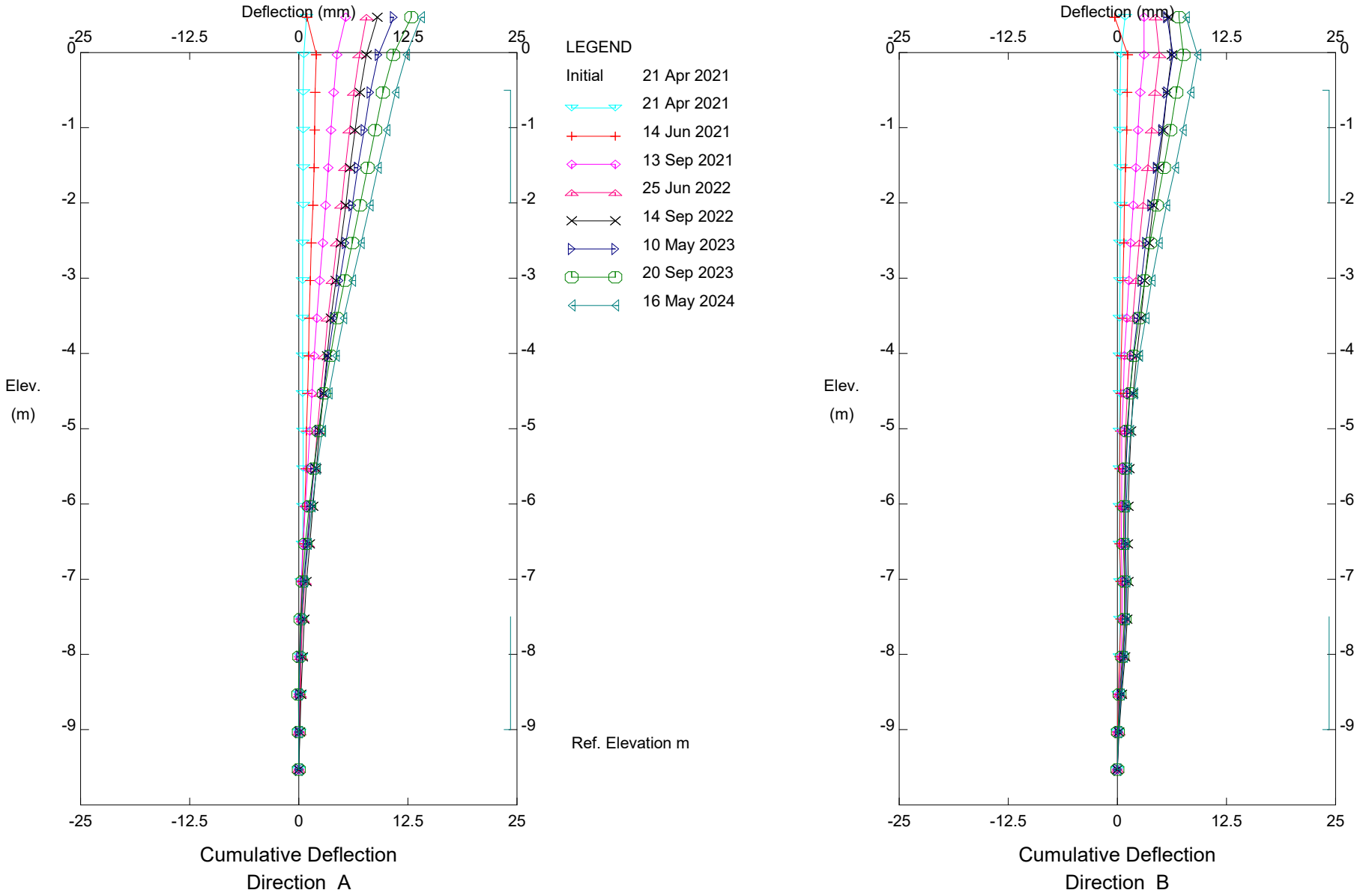
Klohn Crippen Berger - Calgary



C065-IV; H585:02, East of Trochu, Inclinometer SI21-C65-02

Alberta Transportation

Klohn Crippen Berger - Calgary



C065-V; H585:02, East of Trochu, Inclinometer SI21-C65-03

Alberta Transportation

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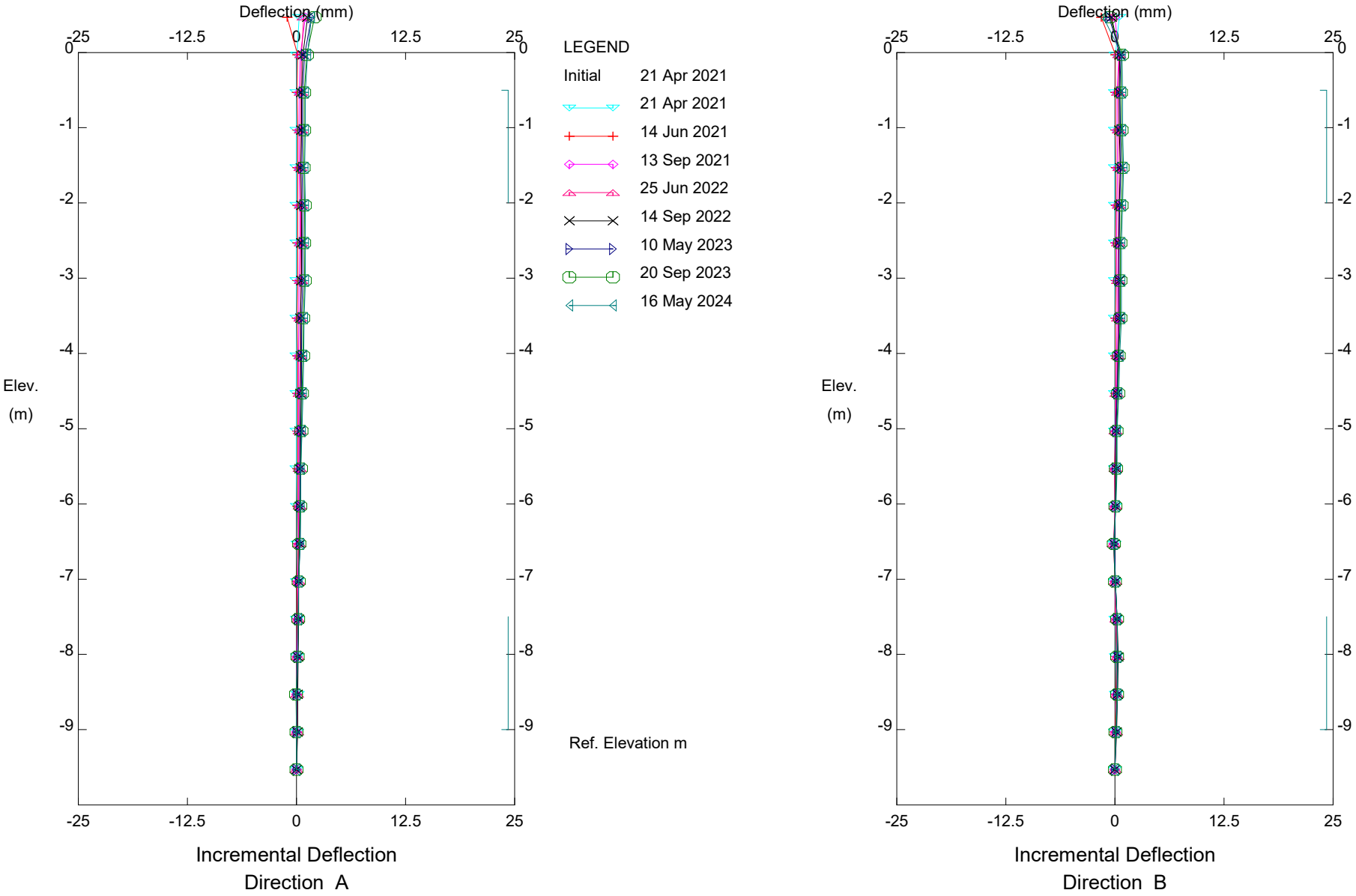
Klohn Crippen Berger - Calgary



C065-V; H585:02, East of Trochu, Inclinometer SI21-C65-03

Alberta Transportation

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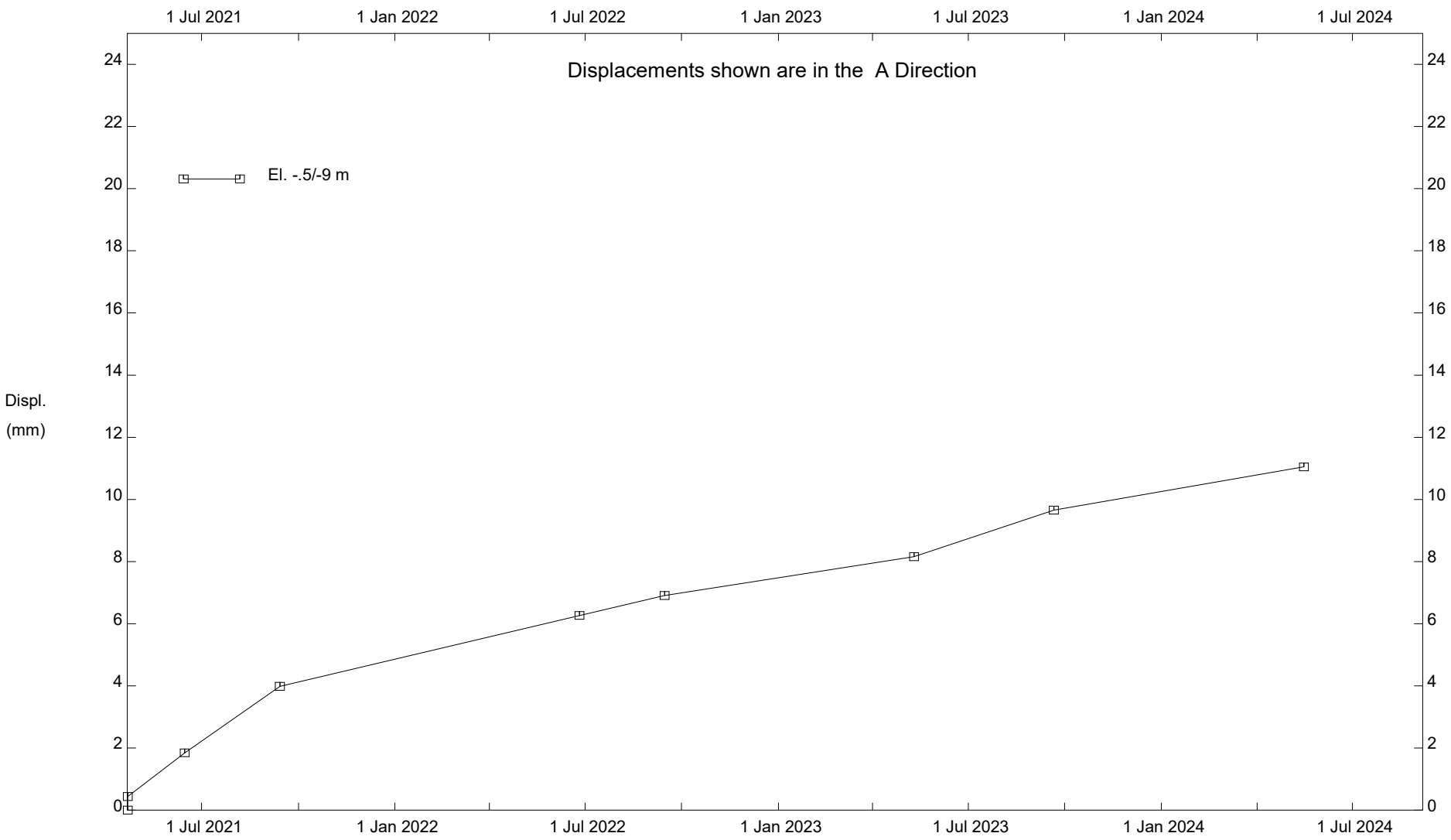
Klohn Crippen Berger - Calgary



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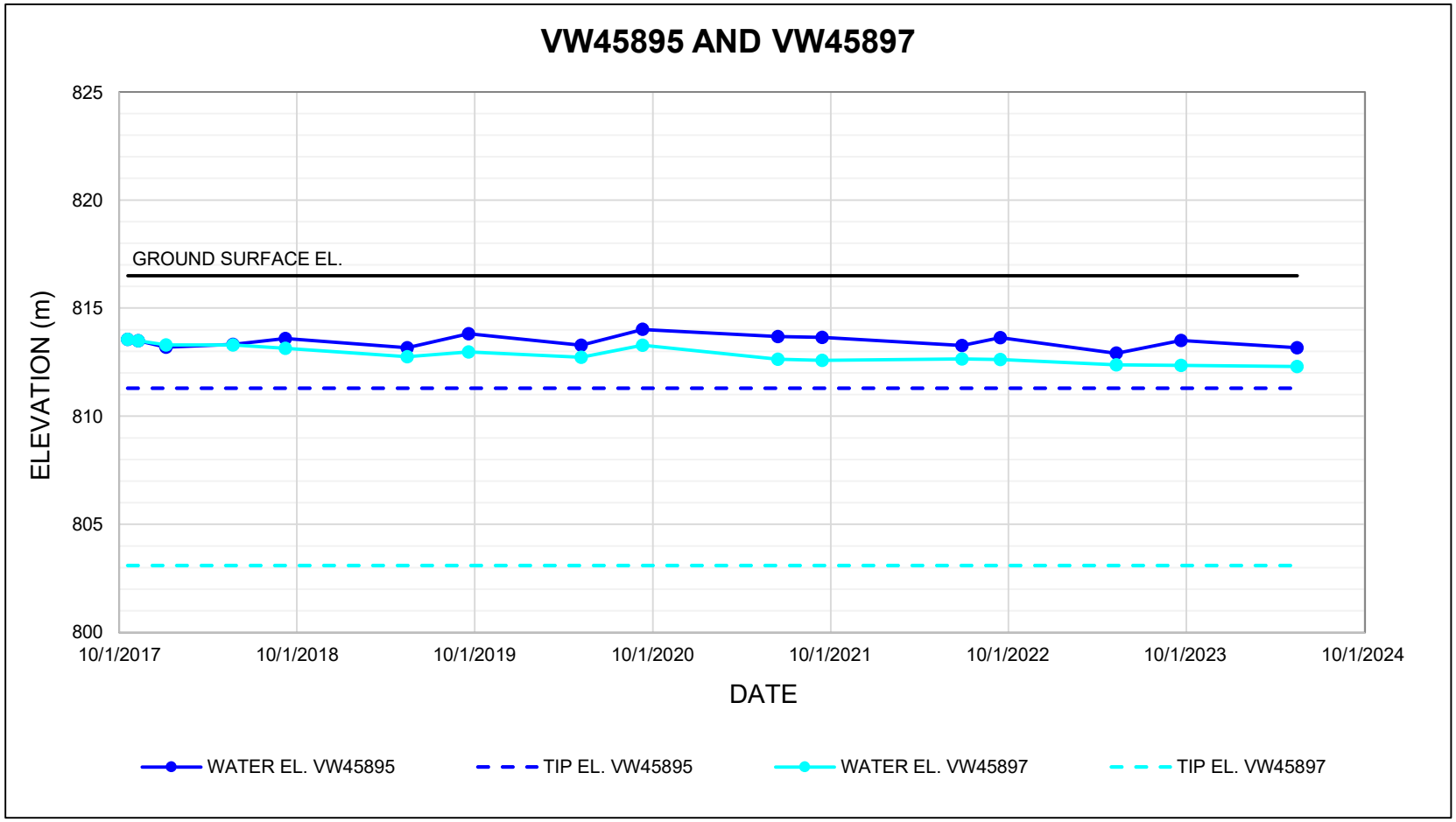
Alberta Transportation



NOTES:
1. GROUND SURFACE ELEVATION ESTIMATED FROM SEPTEMBER 2017 SURVEY DATA.

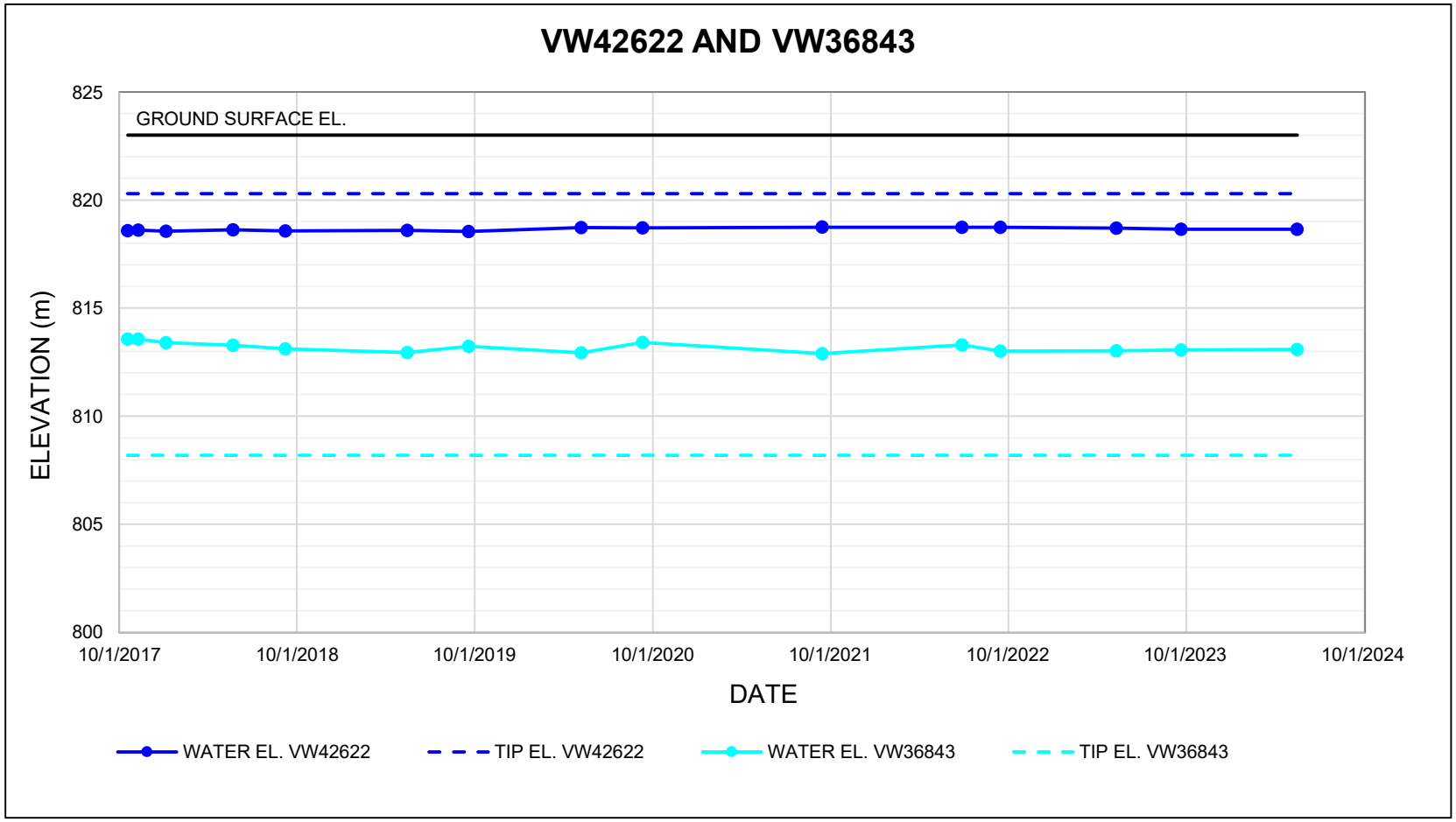
CLIENT: Alberta

Klohn Crippen Berger

PROJECT: CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE: Piezometer Data
C065-3 (Wasp Nest Slide)
Hwy 585:02, km 16.136

SCALE	PROJECT No.	FIG No.
N/A	A05116A02	I-18



NOTES:
1. GROUND SURFACE ELEVATION ESTIMATED FROM SEPTEMBER 2017 SURVEY DATA.

CLIENT: Alberta

Klohn Crippen Berger

PROJECT: CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE: Piezometer Data
C065-4 (Upper Slide)
Hwy 585:02, km 16.136

SCALE	PROJECT No.	FIG No.
N/A	A05116A02	I-19