Klohn Crippen Berger

July 15, 2024

Alberta Transportation and Economic Corridors
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 C007; H16:30, km 23.890 Kenilworth Lake Slide
Section C – 2024 Spring Readings

1 GENERAL

Five slope inclinometers (SIs) (SI15-01, SI15-02, and SI21-C07-01 through SI21-C07-03) were read at the C007 site in the Central Region on May 14, 2024 by Aden Shipton, E.I.T. of Klohn Crippen Berger Ltd. (KCB). These instruments were read as part of the Central Region Geohazard Risk Management Program (GRMP). The site is located on Hwy 16:30, km 23.890, approximately 2 km east of Islay Junction. The approximate site coordinates are 5910761 N, 532907 E (UTM Zone 12, NAD 83). A site plan is presented in Figure 1.

The geohazard at the C007 site consists of a slope failure along the north shore of Kenilworth Lake that impacts the south (eastbound) lanes of Hwy 16:30. The slope failure was first observed in 1977 and appears to be a deep-seated rotational slide. In March 2015, an 18-m-deep, 60-m-long H-pile wall (H360X132) consisting of 80 piles was installed to stabilize the slope, as presented in Figure 1.

In March 2021, the H-pile wall was extended 62 m to the east and 15 m to the west, with 18-m-long H-piles, to address lateral expansion of the slide mass. Previous remedial actions include construction of a granular toe berm in 1980, installation of horizontal drains in 1985 and 1986, construction of a keyed-in granular toe berm in 2011, and regular patching and paving. Twinning of the highway was completed in 1990 or 1991.

In June 2013, KCB conducted a geotechnical site investigation at the C007 site. Drilling was completed by Mobile Augers and Research Ltd. The encountered stratigraphy was as follows: fill (similar material to the underlying silty clay till), overlying medium to high plastic silty clay till, overlying bedrock. The encountered stratigraphy was consistent with the stratigraphy encountered during a 2004 drilling investigation.

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1.1 Instrumentation

Instrumentation installation details are tabulated in Table 1.1. Instrument locations are presented in Figure 1. All instruments installed before June 2013 are considered inoperable and are not presented or discussed herein.

In June 2013, KCB installed two SIs (SI13-01 and SI13-02) and two standpipes (SPs) (SP13-01 and SP13-02) on the south (downslope) side of the Hwy 16:30. The instruments were destroyed during installation of the original H-pile wall in 2015.

In March 2015, two SIs (SI15-01 and SI15-02) were installed in steel pockets between the web and flanges of the H-piles to monitor deflection of the original H-pile wall. The SIs are located approximately one-third (19.8 m) from either end of the original H-pile wall.

In March 2021, three SIs (SI21-C07-01 through SI21-C07-03) were installed to monitor deflection of the east and west H-pile wall extensions. SI21-C07-01 is located approximately in the centre of the west 15-m-long H-pile wall extension. SI21-C07-02 and SI21-C07-03 are located approximately one-third (20.7 m) from either end of the east H-pile wall extension. 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 fine-grained sand.

All operable SIs are protected by above-ground casing protectors, excluding SI21-C07-01.

The operable SIs installed in 2015 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 September 2017, when the SI equipment was changed. This equipment has also been used to read the 2021 SIs since they were installed.

Table 1.1 Instrumentation Installation Details

Instrument ID	Instrument Type	Date Installed	UTM Coordinates[1] (m)		Ground Surface Elevation[1] (m)	Stick Up (m)	Depth (mbgs[2])	Condition[3]
			Northing	Easting				
~~SI13-01~~	~~SI~~	~~Jun. 2013~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~21.2~~	~~Inoperable~~
~~SI13-02~~	~~SI~~	~~Jun. 2013~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~23.9~~	~~Inoperable~~
SI15-01	SI	Mar. 18, 2015	5910733	532917	616	0.9	17.5	Operable
SI15-02	SI	Mar. 18, 2015	5910733	532954	615	0.8	17.0	Operable
SI21-C07-01	SI	Mar. 26, 2021	5910764	532862	616	0.1	16.0	Operable
SI21-C07-02	SI	Mar. 26, 2021	5910733	532954	615	0.7	18.0	Operable
SI21-C07-03	SI	Mar. 26, 2021	5910733	532973	615	0.4	18.0	Operable
~~SP13-01~~	~~SP~~	~~Jun. 2013~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~20.7~~	~~Inoperable~~
~~SP13-02~~	~~SP~~	~~Jun. 2013~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~10.0~~	~~Inoperable~~

Notes:
[1] Coordinates and ground surface elevations have not been surveyed and were approximated based on record drawings and location plan.
[2] Meters below ground surface (mbgs). Bottom reading depth for SI and screen depth for SPs (inoperable).
[3] 2013 instruments were destroyed during installation of the original H-pile wall in 2015.

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, in the X-direction (i.e., the direction of maximum movement obtained at a skew angle from the A0-grooves). SI15-01 and SI15-02 have skew angles of 70^{o} and 15^{o}, respectively, measured clockwise from the direction of the A0-grooves.

The SI plots are included in Appendix I and a summary of the SI data is provided in Table 2.1. The SI data plots presented herein only include data for readings taken with the metric RST equipment.

2.2 Zones of Movement

Before the instruments were destroyed during installation of the original H-pile wall in 2015, movement was being recorded in SI13-01 and SI13-02 at an approximate depth of 8 m and 7 m below ground surface, respectively.

Distributed movement is being recorded in:

- SI15-01 and SI15-02 (original H-pile wall) from ground surface to an approximate depth of 8 m to 9 m below ground surface, respectively;
- SI21-C07-01 and SI21-C07-02 (west H-pile wall extension) to an approximate depth of 16 m and 12 m below ground surface, respectively; and
- SI21-C07-03 (east H-pile wall extension) from ground surface to an approximate depth of 8 m below ground surface. A smaller amount of distributed movement (approximately 3 mm) is occurring near the bottom of the casing (approximately 15 m to 18 m below ground surface).

The H-pile walls are 18 m deep, and the SIs are approximately 16 m to 18 m deep.

Table 2.1 Slope Inclinometer Reading Summary

Instrument ID[3]	Date				Ground Surface Elevation (m)	Depth of Movement (mbgs[1])	Direction of Movement, Skew Angle[5]	Movement (mm)				Rate of Movement (mm/year)		
								Maximum Cumulative			Incremental Since Previous Maximum Cumulative			
	Initialized (Re-initialized)	Previous Maximum Cumulative Movement Recorded	Previous Reading	Most Recent Reading				Before Re-Initialization	After Re-Initialization	Total		Previous Maximum	Most Recent Reading	Change from Previous Reading
SI15-01	Mar. 18, 2015 (Sep. 8, 2017)[4]	May 8, 2023	May 8, 2023	May 14, 2024	616	0.4 – 16.4	A-Direction	153.5	49.9	203.4	4.6	654.6	4.51	3.7
SI15-02	Mar. 18, 2015 (Sep. 8, 2017)[4]	May 8, 2023	May 8, 2023	May 14, 2024	615	0.4– 16.5	X-Direction, 15°	89.4	48.5	137.9	4.6	293.3	4.6	4.5
SI21-C07-01	Apr. 22, 2021	May 8, 2023	May 8, 2023	May 14, 2024	615	0.6 – 15.6	A-Direction	N/A – instruments installed in 2021 and initialized with current SI equipment		6.8	1.2	6.0	1.2	-0.7
SI21-C07-02	Apr. 22, 2021	May 8, 2023	May 8, 2023	May 14, 2024	616	0.0 – 17.5	A-Direction			11.5	1.9	30.5	1.9	1.9
SI21-C07-03	Apr. 22, 2021	May 8, 2023	May 8, 2023	May 14, 2024	616	0.3 – 10.8	A-Direction			15.1	2.9	33.1	2.8	0.6
						14.3-17.8				4.4	1.0	6.5	1.0	0.5

Notes:
[1] Meters below ground surface (mbgs).
[2] Skew angle of X-direction measured clockwise from the A-direction.
[3] SI15-01, SI15-02, and SI21-C07-01 through SI21-C07-03 were installed to monitor deflection of the H-pile walls.
[4] SI15-01 and SI15-02 were re-initialized in September 2017 when the SI equipment was changed.
[5] SI15-01 had a skew angle of 70° prior to re-initialization due to significant lateral displacement (B-Direction). B-Direction movement has since attenuated, and a skew angle is no longer required.

2.3 Interpretation of Monitoring Results

The depth of movement being recorded in the pile-wall SIs (excluding SI21-C07-03) appears to be occurring approximately 5 m above the base of the H-pile walls and approximately 3 m below the depth of movement previously recorded in SI13-01 and SI13-02. SI21-C07-03 is also experiencing deeper seated movement approximately 3 m above the base of the H-pile walls. This indicates the H-pile walls have 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 SI15-01 and SI15-02 indicates that the top of the original H-pile wall has deflected between approximately 172 mm and 138 mm, respectively, since installation, with most of the displacement occurring before June 2015. The maximum rate of movement recorded in SI15-01 and SI15-02 occurred in June 2015, one month after the H-pile wall was installed and was approximately 655 mm/year and 293 mm/year, respectively. The rate of movement has since decreased and is now less than 5 mm/year.

Based on KCB's 2014 design report, the top 8 m of the original H-pile wall was 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). Based on the overall relatively slow rate of movement (now less than 5 mm/year) recorded in these SIs since they were re-initialized in 2017, the H-pile wall will likely not reach 200 mm of deflection for several years.

The May 2024 data obtained from SI21-C07-01 through SI21-C07-03 indicates that the top of the west and east H-pile wall extensions have deflected up to approximately 7 mm and 15 mm, respectively, since installation. In the spring of 2021, shortly after construction of the H-pile wall extensions, the maximum rate of movement recorded in these SIs was between approximately 6 mm/year and 40 mm/year. The rate of movement has since decreased and is now less than approximately 3 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.

Additional displacement of the H-pile walls may occur in response to periods of heavy or prolonged rainfall, resulting in high groundwater conditions. If movement rates accelerate or do not attenuate, Alberta Transportation and Economic Corridors (TEC) should consider installing walers and tie-back anchors to limit the impact of further slide movements on the pavement or potential lateral expansion of the slide mass.

Before SI15-01 was re-initialized in September 2017, approximately 135 mm of distributed movement (i.e., from top to bottom of casing) was recorded in the B-direction. It is unknown if this movement was due to post installation SI casing flexure, shifting in the steel pocket, or twist of the H-piles that occurred when the H-pile wall picked up load while stabilizing the sliding mass. However, movements in the B-direction have attenuated and no additional movement has been recorded in the B-direction of this instrument since it was re-initialized.

3 RECOMMENDATIONS

3.1 Future Work

All operable instruments should continue to be read once per year (spring) until movements attenuate, and all cracking and deformations of the pavement surface cease.

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. However, periodic MCI site visits should continue to assess if voids are still opening between the web and flanges of the H-piles. Additional sand backfill should be placed in any surface voids that develop.

4 CLOSING

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

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

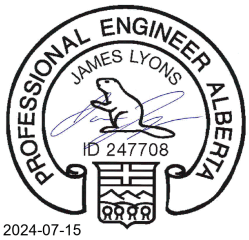
Use of or reliance upon this instrument of service by the Client is subject to the following conditions:

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

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

Yours truly,

KLOHN CRIPPEN BERGER LTD.

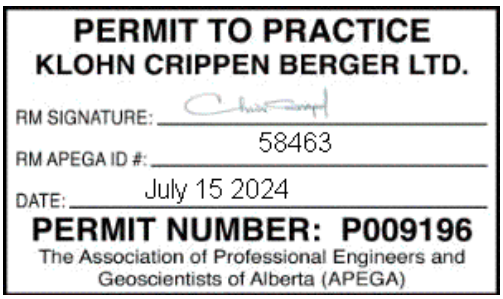


2024-07-15

James Lyons, P.Eng.
Civil Engineer

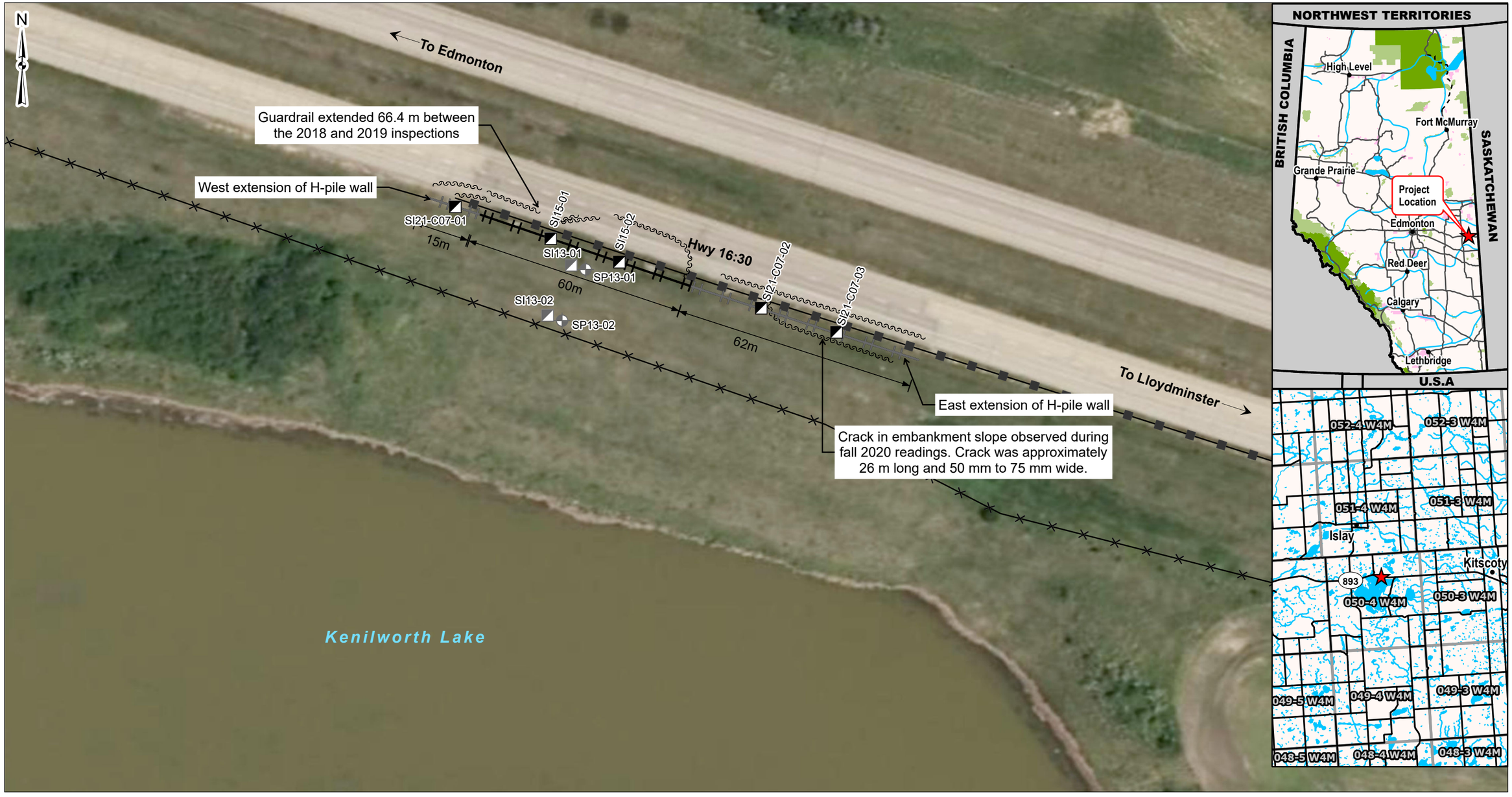
Aden Shipton, E.I.T.
Civil Engineer in Training

JL:bb



ATTACHMENTS
Figure
Appendix I Instrumentation Plots

FIGURE



Legend

- Slope Inclinometer (SI)
- Slope Inclinometer (SI) (inoperable)
- Standpipe Piezometer (SP) (inoperable)
- Guardrail
- Fence
- Crack
- H-Pile Wall

0 50 Meters

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

CLIENT: Alberta

Klohn Crippen Berger

PROJECT: CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE: Site Plan
C007 - Kenilworth Lake Slide
Hwy 16:30, km 23.890

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

APPENDIX I

Instrumentation Plots

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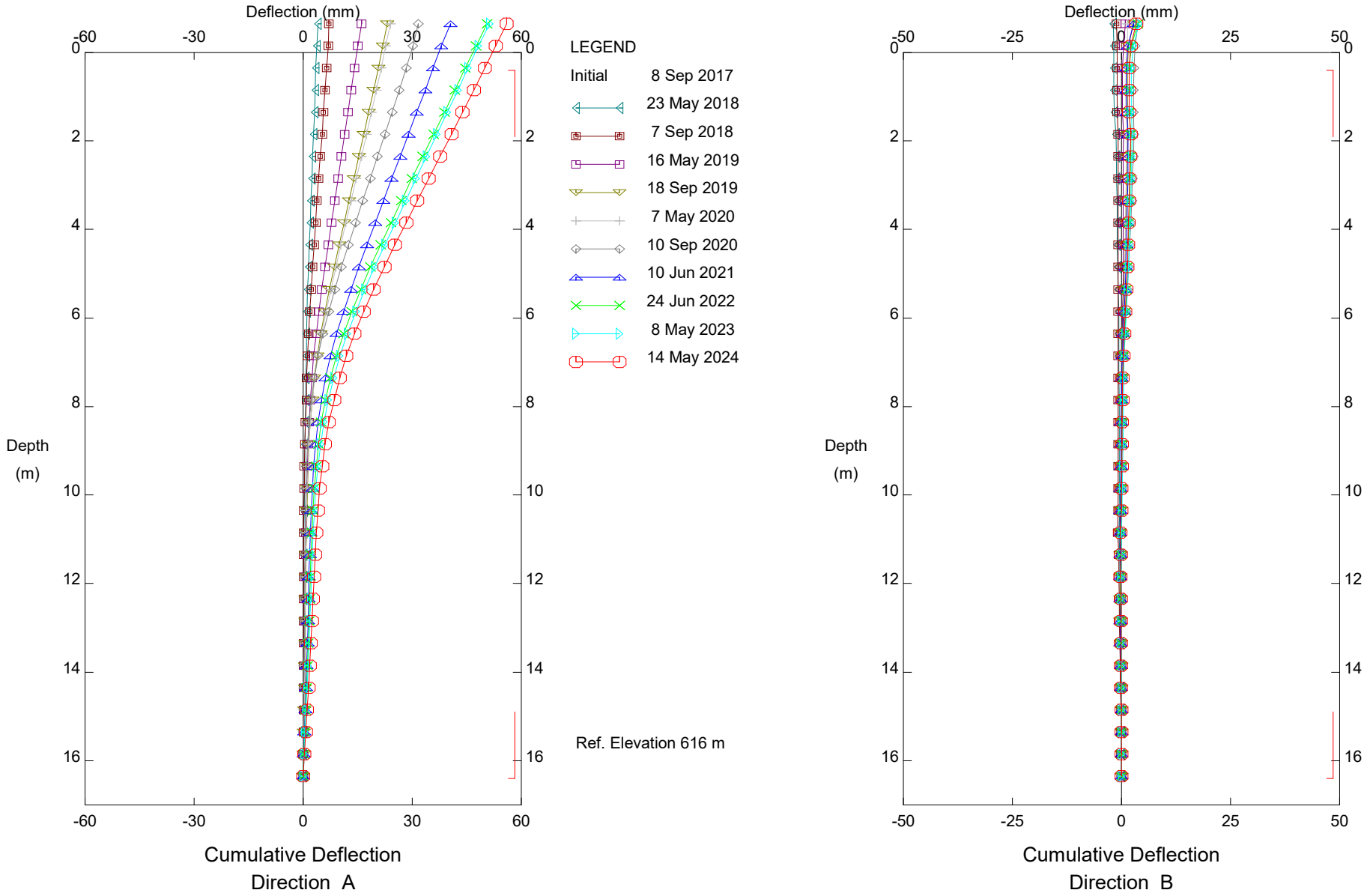
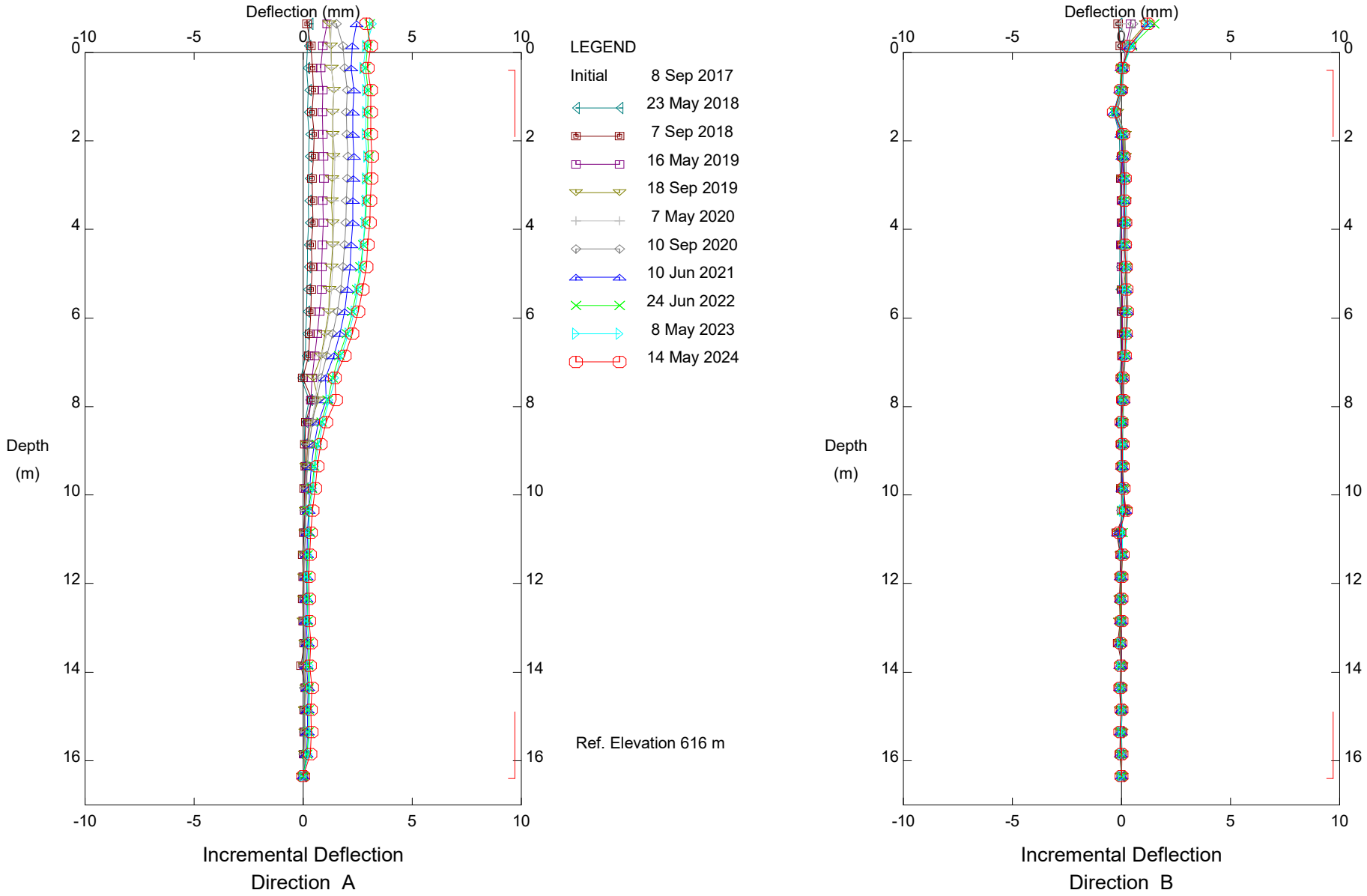


C007; H16:30, Kenilworth Lake Slide, Inclinometer SI15-01

Alberta Transportation

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

Klohn Crippen Berger - Edmonton



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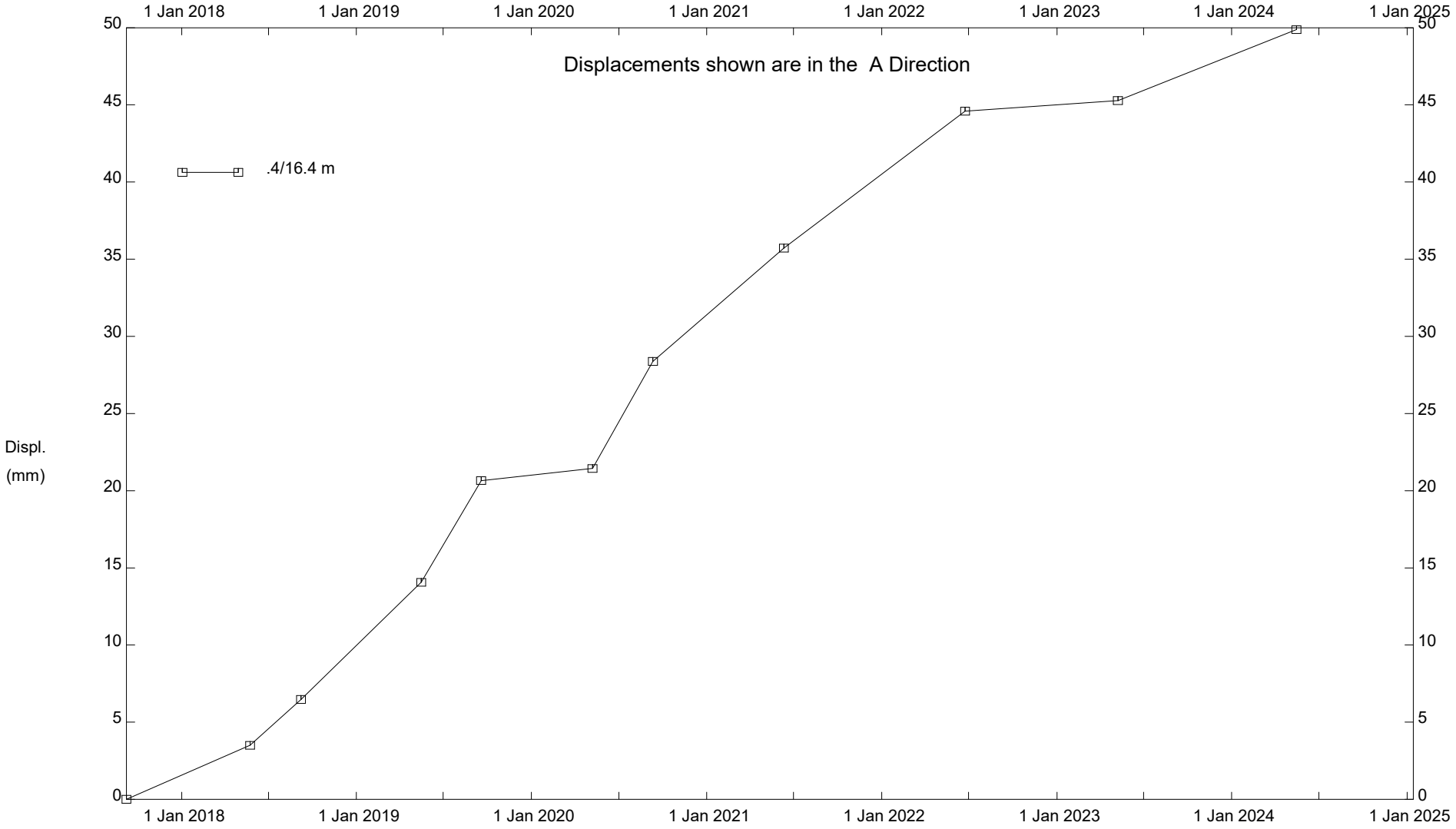

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Alberta Transportation

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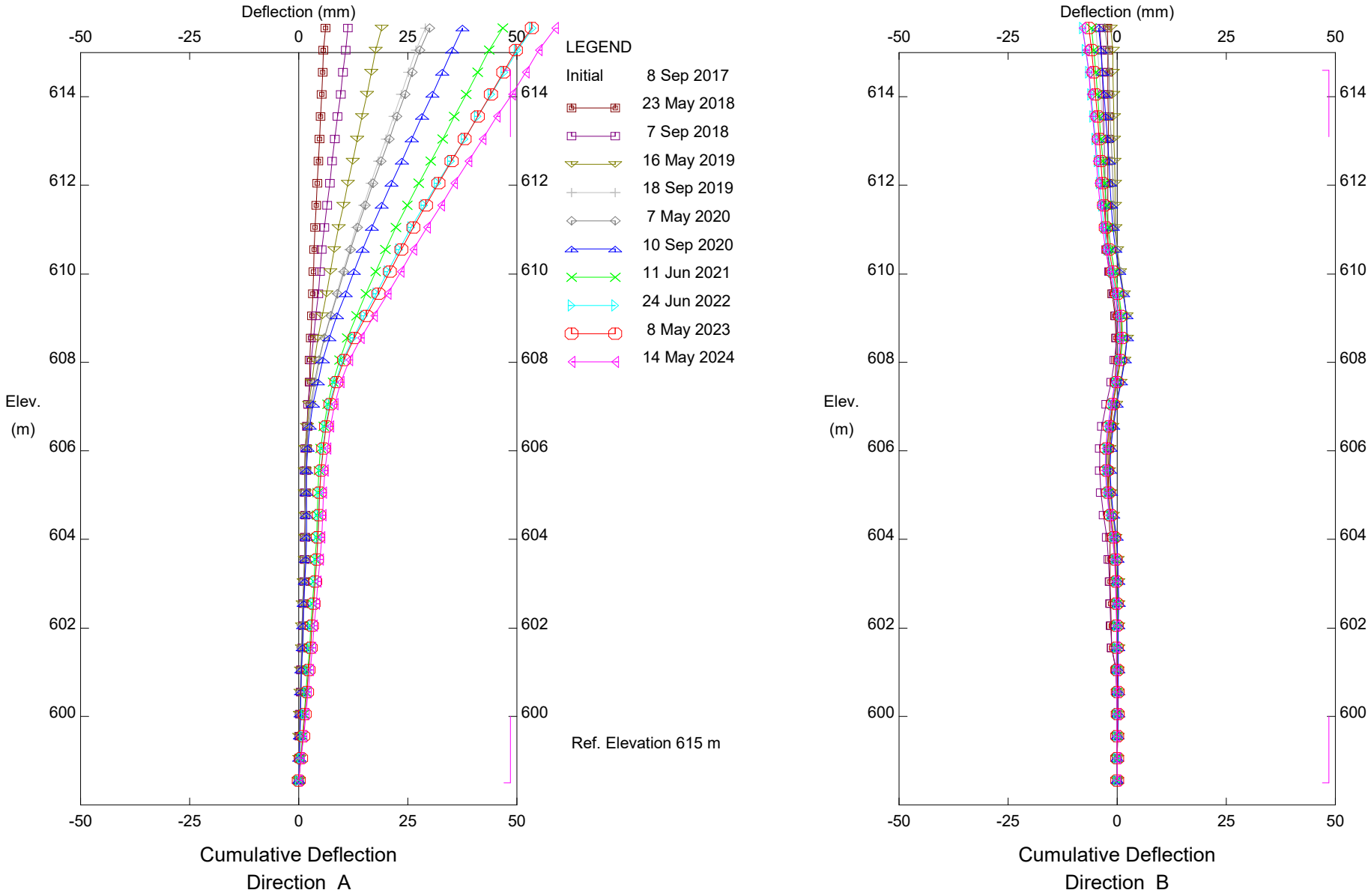

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Alberta Transportation

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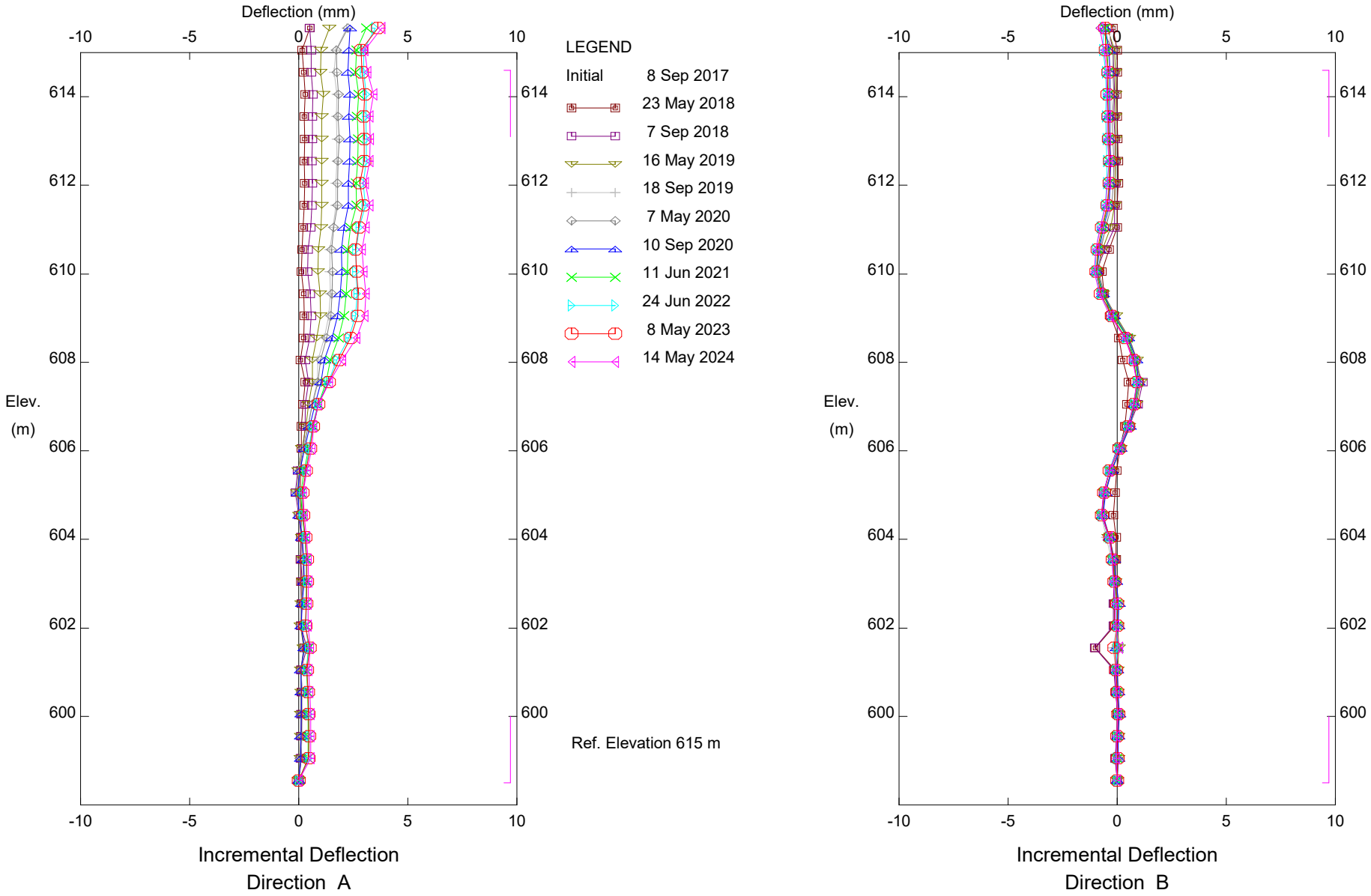

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Alberta Transportation

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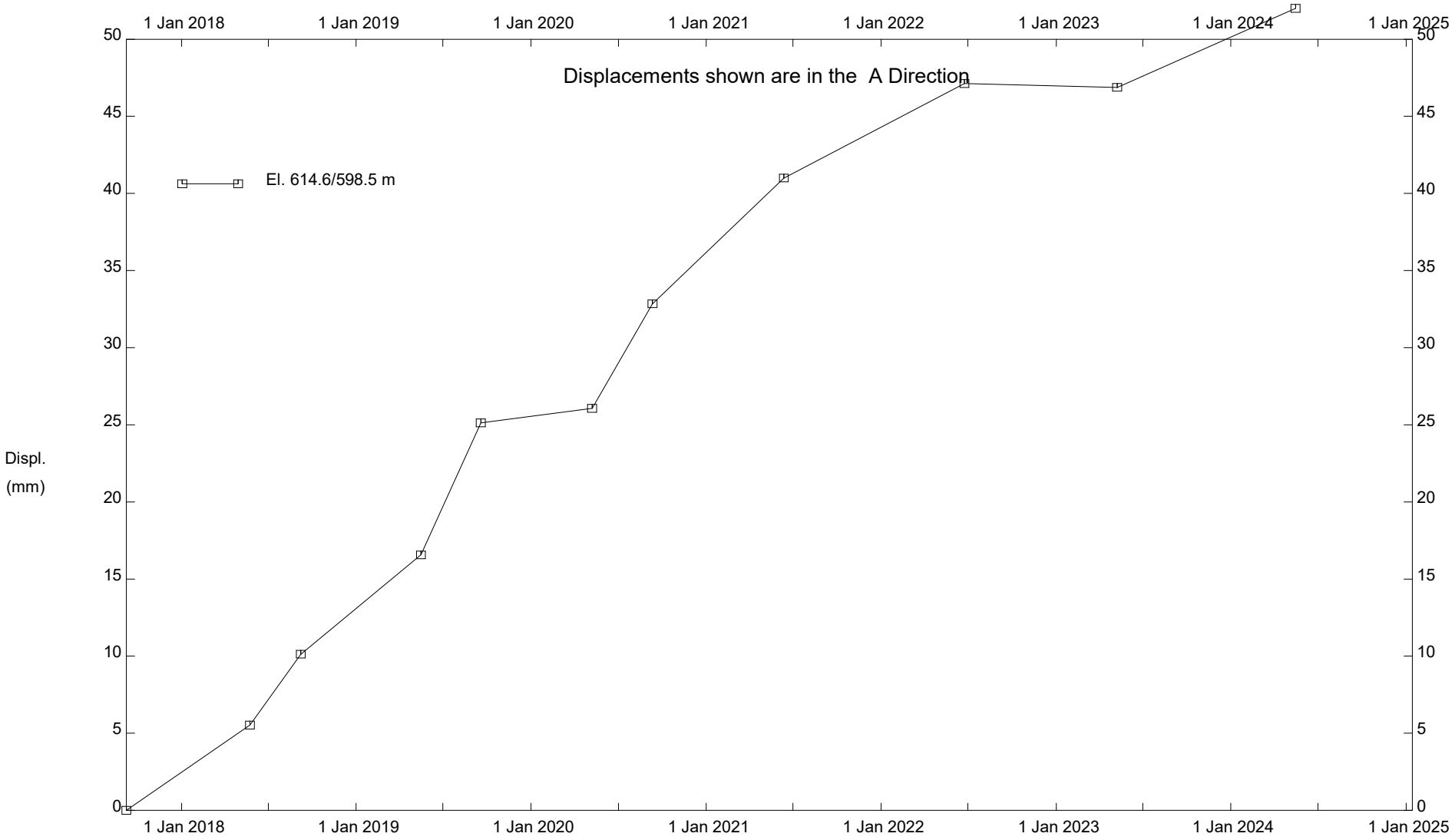

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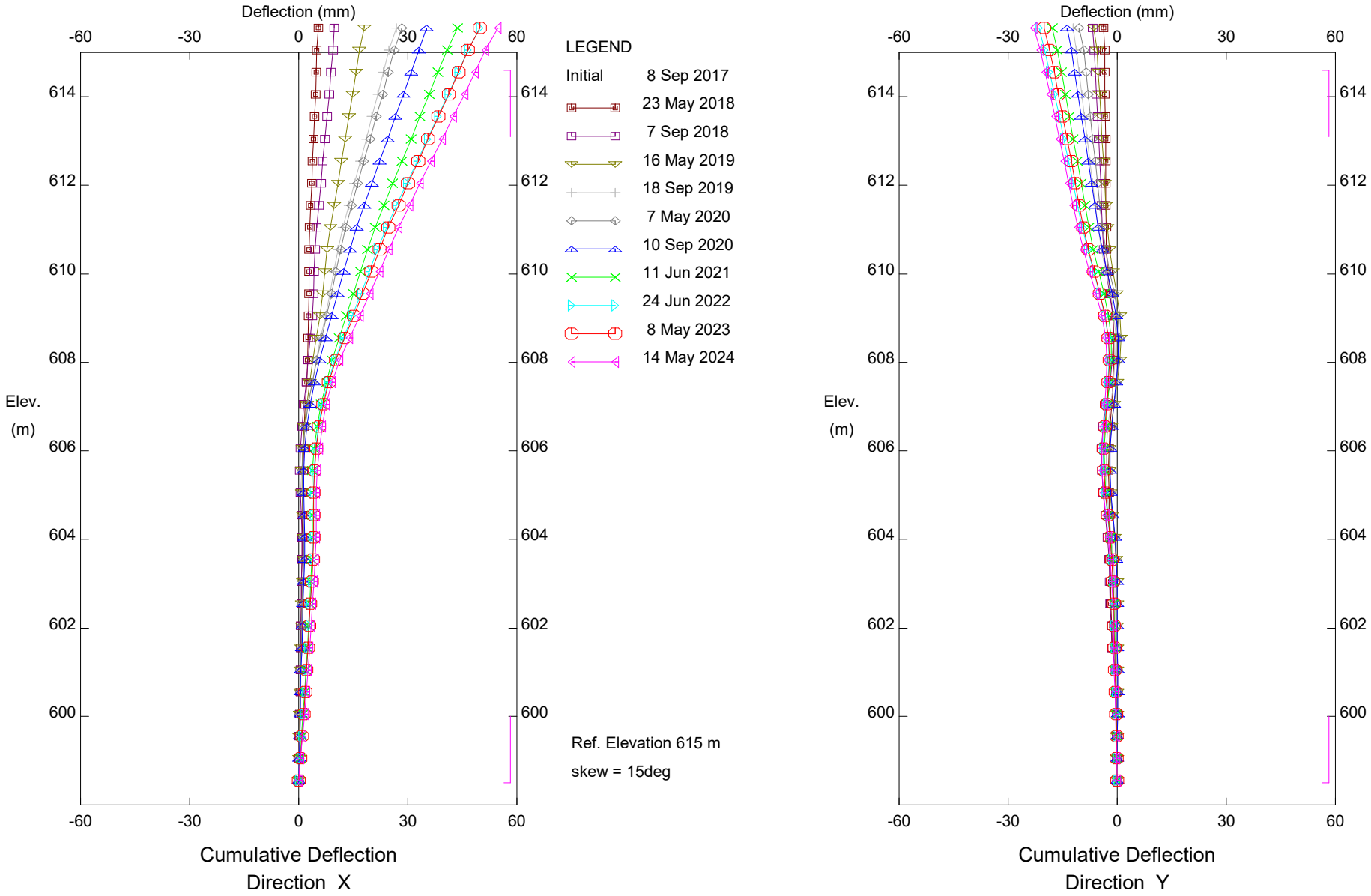

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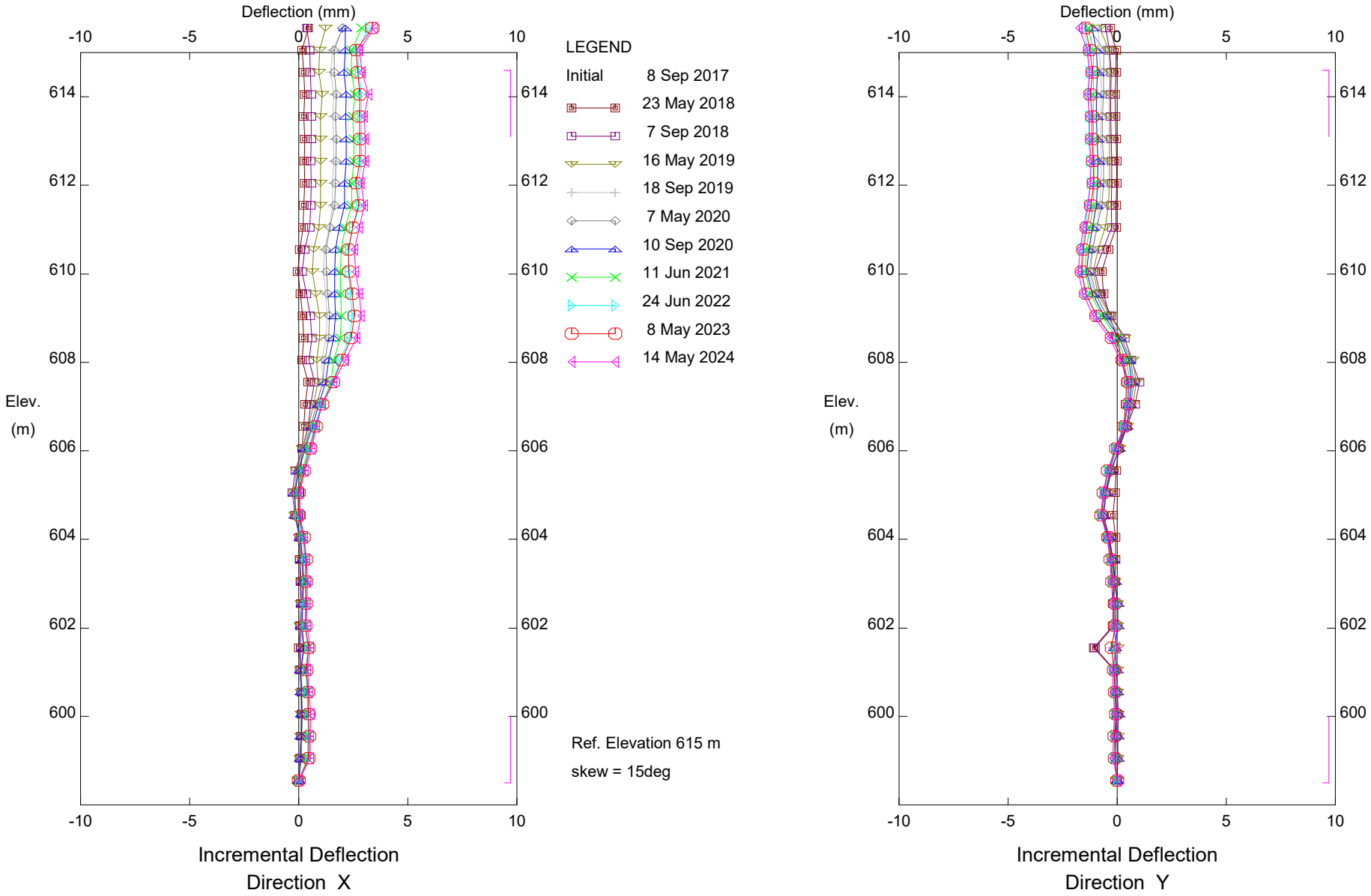

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Instrument re-initialized in September 2017 when the SI equipment was changed.

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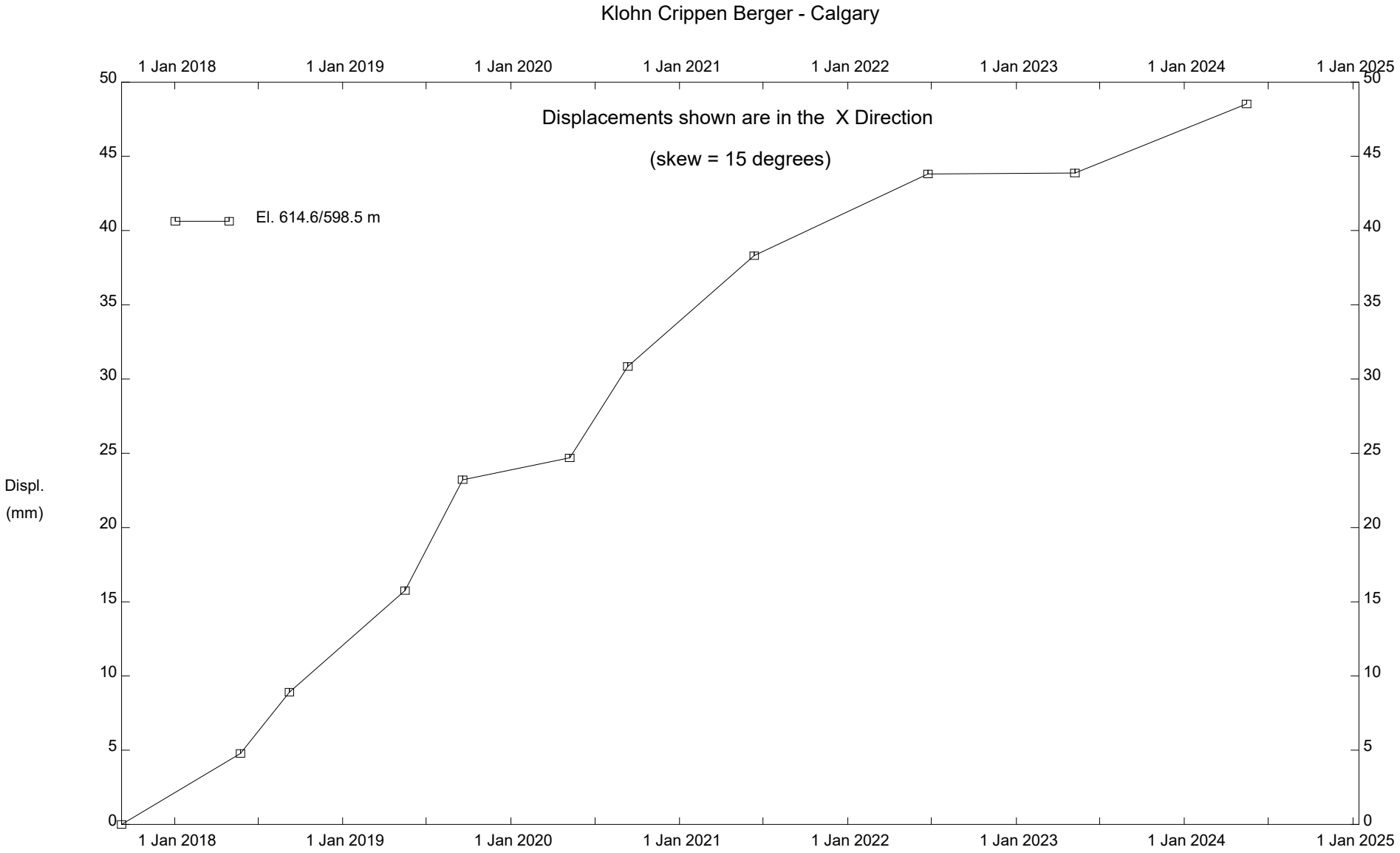
Klohn Crippen Berger - Calgary
Displacements shown are in the X Direction
(skew = 15 degrees)
El. 614.6/598.5 m
Displ.
(mm)
1 Jan 2018
1 Jan 2019
1 Jan 2020
1 Jan 2021
1 Jan 2022
1 Jan 2023
1 Jan 2024
1 Jan 2025
0
5
10
15
20
25
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C007; H16:30, Kenilworth Lake Slide, Inclinometer SI15-02
Alberta Transportation

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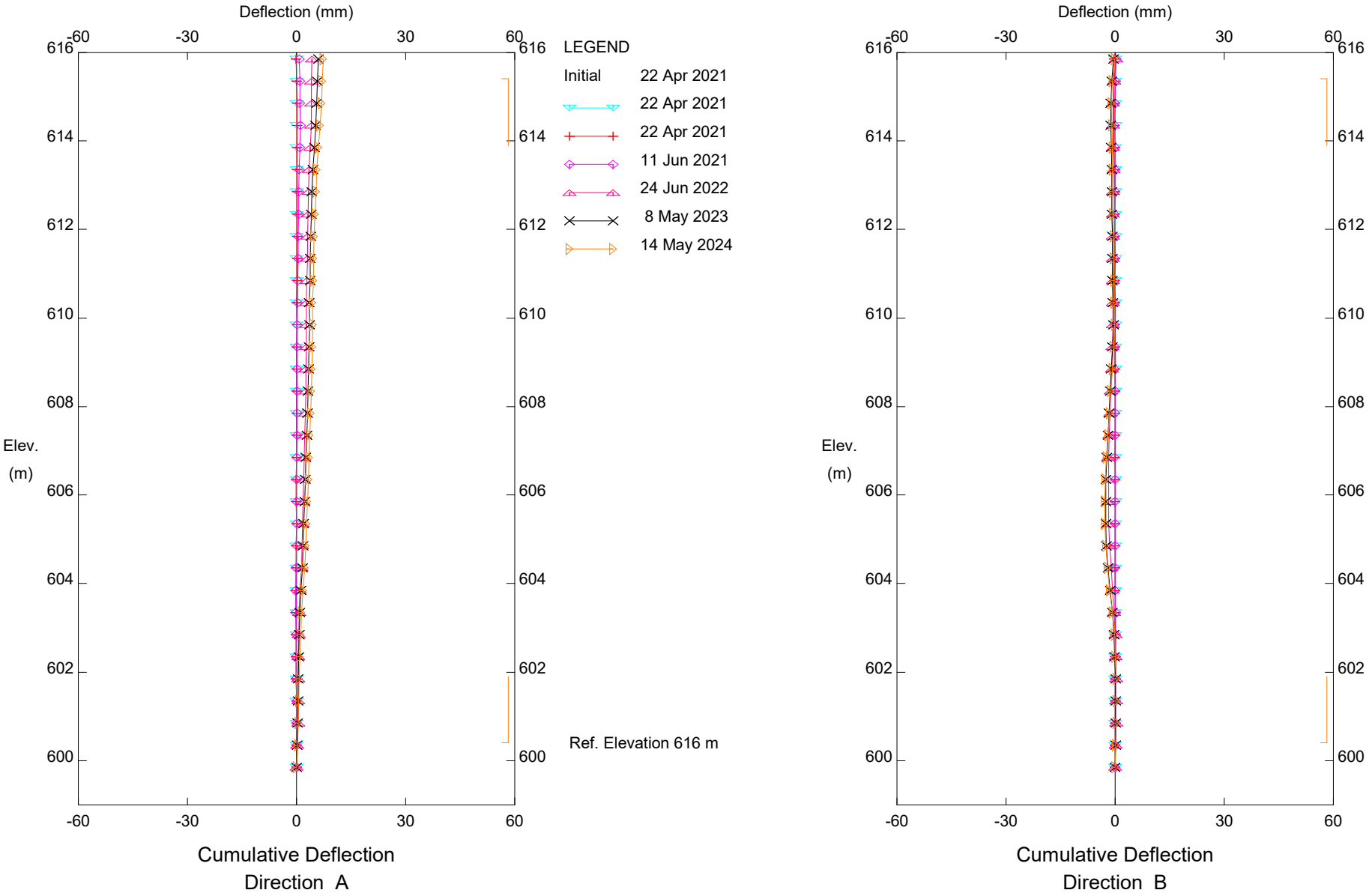

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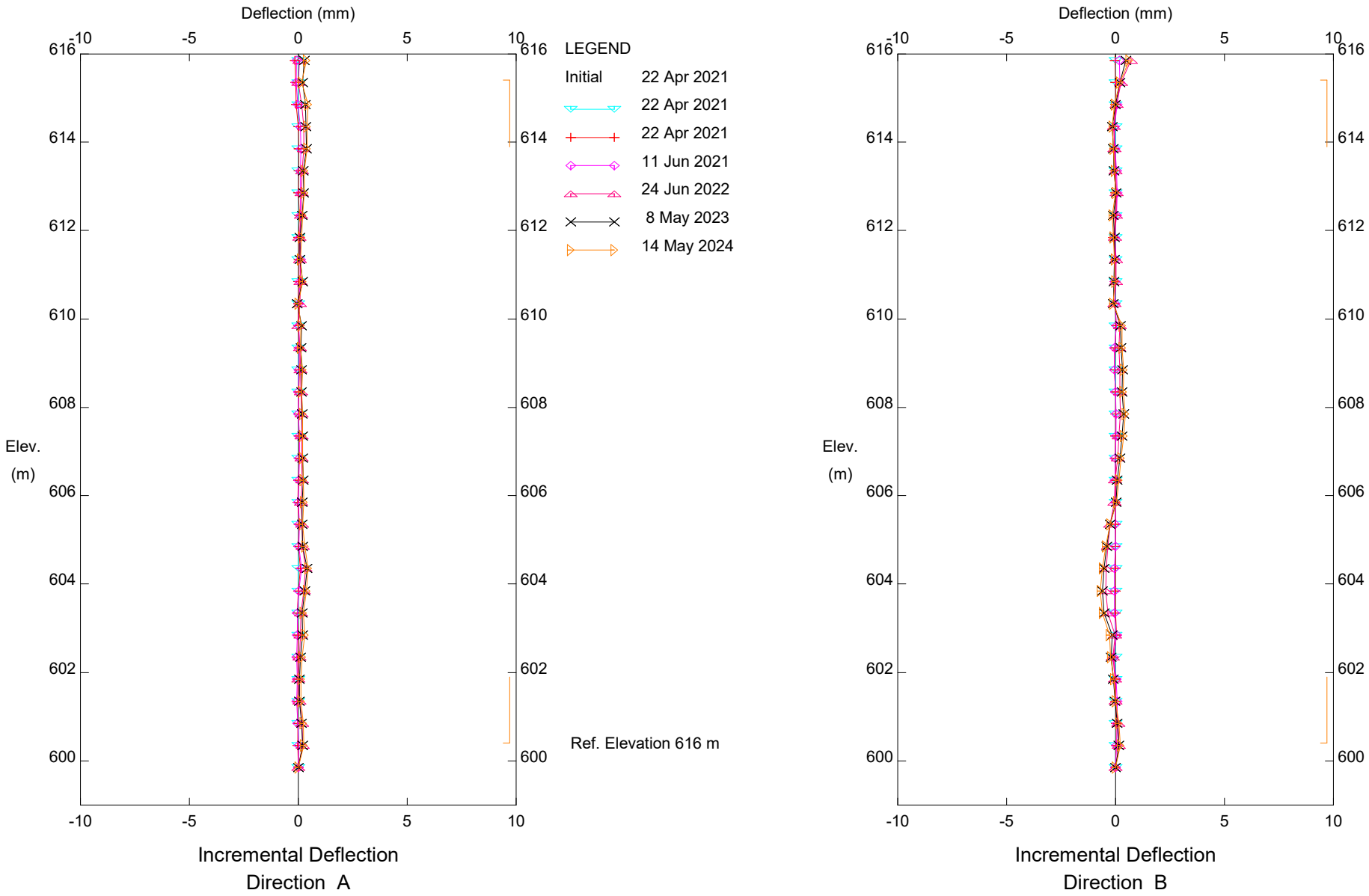

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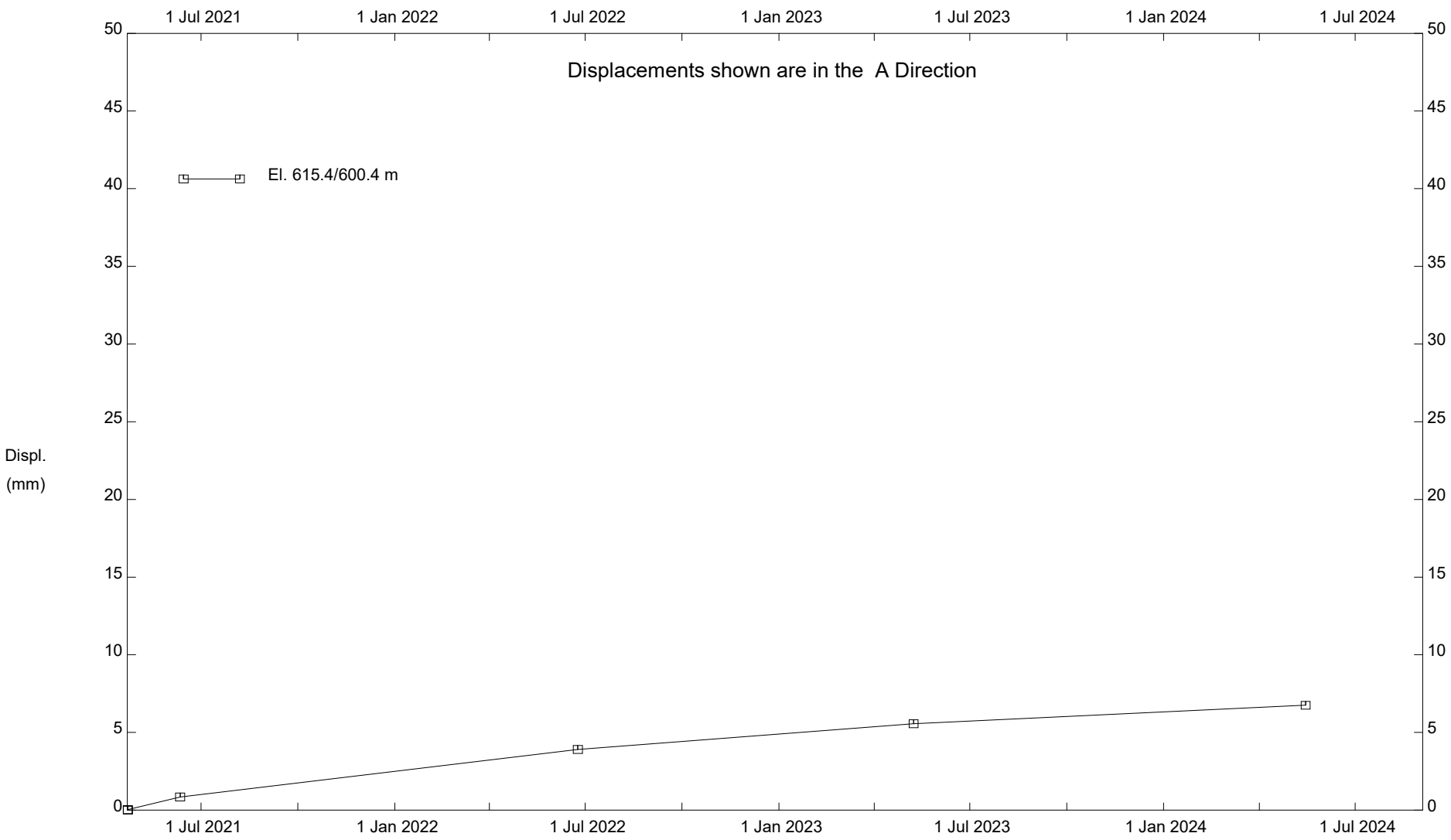

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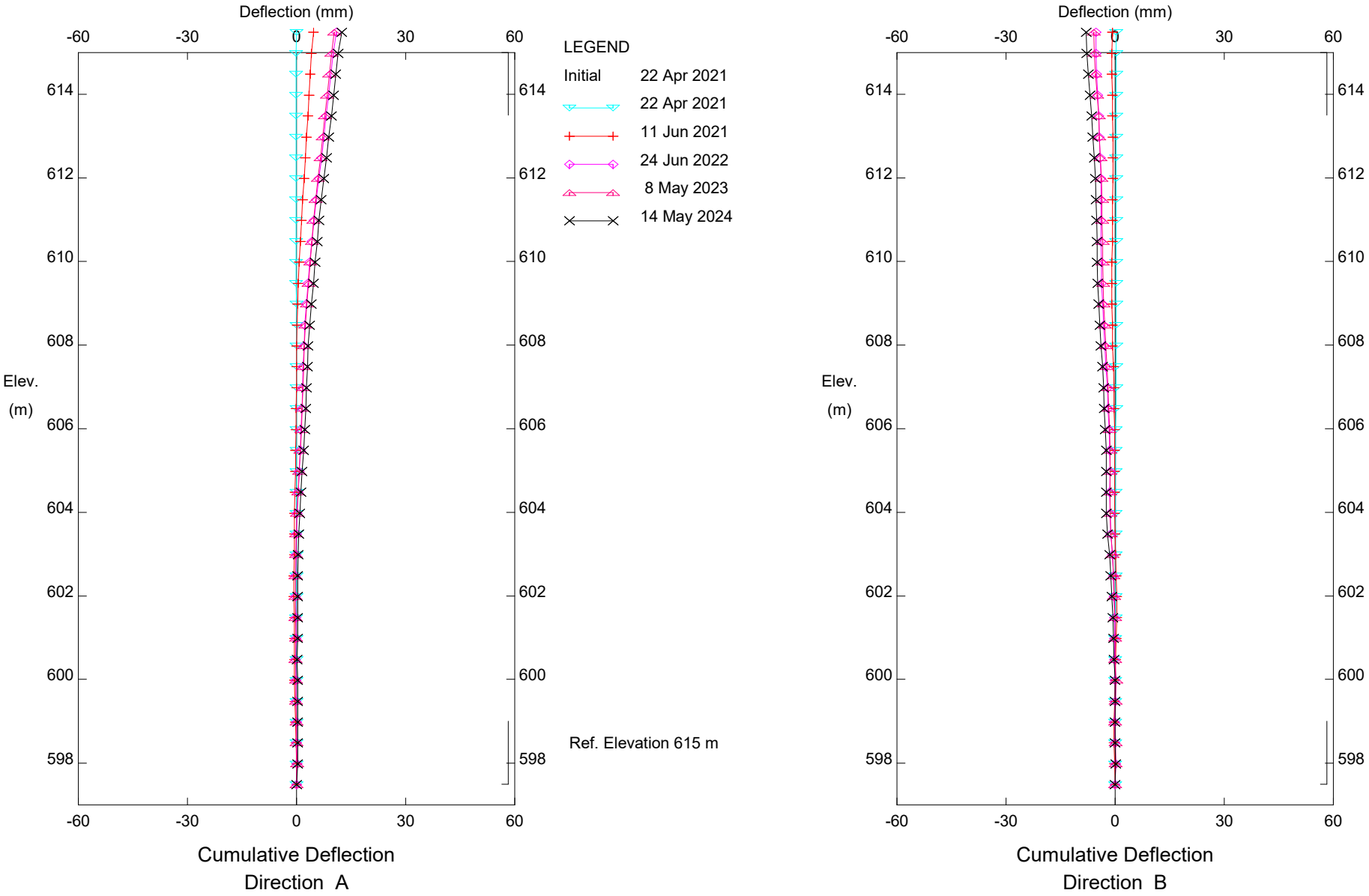

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Alberta Transportation

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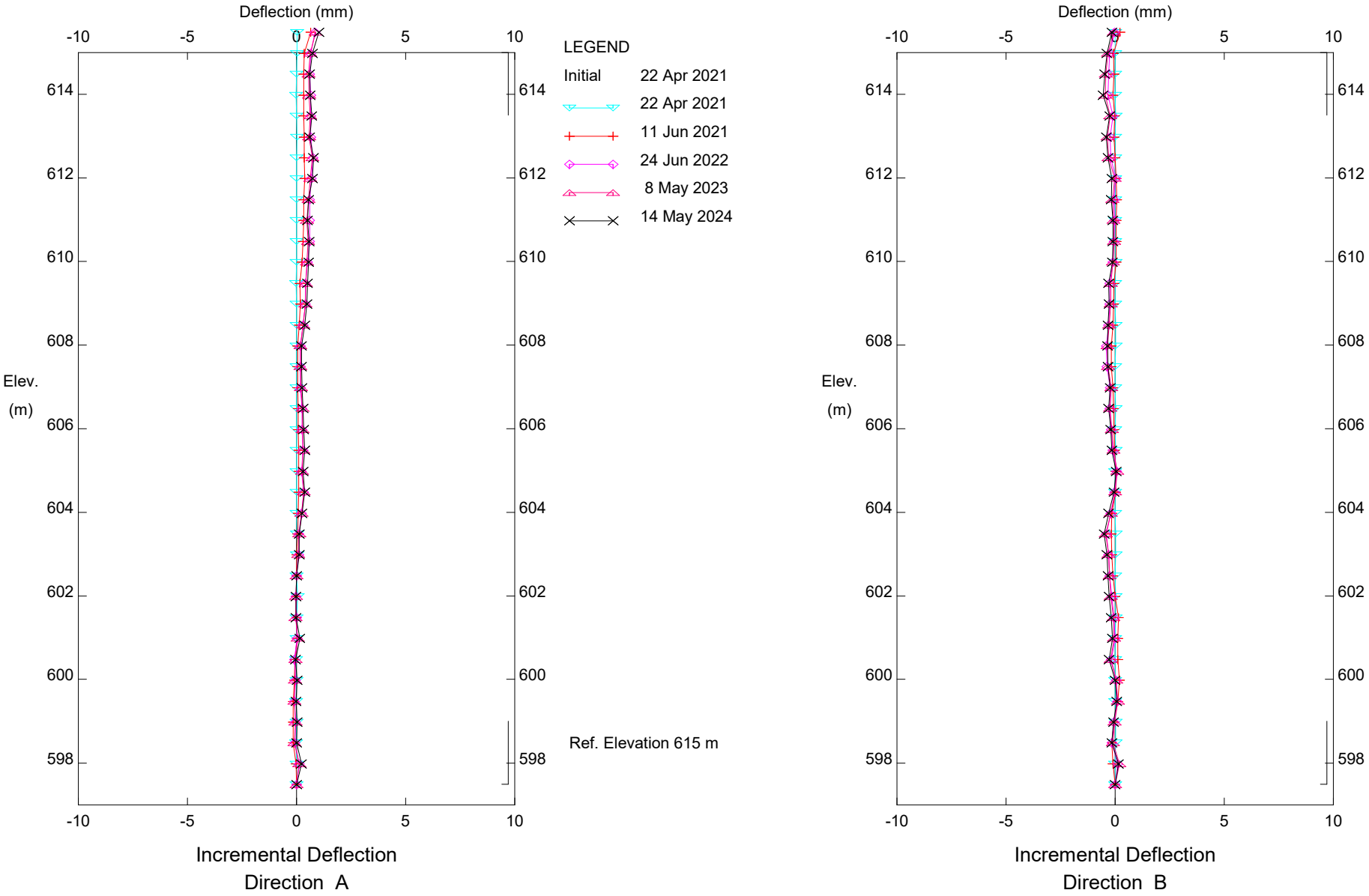
Klohn Crippen Berger - Calgary



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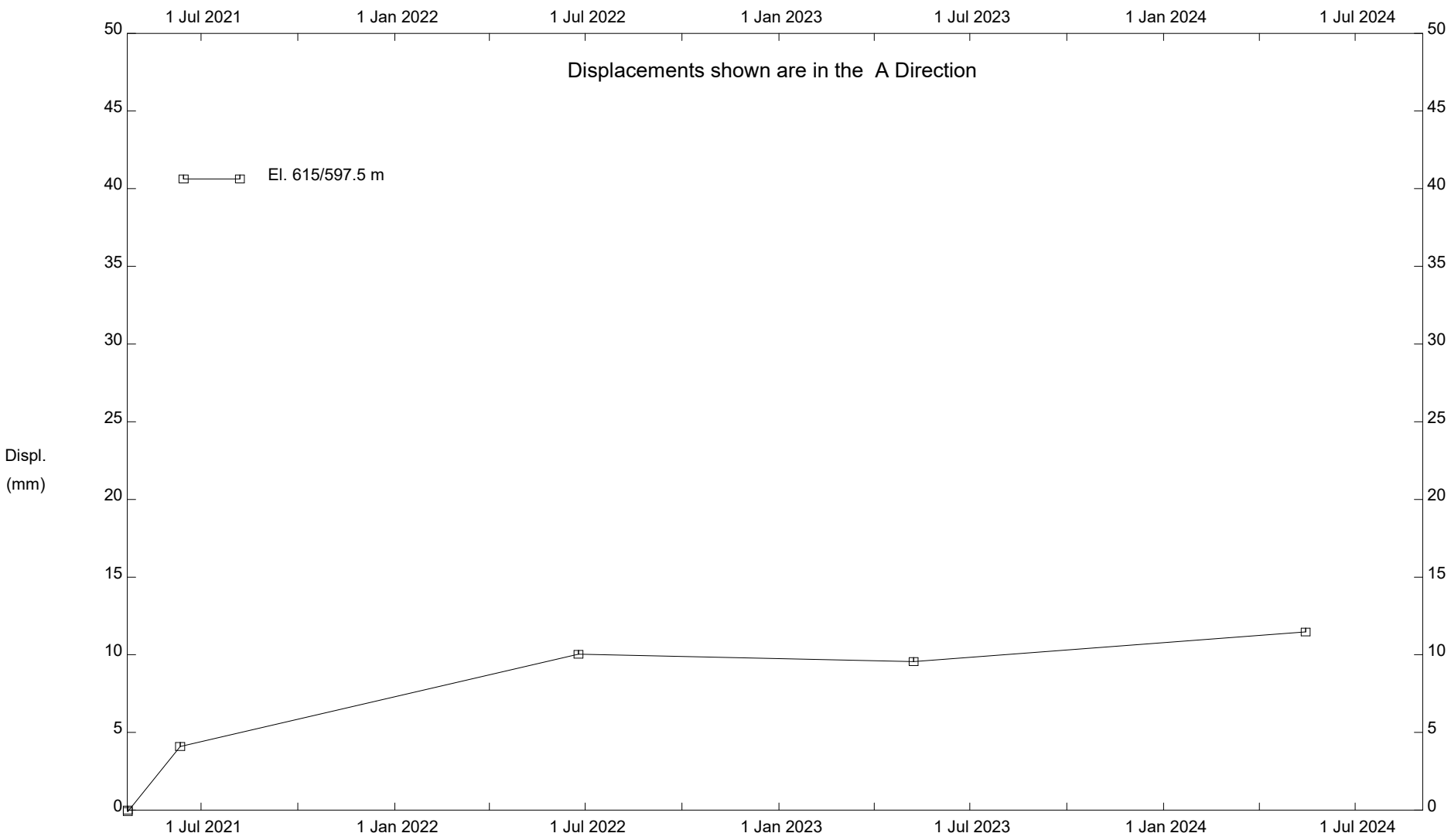

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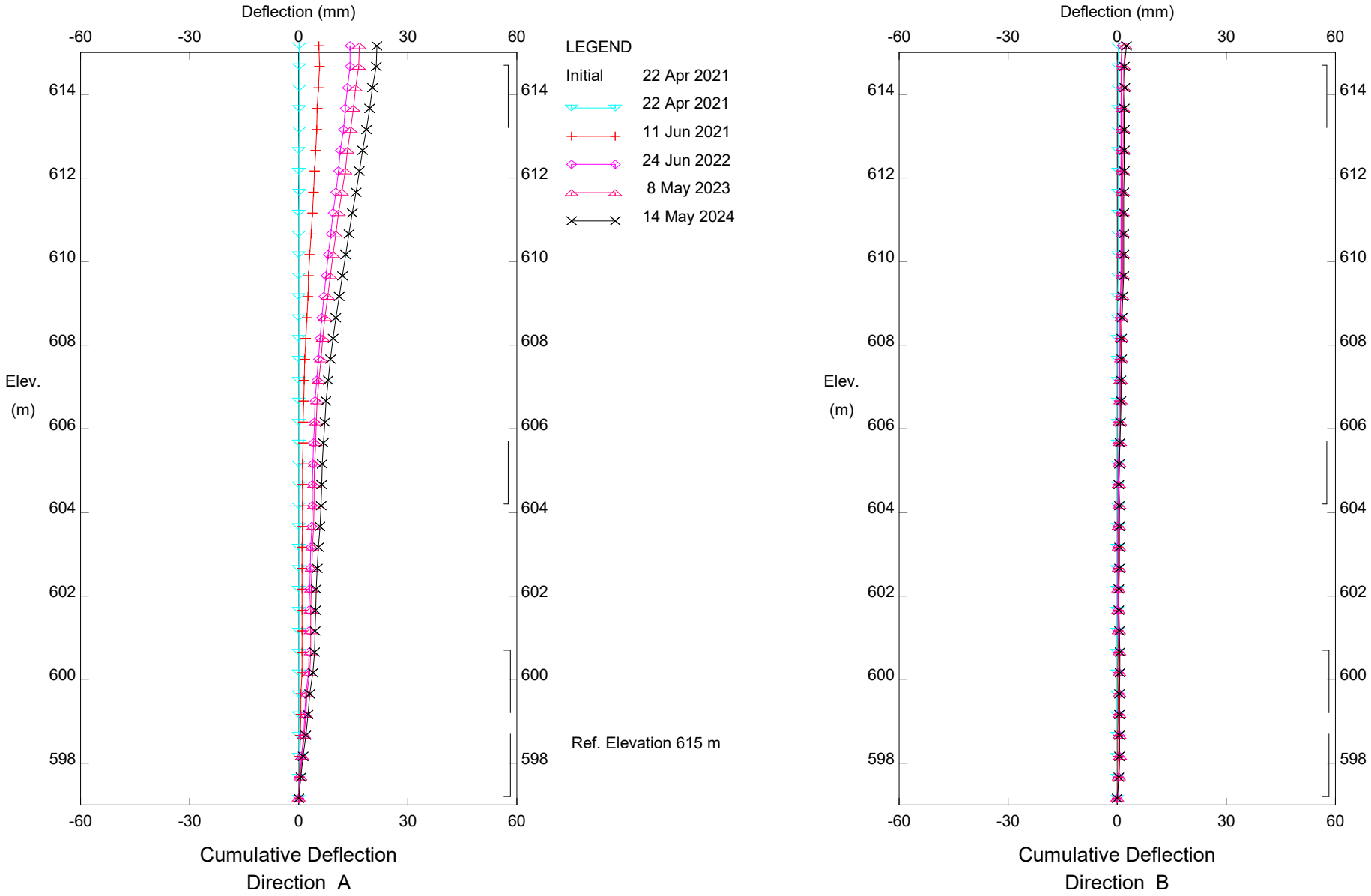

C007; H16:30; Kenilworth Lake Slide, Inclinometer SI21-C07-03

Alberta Transportation

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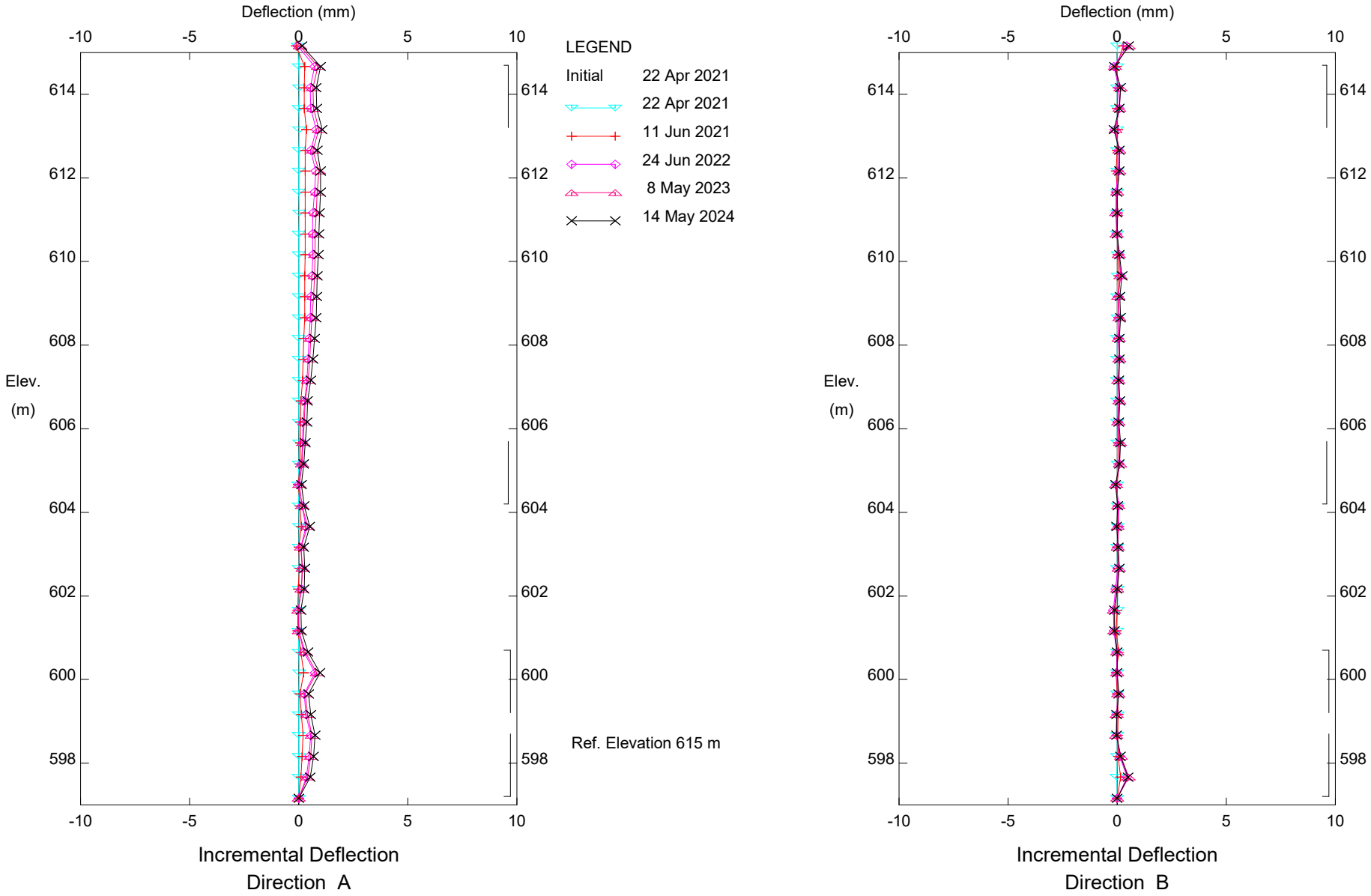
Klohn Crippen Berger - Calgary



C007; H16:30; Kenilworth Lake Slide, Inclinometer SI21-C07-03

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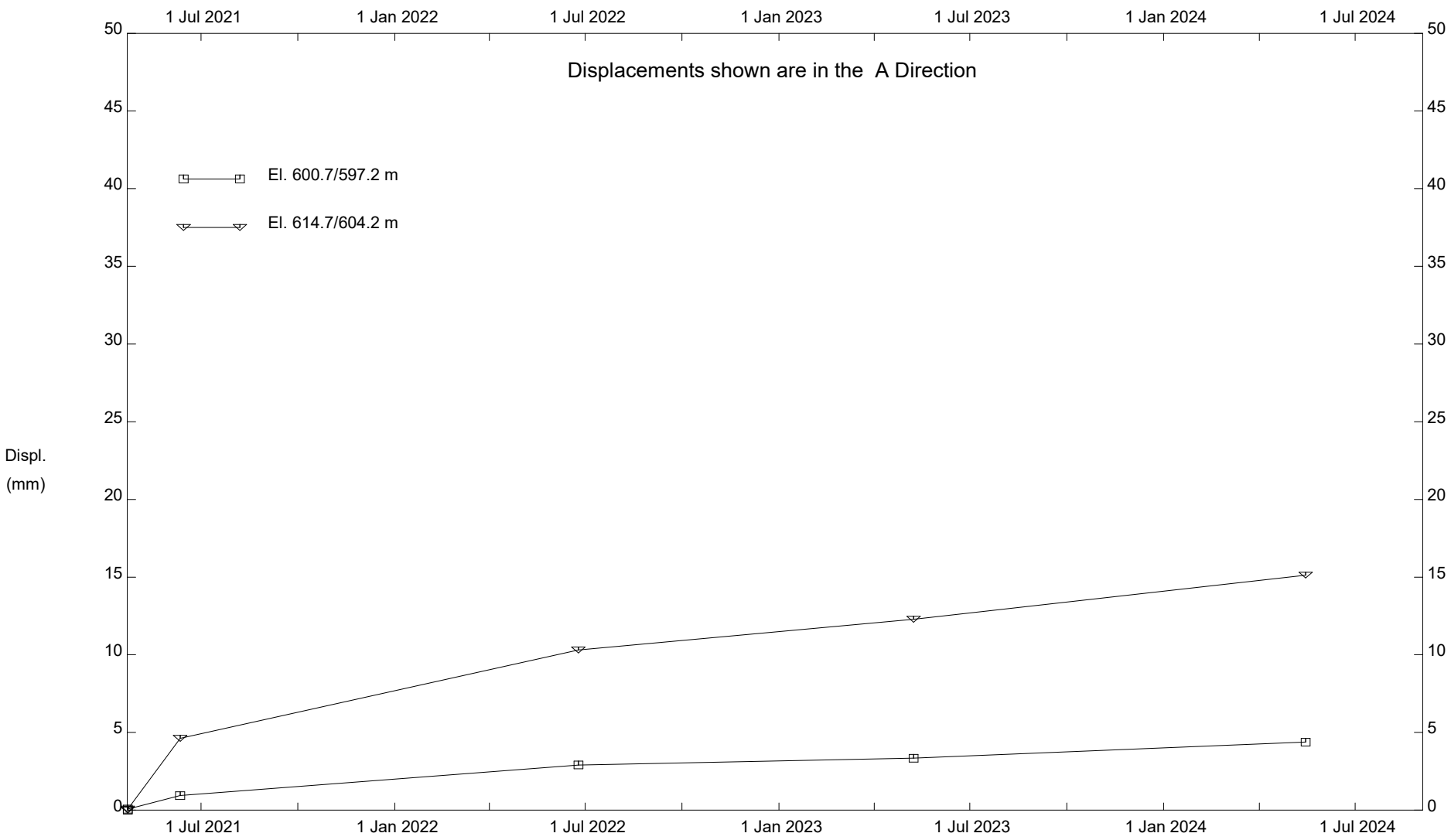

C007; H16:30; Kenilworth Lake Slide, Inclinometer SI21-C07-03

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