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 C048-1; H575:04, km 14.500 Slide West of Carbon Creek
Section C – 2024 Spring Readings

1 GENERAL

Three slope inclinometers (SIs) (SI21-C48-01 through SI21-C48-03) were read at the C048 site in the Central Region on May 13, 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 575:04, km 14.500, approximately 8 km northeast of Carbon, Alberta. The approximate site coordinates are 5707780 N, 358388 E (UTM Zone 12, NAD 83). A site plan is presented in Figure 1.

The C048 site consists of two active geohazard subsites, C048-1 and C048-3, along an approximate 250 m length of Hwy 575:04. C048-2, located to the west of C048-1, was repaired in 2012 and removed from the active list of sites for the Central Region GRMP. The geohazard at each subsite includes a shallow slide in the highway embankment fill on either the south (C048-1 and C048-3) or north (C048-2) slope of Hwy 575:04.

In 2012, the C048-2 site was repaired by removing the failed material and reconstructing the slide area with granular fill. No instrumentation is installed at this site, so this site will not be discussed further herein.

In late 2020, the C048-3 site was repaired by removing the failed material and reconstructing the slide area with geogrid-reinforced granular fill and two perforated-drain pipes installed at the base of the excavation. No instrumentation is installed at this site, so this site will not be discussed further herein.

Previous remedial actions at the C048-1 site include:

- July 2010: Installation of 52 soil nails installed in four rows.

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- July 2014: Construction of a 12-m-deep, 48-m-long H-pile wall (JP310x93) consisting of 65 piles. A "retaining wall" was also constructed behind the H-pile wall by excavating to a depth of 2 m, placing filter cloth, installing 2''x10'' pressure-treated residential deck boards as lagging behind the H-piles, and then backfilling behind the deck boards with granular fill. During the 2020 Section B inspection, the pile wall was reported to be outflanked to the east and west by slide movement.
- March 2021: The existing H-pile wall (upper pile wall) was extended approximately 41 m to the west and 17 m to the east (HP360X132). A 12-m-deep, 66-m-long H-pile wall (HP360x132) (lower pile wall) was also installed downslope of the existing H-pile wall. Additional pressure-treated timber lagging was placed on the existing and extended portions of the upper H-pile wall. The work was completed under TEC Contract No. CON0021394 and the final details report was issued to TEC on October 12, 2022.
- Summer 2023: A highway overlay project was completed along Hwy 575:04, which included removing the thick layer of pavement and a portion of the subgrade to reduce the loading at the C048 site. TEC informed KCB that the highway surface was lowered approximately 0.5 m at the C048-1 site. The overlay project also included removing and replacing the guardrails on the north and south side of the highway along the site. During the 2024 Section B inspection, KCB and TEC drove across the reconstructed area and did not observe any new pavement distress (cracking and/or settlement).

In March 2019, KCB conducted a geotechnical site investigation at the C048-1 and C048-3 sites. Drilling was completed in the south (eastbound) lane by Mobile Augers and Research Ltd. The encountered stratigraphy was as follows: pavement, overlying gravel fill, overlying clay fill, overlying clay till, overlying bedrock (sandstone and mudstone). The encountered stratigraphy was consistent with the stratigraphy encountered during a 2011 drilling investigation monitored by KCB.

1.1 Instrumentation

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

In November 2011, KCB installed one SI (SI11-01) and one standpipe piezometer (SP) (SP11-01) at the C048-1 site to monitor depth of movement and groundwater conditions, respectively. The instruments were installed in boreholes located on the south (eastbound) shoulder of Hwy 575:04 and are now inoperable.

On March 25, 2021, three SIs (SI21-C48-01 through SI21-C48-03) were installed in the H-pile walls at the C048-1 site to monitor deflection of the H-pile walls. SI21-C48-01 is located approximately 20 m from the west end of the upper H-pile wall. SI21-C48-02 and SI21-C48-03 are located approximately one-third (22 m) from either end of the lower H-pile wall. Each SI was installed 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 SIs 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.

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[1])	Condition
			Northing	Easting				
~~SI11-01~~	~~SI~~	~~Nov. 22, 2011~~	~~5707782~~	~~358492~~	~~825~~	~~Unknown~~	~~20.5~~	~~Inoperable~~
SI21-C48-01	SI	Mar. 25, 2021	5707781	358444	Unknown	0.5	11.3	Operable
SI21-C48-02	SI	Mar. 25, 2021	5707773	358468	Unknown	0.8	11.0	Operable
SI21-C48-03	SI	Mar. 25, 2021	5707771	358491	Unknown	0.5	11.3	Operable
~~SP11-01~~	~~SP~~	~~Nov 22, 2011~~	~~5707782~~	~~358492~~	~~Unknown~~	~~Unknown~~	~~13.0~~	~~Inoperable~~

Notes:
[1] Coordinates were obtained by KCB with a handheld GPS during installation with a horizontal accuracy of ± 5 m.
[2] Meters below ground surface (mbgs).

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 in the SIs are aligned approximately perpendicular to the highway in the direction of anticipated maximum movement (i.e., in the downslope direction).

The SI data plots are included in Appendix I and a summary of the SI data is provided in Table 2.1.

2.2 Zones of Movement

Before the instrument became inoperable, movement was being recorded in SI11-01 at an approximate depth of 2 m below ground surface in the highway embankment fill.

Distributed movement is being recorded in SI21-C48-01 (upper H-pile wall) along the length of the instrument from near ground surface to approximately 11 m below ground surface.

Distributed movement is being recorded in SI21-C48-02 and SI21-C48-03 (lower H-pile wall) along the length of the instruments from near ground surface to approximately 9 m and 8 m below ground surface, respectively.

The H-pile walls are 12 m deep, and the SIs are approximately 11 m deep.

2.3 Interpretation of Monitoring Results

Based on the stratigraphy encountered during the 2011 and 2019 drilling investigations, and the blows counted during H-pile wall construction in 2021, the upper and lower H-pile walls are likely

driven into firm clay fill and/or hard clay till, respectively. Discussions in the spring of 2021 with a former resident of the Town of Drumheller familiar with local engineering work revealed that the highway embankment was constructed using end-dumped fill with little compaction.

The depth of movement being recorded in the upper H-pile wall SI appears to be occurring approximately at the base of the H-pile wall, while the movement recorded in the lower H-pile wall appears to be occurring between 2 m and 3 m above the base of the H-pile walls. This indicates that the H-pile walls have intercepted the failure surface and have transferred the load to depths below the failure plane as the piles stabilize the slide mass.

The spring 2024 data obtained from the pile-wall SIs indicates that the tops of the upper and lower H-pile walls have deflected up to approximately 37 mm and 48 mm, respectively, since installation.

In the fall of 2021, shortly after construction of the H-pile walls, the maximum rate of movement recorded in SI21-C48-01 (upper H-pile wall) was approximately 31 mm/year. Between fall of 2021 and spring of 2023, the rate of movement was relatively steady (less than 15 mm/year) before increasing in the fall of 2023 (24 mm/year) likely due to construction activities at the site. The rate of movement has since slowed and is now less than 5 mm/year.

Between spring of 2021 of fall of 2022, relatively steady movement of approximately 18 mm/year was recorded in SI21-C48-02 (lower H-pile wall). Since fall of 2022, the rate of movement has slowed and is currently approximately 1 mm/year.

In the fall of 2021, shortly after construction of the H-pile walls, the maximum rate of movement recorded in SI21-C48-03 (lower H-pile wall) was approximately 59 mm/year. Between the fall of 2021 and spring of 2024, the overall rate of movement has been approximately 10 mm/year. The rate of movement appears to fluctuate seasonally for this instrument (i.e., increases and decreases recorded in the fall and spring, respectively) between approximately 3mm/year and 29 mm/year.

Increased rates of movement were recorded in all three SIs in September 2023, which may be attributed to a higher volume of heavy truck traffic due to the summer 2023 pavement overlay project. The spring 2024 readings indicates that movement rates have since slowed to between 1 mm/year and 5 mm/year.

Distributed movement (i.e., from top to bottom of casing) up to approximately 21 mm has also recorded in the B-direction of the SIs. Between the spring and fall 2023 readings, the rate of movement increased significantly from approximately 4 mm/year to approximately 15 mm/year (maximum rate of movement recorded in SI21-C48-02 in the lower H-pile wall). The rate of movement has since slowed to less than 1 mm/year. It is unknown if this movement was 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 and stabilizing the sliding mass.

Table 2.1 Slope Inclinometer Reading Summary

Instrument ID	Location	Date				Ground Surface Elevation (m)	Depth of Movement (mbgs[1])	Direction of Movement	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
SI21-C48-01	Upper H-Pile Wall	Apr. 21, 2021	Sep. 20, 2023	Sep. 20, 2023	May 13, 2024	Unknown	0.8 – 10.8	A-Direction	36.9	3.1	31.1	4.8	-18.7
SI21-C48-02	Lower H-Pile Wall	Apr. 21, 2021	Sep. 20, 2023	Sep. 20, 2023	May 13, 2024	Unknown	0.4 – 10.4	A-Direction	28.0	0.7	27.8	1.0	-6.3
SI21-C48-03	Lower H-Pile Wall	Apr. 21, 2021	Sep. 20, 2023	Sep. 20, 2023	May 13, 2024	Unknown	0.3 – 10.8	A-Direction	48.0	2.0	59.1	3.1	-17.3

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

3 RECOMMENDATIONS

3.1 Future Work

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

3.2 Instrument Repairs and Maintenance

No instrument repairs or maintenance are required.

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:

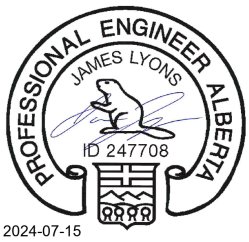
1. The report is to be read in full, with sections or parts of the report relied upon in the context of the whole report.
2. The observations, findings and conclusions in this report are based on observed factual data and conditions that existed at the time of the work and should not be relied upon to 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.

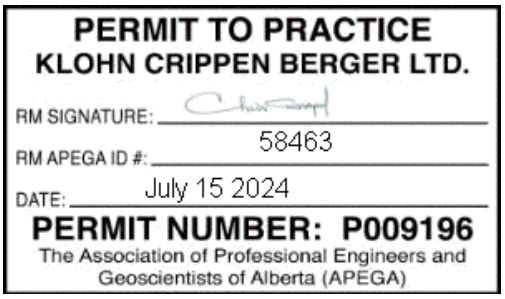


2024-07-15

James Lyons, P.Eng.
Civil Engineer

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

JL:bb



ATTACHMENTS
Figure
Appendix I Instrumentation Plots

FIGURE

Meters
0 100

Legend

- Slope Inclinometer
- Fence
- Top of Slope
- Scarp
- Crack
- H-Pile Wall
- Flow Direction
- Power Pole
- Guardrail
- Toe Roll

NOTES:
1. HORIZONTAL DATUM: NAD83
2. GRID ZONE: UTM Zone 12N
3. IMAGE SOURCE: World Imagery, ESRI ArcGIS Online Source date July 2020
4. Instrument locations are approximate (not surveyed).
5. Strikethrough indicates the instrument is inoperable.

CLIENT: Alberta

Klohn Crippen Berger

PROJECT: CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE: Site Plan
C048-1 and -3 Slides
Hwy 575:04, km 14.5

SCALE	PROJECT No.	FIG No.
1:2,000	A05116A02	1

APPENDIX I

Instrumentation Plots

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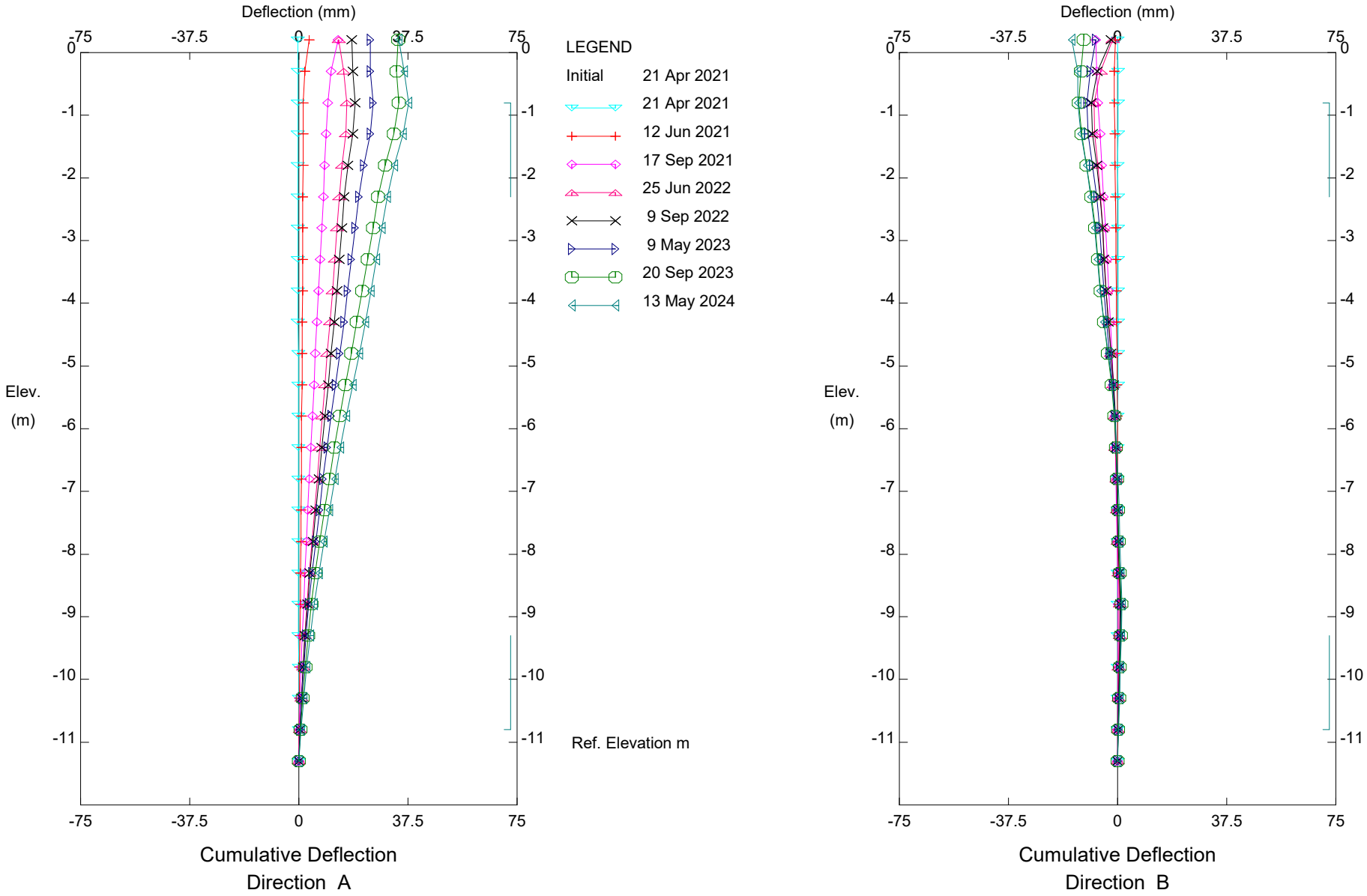

C048; H575:04; Slide W of Carbon Creek, Inclinometer SI21-C48-01

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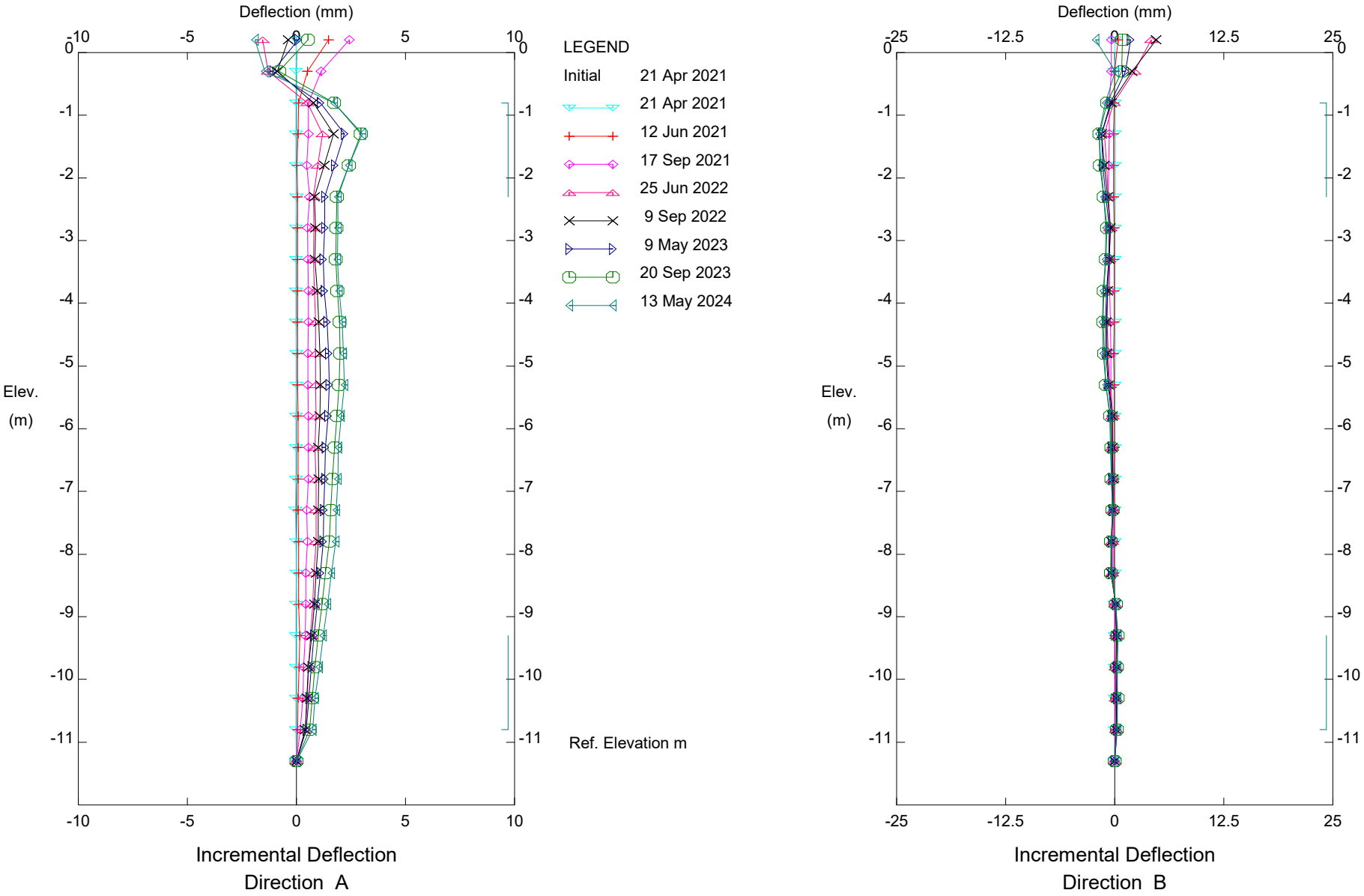

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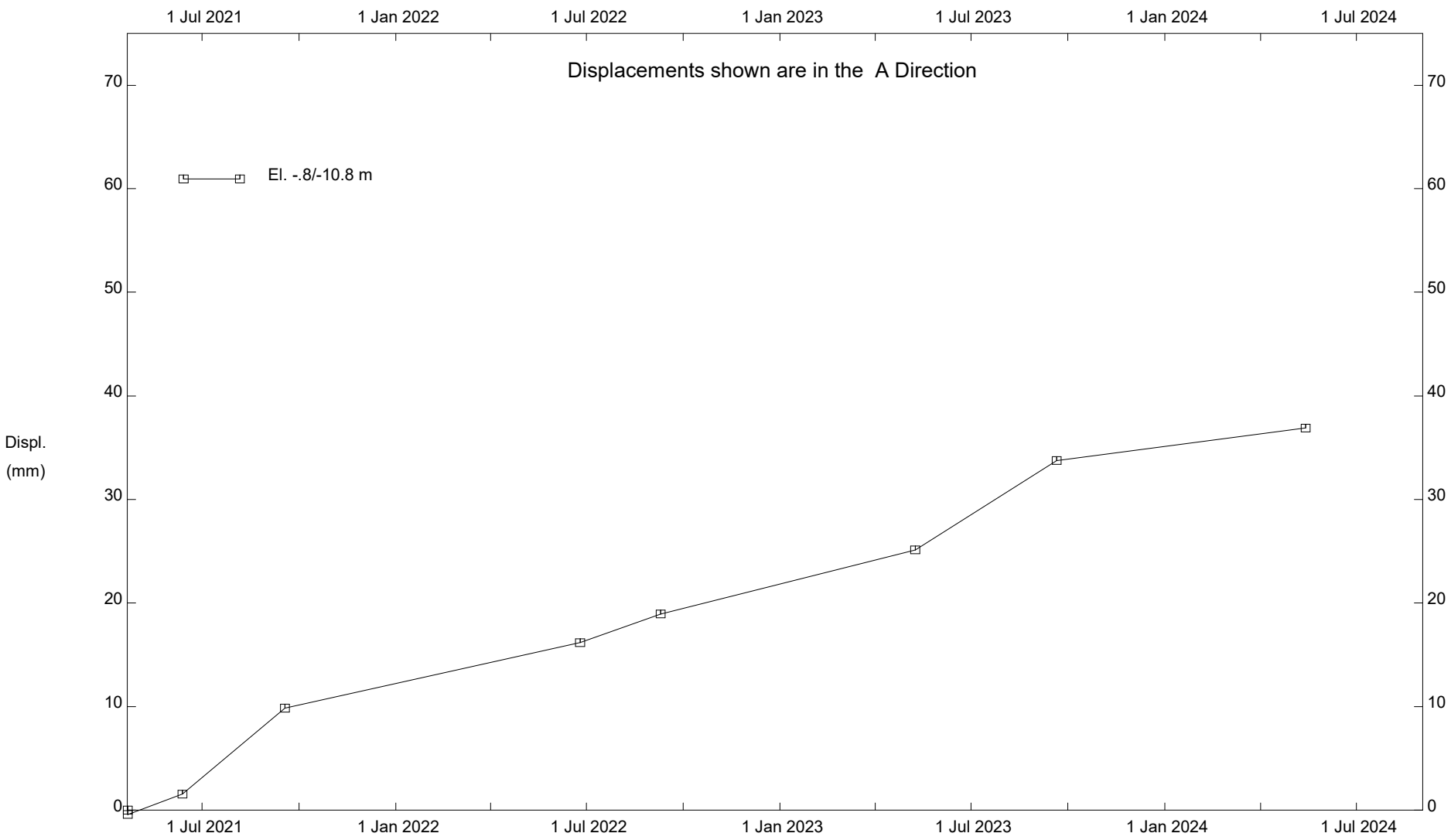

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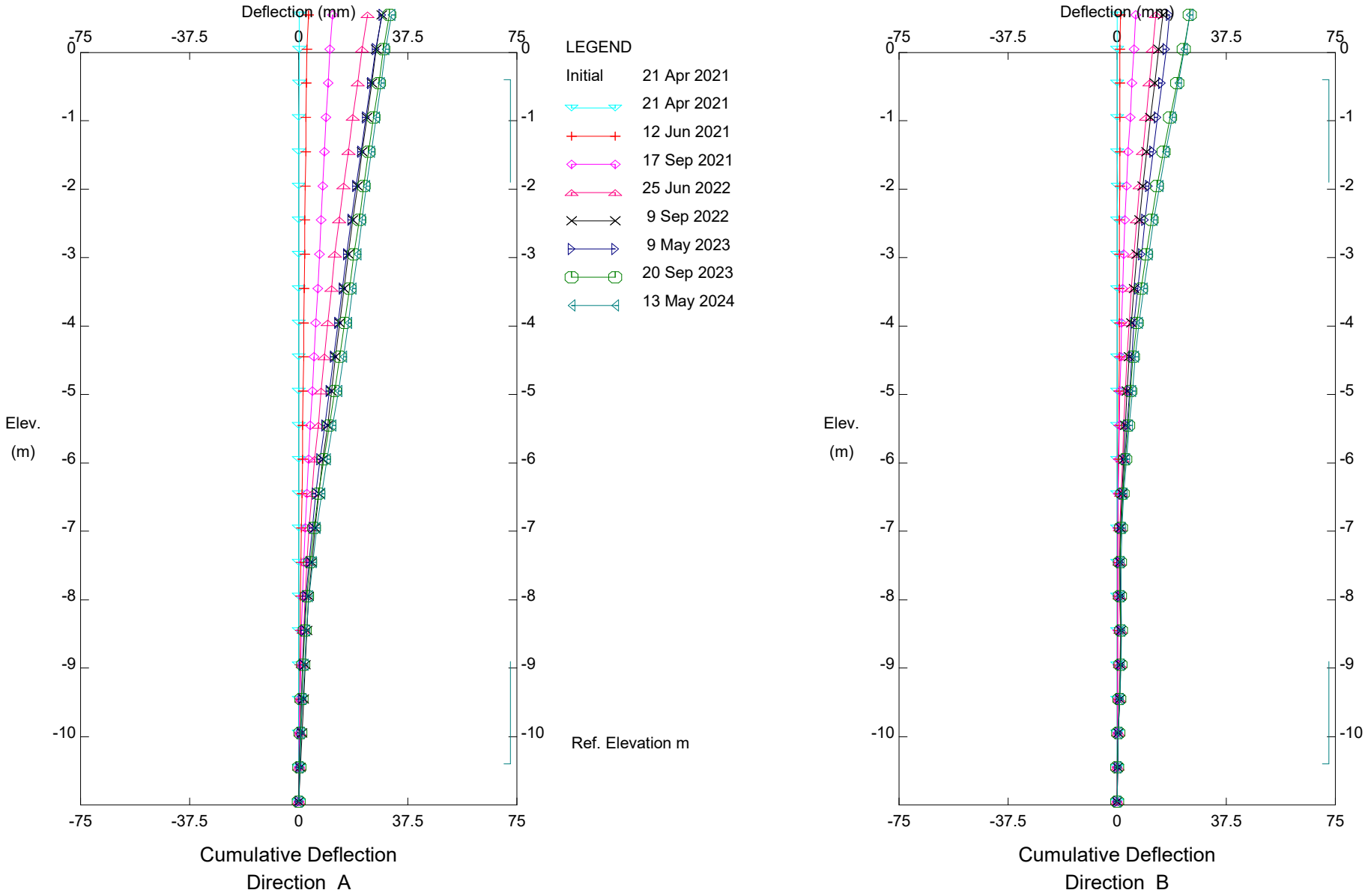

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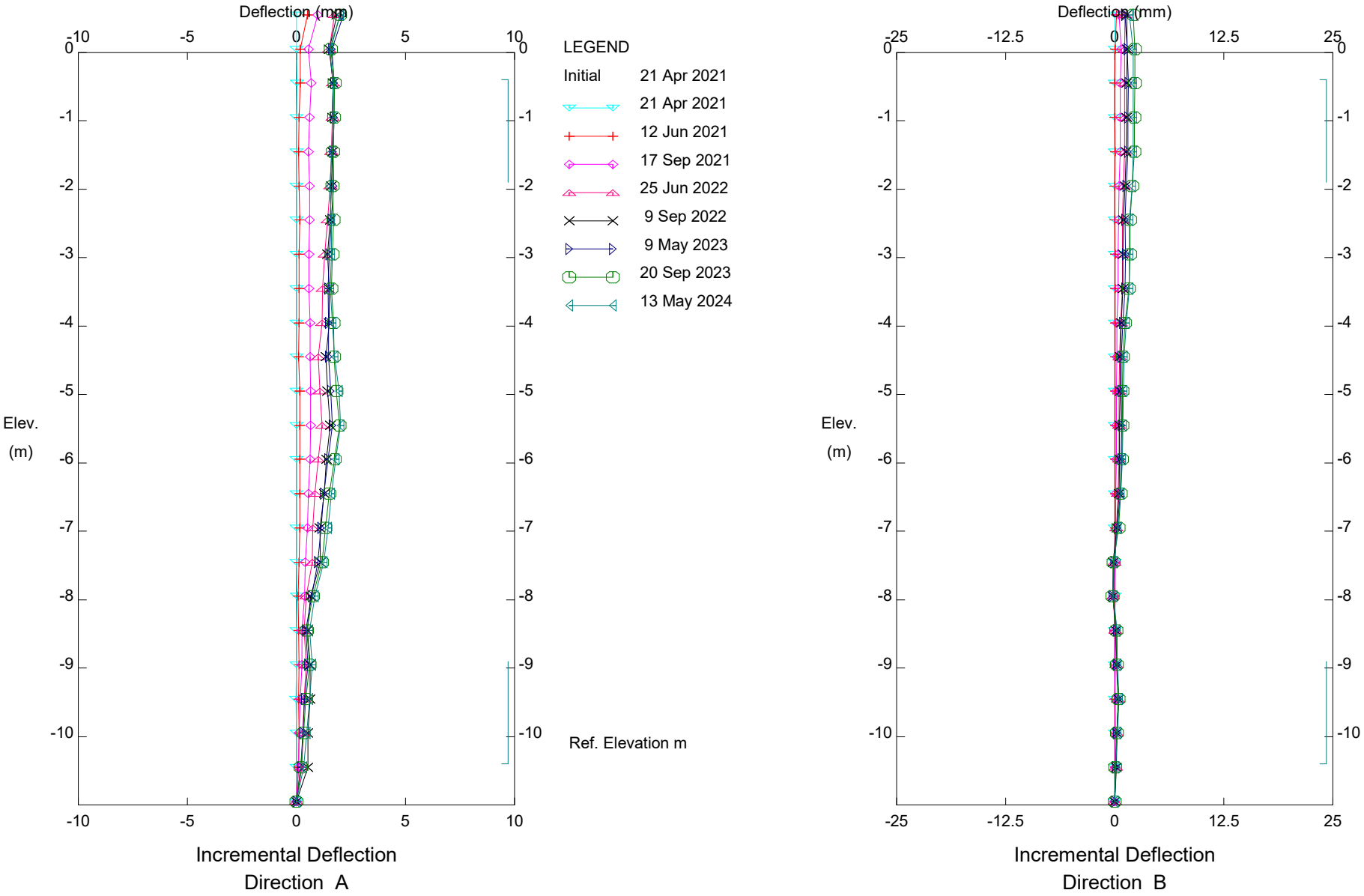

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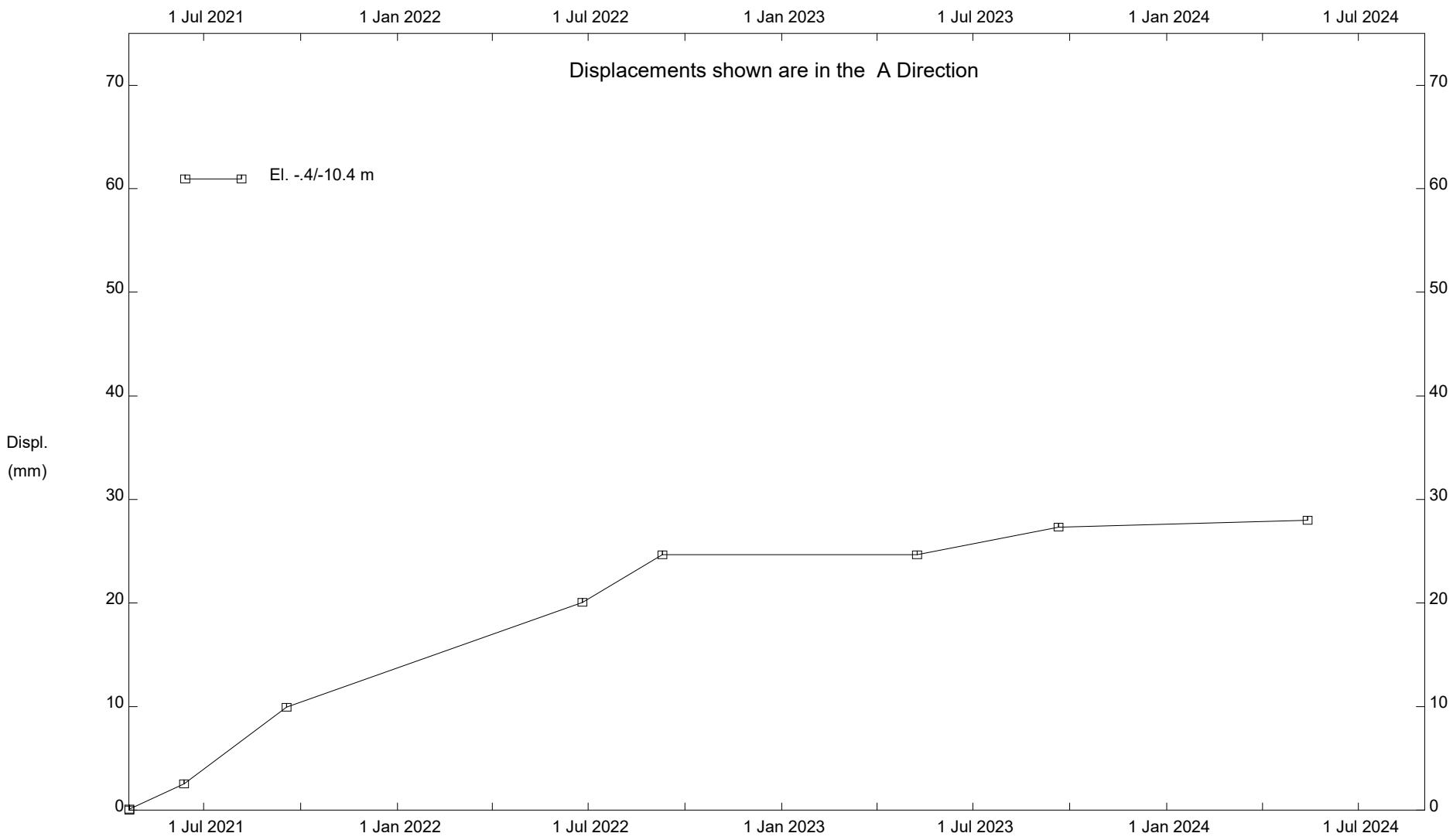

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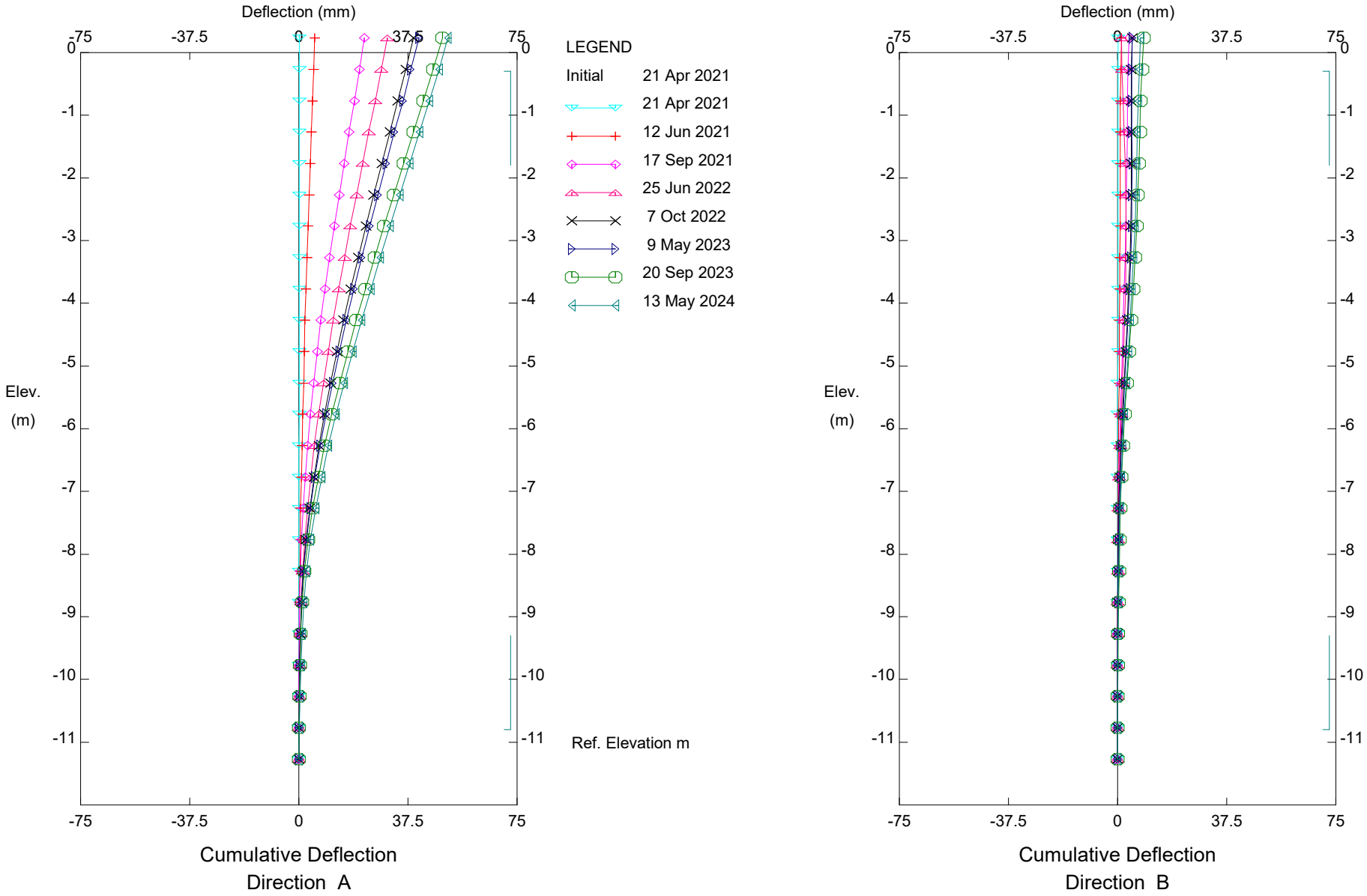

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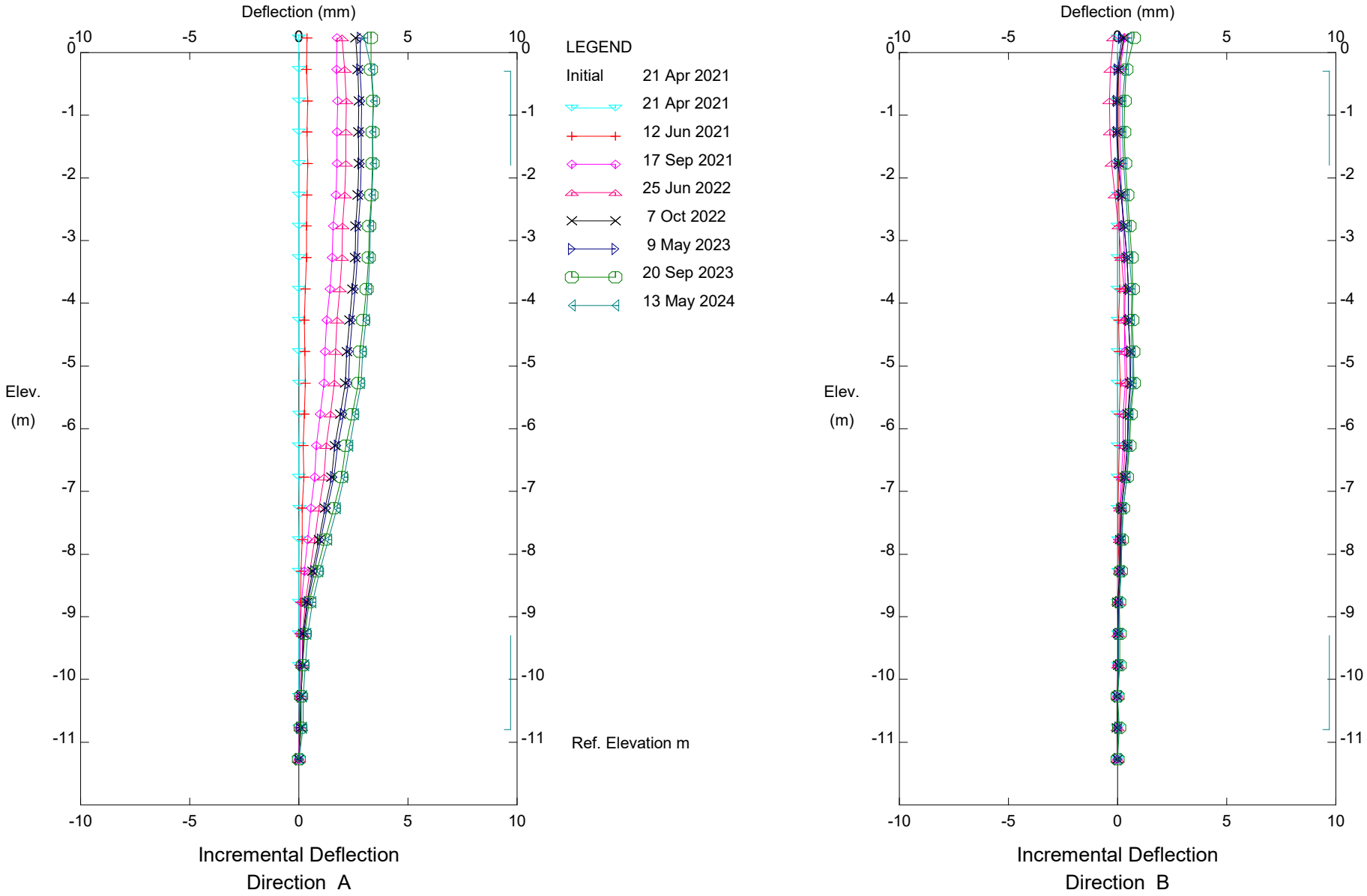

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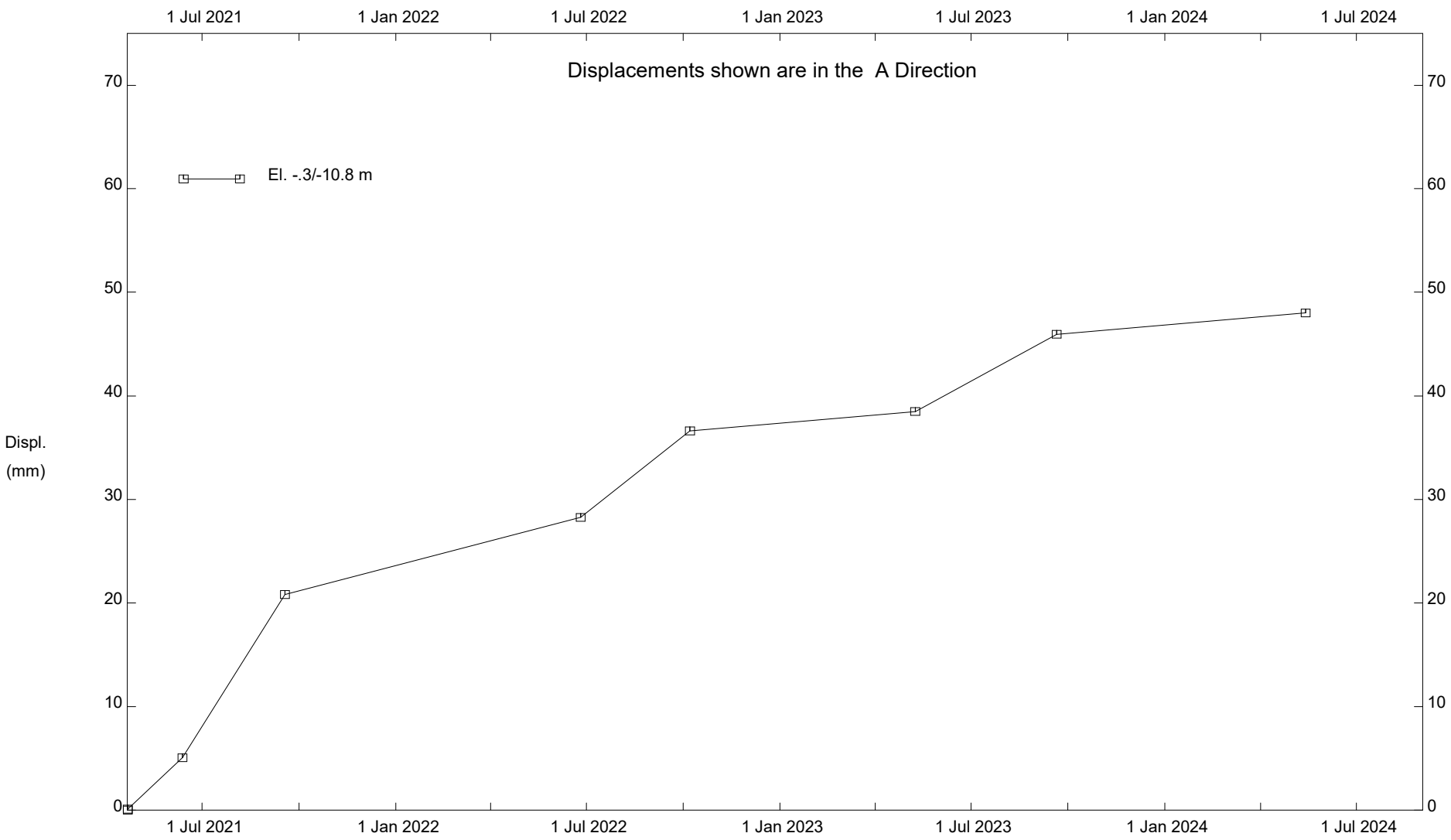
Klohn Crippen Berger - Calgary



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