

July 10, 2024

Alberta Transportation and Economic Corridors
2nd Floor, 803 Manning Road N.E.
Calgary, Alberta
T2E 7M8

Alex Frotten, P.Eng.
Construction Engineer – Delivery Services Division (Southern Region)

Dear Mr. Frotten:

CON0022161 Southern Region GRMP Instrumentation Monitoring
Site S004; H02:08, km 6.284 Willow Creek
Section C – 2024 Spring Readings

1 GENERAL

Six vibrating wire piezometers (VWPs) (VW14-01A/B, VW14-02A/B, and VW14-03A/B) , six standpipe piezometers (SPs) (SP-1B/C, SP-5B/C, SP-9B, and SP-10B) and four slope inclinometers (SIs) (SI-1A, SI-5A, SI-9A, and SI-10A) were read on May 15, 2024, by Mr. Bradley Lawson, E.I.T. of KCB. These instruments were read as part of the Southern Region Geohazard Risk Management Program (GRMP). The site is located at Hwy 02:08 km 6.284, north of Fort Macleod, Alberta, approximately 1.9 km north of the junction of RR 264 and Hwy 2. The approximate site coordinates are 5514351 N, 320169 E (UTM Zone 12, NAD 83). A site plan is presented in Figure 1.

The geohazard at the S004 site consists of a landslide at the outside bend of Willow Creek with the slope crest retrogressing into the northbound lane ditch of Hwy 02:08. Previous remedial actions at the site include soil nailing, grading, bioengineering (live staking), and bank armoring in 2008. A guardrail was also installed in 2014.

In 1994 and 2014, geotechnical site investigations, which included installing instruments, were conducted at the S004 site by the previous consultants. Based on files received from the previous consultant, the encountered stratigraphy was as follows: clay till, overlying bedrock (shale).

1.1 Instrumentation

KCB has been reading the instruments at this site since readings resumed in the fall of 2020 at the request of Alberta Transportation and Economic Corridors (TEC). No readings were completed at this site between 2003 and 2020. Instrumentation installation details are tabulated in Table 1.1. Instrument locations are shown in Figure 1. Any instruments not included in Table 1.1 or shown in Figure 1 are assumed to be inoperable and are not presented or discussed herein.

In 1994 and 2014, 16 SIs and 41 piezometers were installed at the site by the previous consultants to monitor movement and groundwater conditions, respectively. Some of these instruments are now inoperable (e.g., destroyed, sheared, or lost), including several SIs installed within the slide mass (SI-2A through SI-8A, excluding SI-5A).

In June 2023, data loggers were installed on all six VWPs.

The operable instruments are protected by either a flush-mounted or an above-ground casing protector.

The SI equipment was changed in 2020 when KCB began reading the instruments, and again in October 2021 after the previous equipment became inoperable. Currently, KCB is reading the SIs with a metric RST Digital MEMS Inclinometer System.

The VWPs and SPs were read using an RST VWP readout box and Water Level Meter, respectively.

Table 1.1 Instrument Installation Details

Instrument ID	Instrument Type	Date Installed ¹	UTM Coordinates ² (m)		Ground Surface Elevation (m)	Stick Up (m)	Depth ³ (mbgs ³)	Condition
			Northing	Easting				
SI-1A	SI	Jul. 1994	5514354	320200	Unknown	0.8	38.9	Operable
SI-2A	SI	Jul. 1994	Unknown	Unknown	Unknown	Unknown	Unknown	Inoperable ⁴
SI-3A	SI	Jul. 1994	Unknown	Unknown	Unknown	Unknown	Unknown	Inoperable ⁴
SI-4A	SI	Jul. 1994	Unknown	Unknown	Unknown	Unknown	Unknown	Inoperable ⁴
SI-5A	SI	Jul. 1994	5514343	320213	Unknown	0.7	38.2	Operable
SI-6A	SI	Jul. 1994	Unknown	Unknown	Unknown	Unknown	Unknown	Inoperable ⁴
SI-7A	SI	Jul. 1994	Unknown	Unknown	Unknown	Unknown	Unknown	Inoperable ⁴
SI-8A	SI	Jul. 1994	Unknown	Unknown	Unknown	Unknown	Unknown	Inoperable ⁴
SI-9A	SI	Jul. 1994	5514472	320115	971.2	0.6	38.7	Operable
SI-10A	SI	Jul. 1994	5514542	320186	971.0	0.8	38.8	Operable
SP-1B	SP	Jul. 1994	5514354	320200	970.0	0.8	Unknown	Operable
SP-1C	SP	Jul. 1994	5514354	320200	970.0	0.6	Unknown	Operable
SP-5B	SP	Jul. 1994	5514343	320213	970.0	0.7	Unknown	Operable
SP-5C	SP	Jul. 1994	5514343	320213	970.0	0.7	Unknown	Operable
SP-9B	SP	Jul. 1994	5514472	320115	971.1	0.6	Unknown	Operable
SP-9C	SP	Jul. 1994	5514472	320115	Unknown	Unknown	Unknown	Inoperable ⁴
VW14-01A	VWP	Jul. 2014	5514310	320229	968.8	N/A	14.7	Operable
VW14-01B	VWP	Jul. 2014	5514310	320229	968.8	N/A	6.0	Operable
VW14-02A	VWP	Jul. 2014	5514449	320122	969.2	N/A	14.8	Operable
VW14-02B	VWP	Jul. 2014	5514449	320122	969.2	N/A	6.1	Operable
VW14-03A	VWP	Jul. 2014	5514367	320141	969.0	N/A	14.9	Operable
VW14-03B	VWP	Jul. 2014	5514367	320141	969.0	N/A	5.9	Operable

Notes:

¹ Instrument installation details taken from reports and data files prepared or provided by the previous consultant(s) or Alberta Transportation.

² Coordinates were obtained by KCB with a handheld GPS. The handheld GPS had an accuracy of ±5 m.

³ Meters below ground surface (mbgs).

⁴ Instruments (SI-2A through SI-8A, excluding SI-5A, and SP-9C) located within the slide mass are assumed inoperable.

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).

For the operable SPs, the recorded water levels were converted to an equivalent water/piezometric elevation and plotted relative to ground surface elevation. Screen elevations are not available for the SPs.

For the operable VWPs, the recorded porewater pressures were converted to an equivalent water/piezometric elevation and plotted relative to ground surface elevation and each instrument's tip elevation.

Monthly precipitation data is also plotted with the piezometer data. The data was obtained from the Alberta Climate Information Service (ACIS) database, referencing legal subdivision TWP009-26-W4. At the time of issuing of this report, data up to the end of March 2024 was available.

The SI and piezometer data plots are included in Appendix I, and a summary of the SI and piezometer data is provided in Table 2.1, Table 2.2, and Table 2.3, respectively. The September 2022 reading was the first time KCB read SI-10A and SP-10B. The SI data plots only include data obtained by KCB. Data obtained by previous consultants has not been provided to KCB.

The SI data obtained with KCB's new SI reading equipment appears relatively noisy (despite good data quality) compared to the baseline reading obtained with KCB's old SI reading equipment and is difficult to interpret, especially for SI-5A (the instrument was read twice during both the spring and fall 2022 readings and twice during the spring 2023 readings). It is unclear if the noise is due to changing the SI reading equipment, the low rate of movement being recorded in these instruments, or installation issues (e.g., casing kinked or titled). Based on the plots for these instruments, it is noted that the casing for:

- SI-1A is “wavy” with kinks at approximately 22 m, 28 m, and 36 m below ground surface;
- SI-5A is tilted approximately 1.0 m in the A-direction and 1.7 m in the B-direction, and there is also a kink in the casing at approximately 22 m below ground surface; and
- SI-9A is “wavy” with kinks at approximately 5 m, 11 m, and 25 m below ground surface.
- SI-10A is “wavy” with kinks at approximately 5 m and 25 m below ground surface.

The SI data plots presented herein include data for readings taken with both our new and old SI reading equipment. More data is needed to assess if the instruments need to be re-initialized.

Table 2.1 Slope inclinometer Reading Summary

Instrument ID	Date				Ground Surface Elevation (m)	Depth of Movement (mbgs ¹)	Direction of Movement	Movement (mm)			Rate of Movement (mm/year)			
	Initialized (Re-initialized) ^{2,4}	Previous Maximum Cumulative Movement Recorded	Previous Reading	Most Recent Reading				Maximum Cumulative			Incremental Since Previous Maximum Cumulative	Previous Maximum	Most Recent Reading	Change from Previous Reading
								Before Re-Initialization	After Re-Initialization	Total				
SI-1A	1994 (Sep. 23, 2020)	N/A – no discernible movement recorded since re-initialization and historical data was not provided for KCB’s review ²	October 11, 2023	May 15, 2024	970.0	4 m – 6 m	X-Direction 45°	N/A	1.3	1.3	0.7	0.8	2.8	5.8
SI-5A	1994 (Sep. 23, 2020)		October 11, 2023	May 15, 2024	970.0									
SI-9A	1994 (Sep. 23, 2020)		October 11, 2023	May 15, 2024	971.2									
SI-10A ³	1994 (Sep. 23, 2020)		October 11, 2023	May 15, 2024	971.0									

Notes:
¹ Meters below ground surface (mbgs).
² All SIs were re-initialized to the September-2020 readings when KCB took over the readings at the site and changed the SI reading equipment. Data recorded before September 2020 has not been provided to KCB for review. Historical reports prepared by the previous consultant between 1999 and 2003 did not report significant movements in these SIs.
³ SI-10A read by KCB for the first time in September 2022. Previous data for the instrument has not been provided to KCB.
⁴ SI-5A was re-initialized to the October 7, 2021 reading due to the readings not aligning with the previous readings.

Table 2.2 Standpipe Piezometer Reading Summary

Instrument ID	Geologic Installation Unit	Date			Ground Surface Elevation (m)	Screen 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)
SP-1B	Clay Shale	Jul. 1994	Oct. 11, 2023	May 15, 2024	970.0	Unknown	13.8	14.2	-0.4
SP-1C	Not Provided	Jul. 1994	Oct. 11, 2023	May 15, 2024	970.0	Unknown	16.0	16.5	-0.5
SP-5B	Clay Shale	Jul. 1994	Oct. 11, 2023	May 15, 2024	970.0	Unknown	13.6	14.0	-0.4
SP-5C	Till Above Clay Shale	Jul. 1994	Oct. 11, 2023	May 15, 2024	970.0	Unknown	3.3	3.3	0.0
SP-9B	Clay Shale	Jul. 1994	Oct. 11, 2023	May 15, 2024	971.2	Unknown	13.8	14.0	-0.2
SP-10B	Unknown	Jul. 1994	Oct. 11, 2023	May 15, 2024	971.0	Unknown	14.4	14.4	0.0

Notes:
¹ Meters below ground surface (mbgs).

Table 2.3 Vibrating Wire Piezometer Reading Summary

Instrument ID	Serial No.	Date			Ground Surface Elevation (m)	Screen 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)
VW14-01A	1400848	Jul. 2014	Oct. 11, 2023	May 15, 2024	968.8	14.7	12.3	12.1	0.2
VW14-01B	1400846	Jul. 2014	Oct. 11, 2023	May 15, 2024	968.8	6.0	4.3	1.7	2.6
VW14-02A	1400849	Jul. 2014	Oct. 11, 2023	May 15, 2024	969.2	14.8	7.5	7.0	0.5
VW14-02B	1400248	Jul. 2014	Oct. 11, 2023	May 15, 2024	969.2	6.1	3.2	1.3	1.9
VW14-03A	1400843	Jul. 2014	Oct. 11, 2023	May 15, 2024	969.0	14.9	5.7	5.5	0.2
VW14-03B	1400842	Jul. 2014	Oct. 11, 2023	May 15, 2024	969.0	5.9	2.7	0.9	1.8

Notes:
¹ Meters below ground surface (mbgs).

2.2 Zones of Movement

KCB has assumed all SIs located within the slide mass are damaged (i.e., sheared) due to slide movements. During the next site visit a dummy probe can be used to assess if any of these SIs are able to be read.

Data recorded before September 2020 for the operable SIs (SI-1A, SI-5A, SI-9A, and SI-10A) has not been provided to KCB for review. However, historical reports prepared by the previous consultant between 1999 and 2003 did not report significant movements in these SIs, which is not considered unusual because these SIs are located outside the slide mass. No discernible movement has been recorded in SI-1A, SI-5A, or SI-9A since they were re-initialized to the September-2020 readings when KCB took over the readings at the site and changed the SI reading equipment. The second reading for SI-10A notes a possible shear plane at a depth of approximately 5 m below ground surface; more data is needed to assess movement trends for this instrument.

Distributed movement has been recorded in SI-5A from an approximate depth of 14 m to the base of the instrument. However, given the data is difficult to interpret, more data is needed to assess the movement trends for this instrument.

2.3 Interpretation of Monitoring Results

Data is not available for the SIs and PNs between 1994 and 2020 or the VWPs between 2015 and 2020. More data is needed to assess long-term trends for these instruments, especially in response to prolonged or heavy periods of rainfall or freshet infiltration.

The nature of sliding (back tilting blocks) observed on site suggests a combination of rotational failure and failure along a weak layer at depth. The right (south) flank of the slide appears to be retrogressing faster than other areas of the slide.

Since KCB took over reading the instruments in 2020, decreasing water levels have generally been recorded in the majority of the piezometers. The spring 2024 SP readings show a general trend of decreasing water levels, with the VWPs showing increases in water level starting in late March/early April 2024. Data loggers were installed on the six VWPs in early June 2023 and data downloaded in May 2024 to collect more data to determine if irrigation is influencing the groundwater at this site.

Generally, all six VWPs measured groundwater increases starting in 2024 with the most increase seen in late March/early April 2024 of up to 4 m as measured in VW14-01B. VW14-02B recorded the highest water level based on the data available, however previously no data loggers were installed which provides a limited data set. Rainfall data from station T009R26W4 only included data up to March 31, 2024, at the time of writing this report. Based on the data available, rainfall and snow melt have contributed to the rise in water levels in the VWPs. Water level responses to rainfall will be commented on in the fall 2024 report once the data is available.

The 1994 reading for SP-05C was most likely bad as it is approximately 10 m lower than the previous and current readings.

Water levels recorded in the nested VWP's installed between the highway and crest of the slide (VW14-01A/B and VW14-02A/B) varied from an approximate depth of 1.3 m to 1.7 m below ground surface in the upper "B" tips and 7.0 m to 12.1 m below ground surface in the lower "A" tips. Both the upper "A" tips have a similar elevation (El. 962.8 m and El. 963.1 m, respectively), and both the lower "B" tips have a similar tip elevation (El. 954.1 m and El. 954.4 m, respectively).

Water levels recorded in the nested VWP's installed in the median ditch of Hwy 02:08 (VW14-03A/B) were at approximate depths of 0.9 m and 5.5 m below ground surface in the upper "B" tip and the lower "A" tip, respectively.

The data recorded in the piezometers, specifically the upper versus lower SP screens/VWP tips, indicates there could be two independent water levels, which could indicate the presence of a perched water table.

3 RECOMMENDATIONS

3.1 Future Work

All operable instruments should continue to be read twice per year (spring and fall).

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

3.2 Instrument Repairs and Maintenance

No instrument repairs are required.

4 CLOSURE

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 Southern Region Geohazard Risk Management Program (Contract No. CON0022161), 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.
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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.

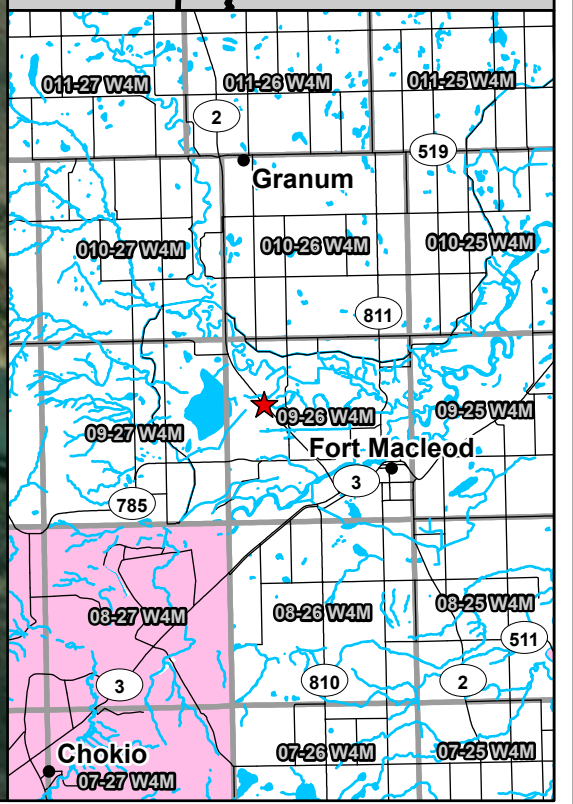
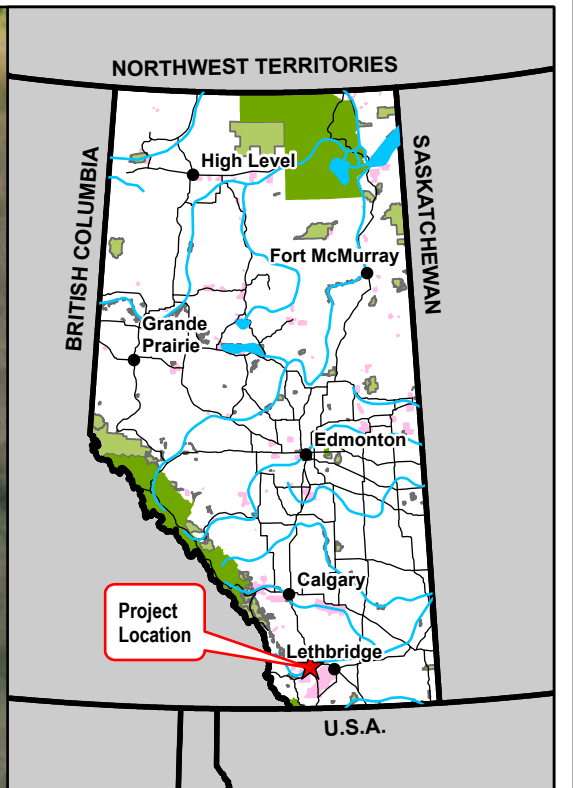
Peter Roy., P.Eng.
Civil Engineer

PR:kb

ATTACHMENTS

Figure
Appendix I Instrumentation Plots

FIGURE



- Legend**
- Slope Inclinator (SI)
 - ◆ Standpipe Piezometer (SP)
 - ⊗ Vibrating Wire Piezometer (VW)
 - Flow Direction
 - ┌ Scarp
 - × Fence

NOTES:
 1. HORIZONTAL DATUM: NAD83
 2. GRID ZONE: UTM ZONE 12N
 3. IMAGE SOURCE: MD OF WILLOW CREEK NO. 26, TOWN OF CARDSTON, MAXAR

CLIENT

Alberta

Klohn Crippen Berger

PROJECT SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM		
TITLE Site Plan S004 - Willow Creek (North of Ft. Macleod) Hwy 2:08, km 6.284		
SCALE 1:2,000	PROJECT No. A05116A03	FIG No. 1

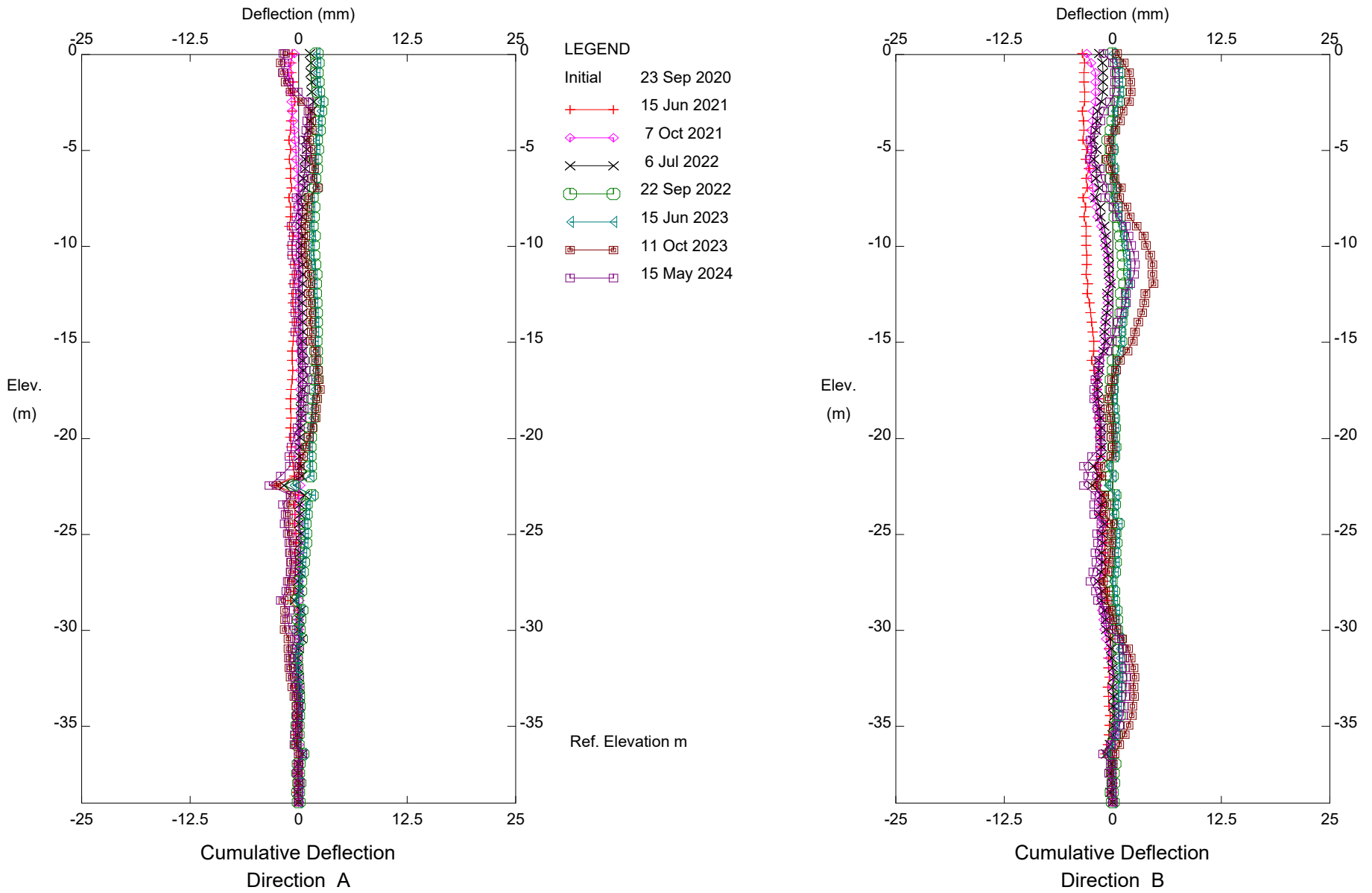


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APPENDIX I

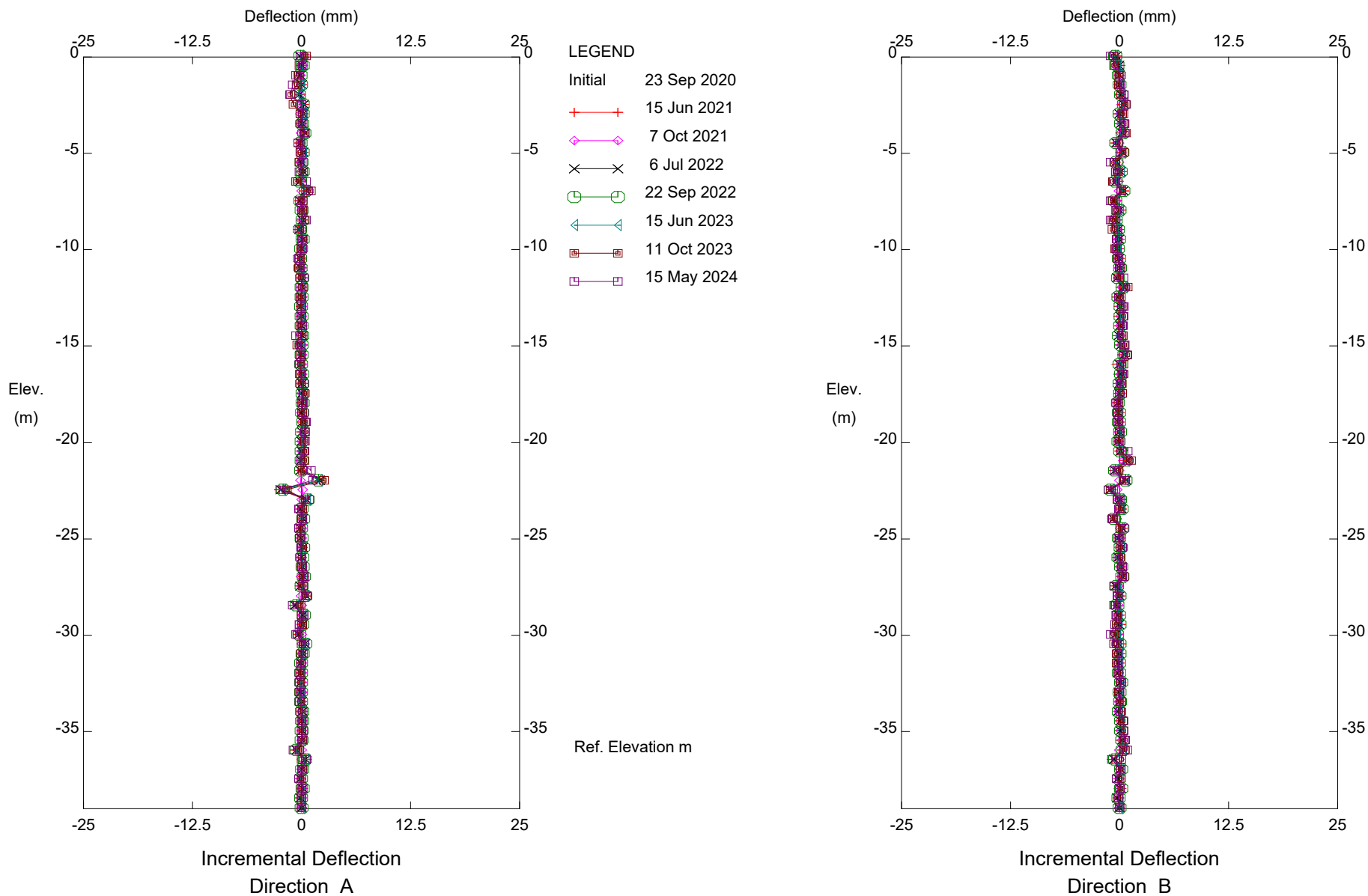
Instrumentation Plots

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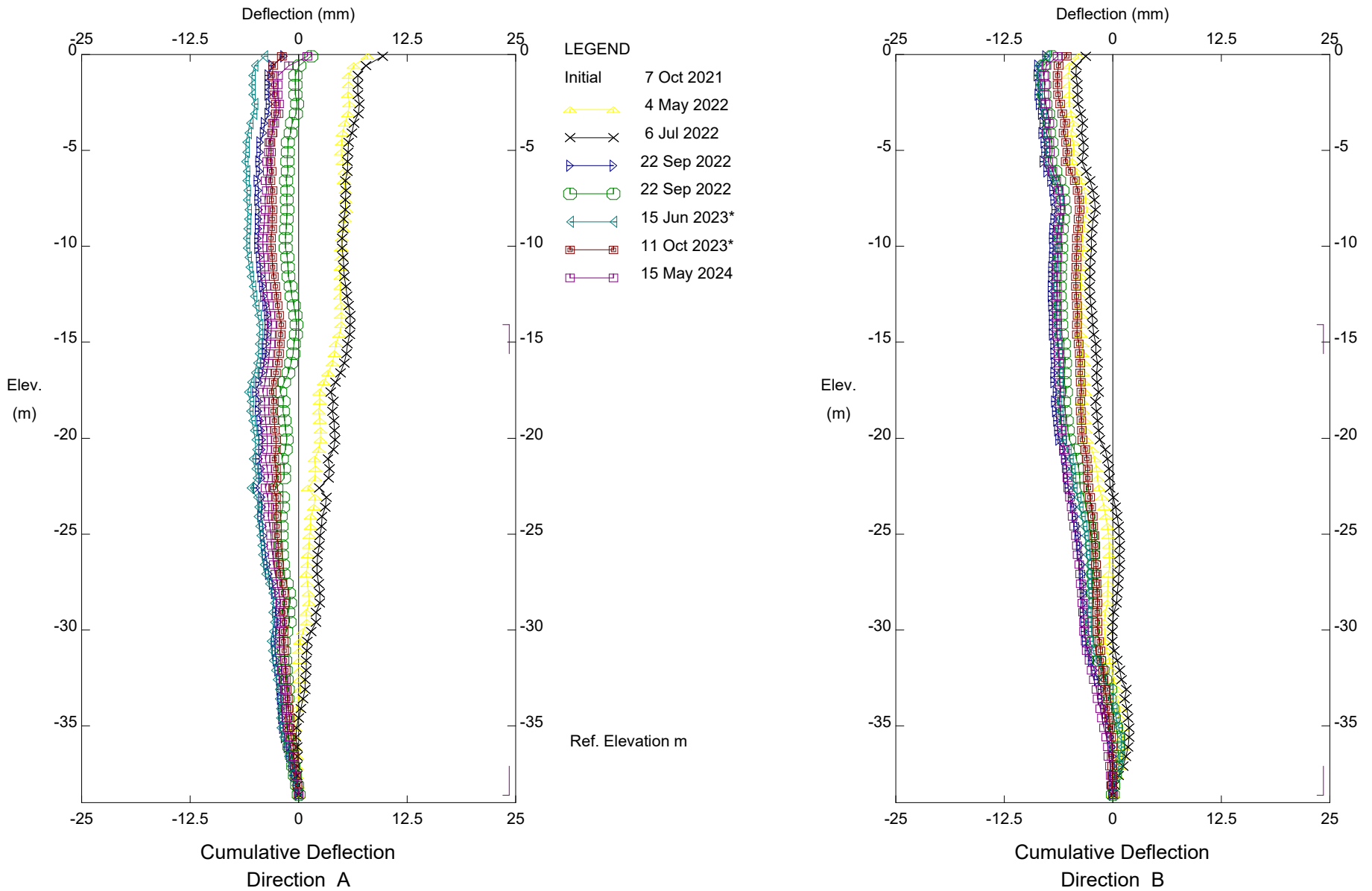
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 Alberta Transportation

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 Alberta Transportation

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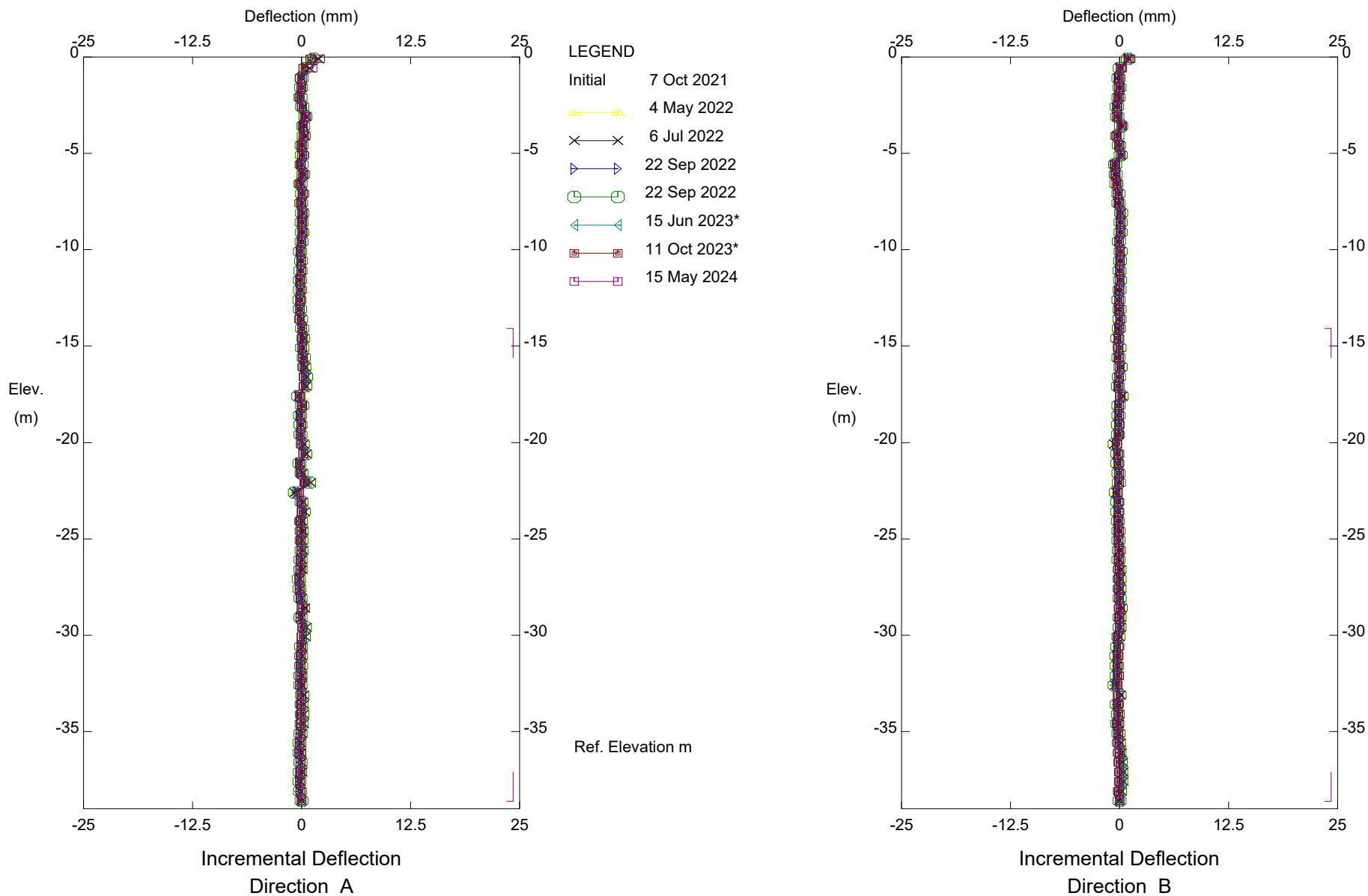


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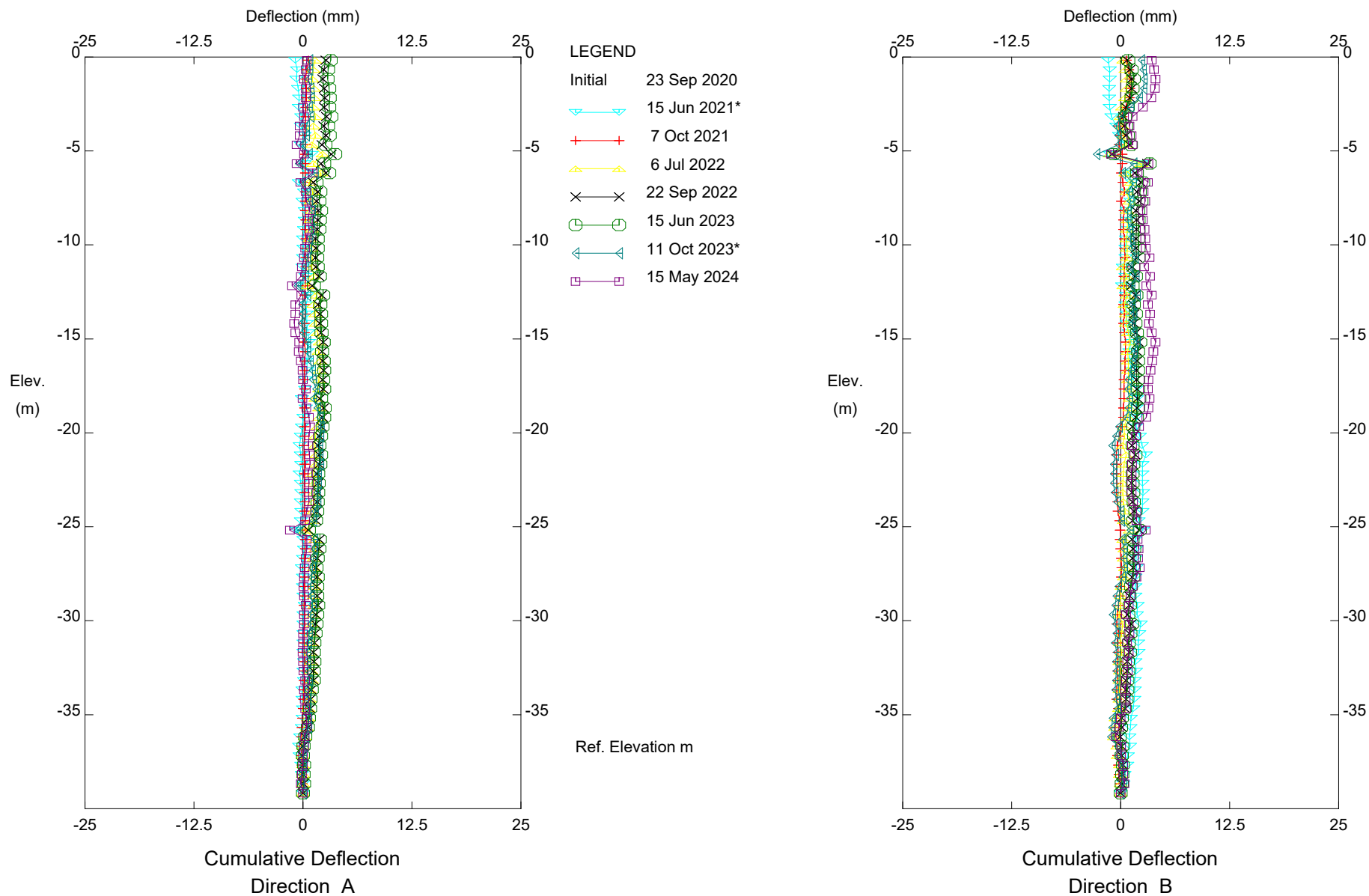


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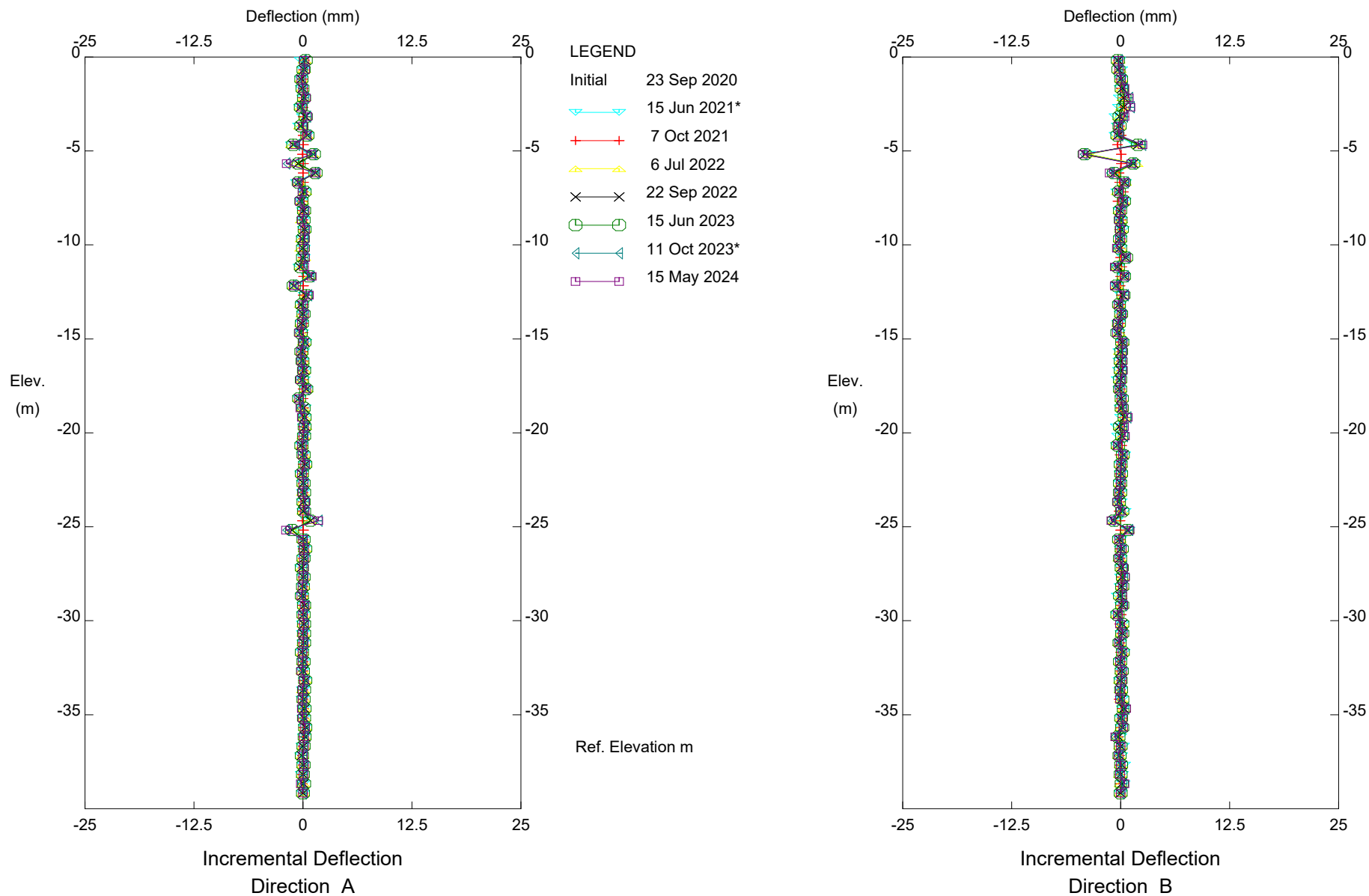


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Alberta Transportation

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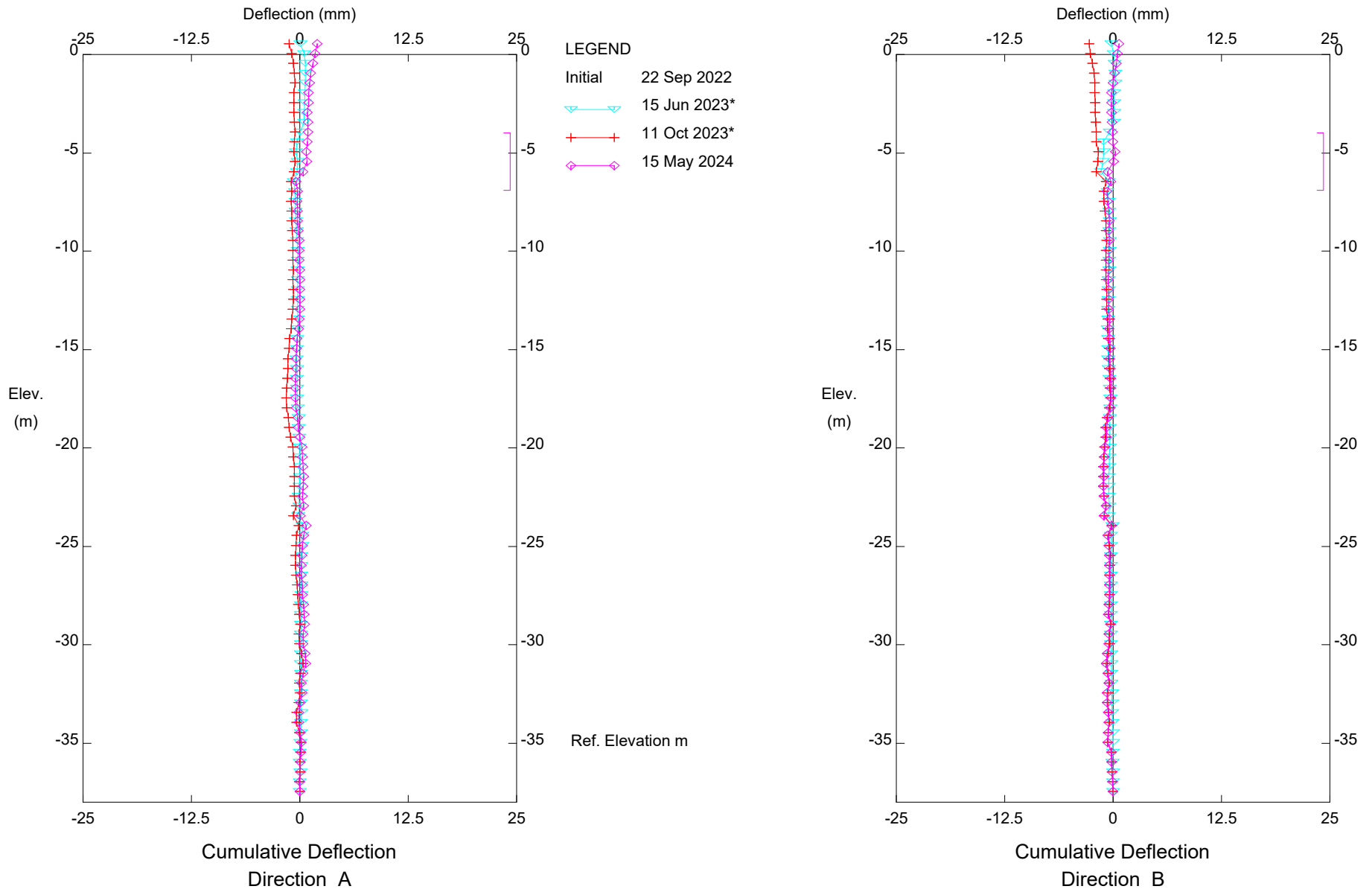
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 Alberta Transportation

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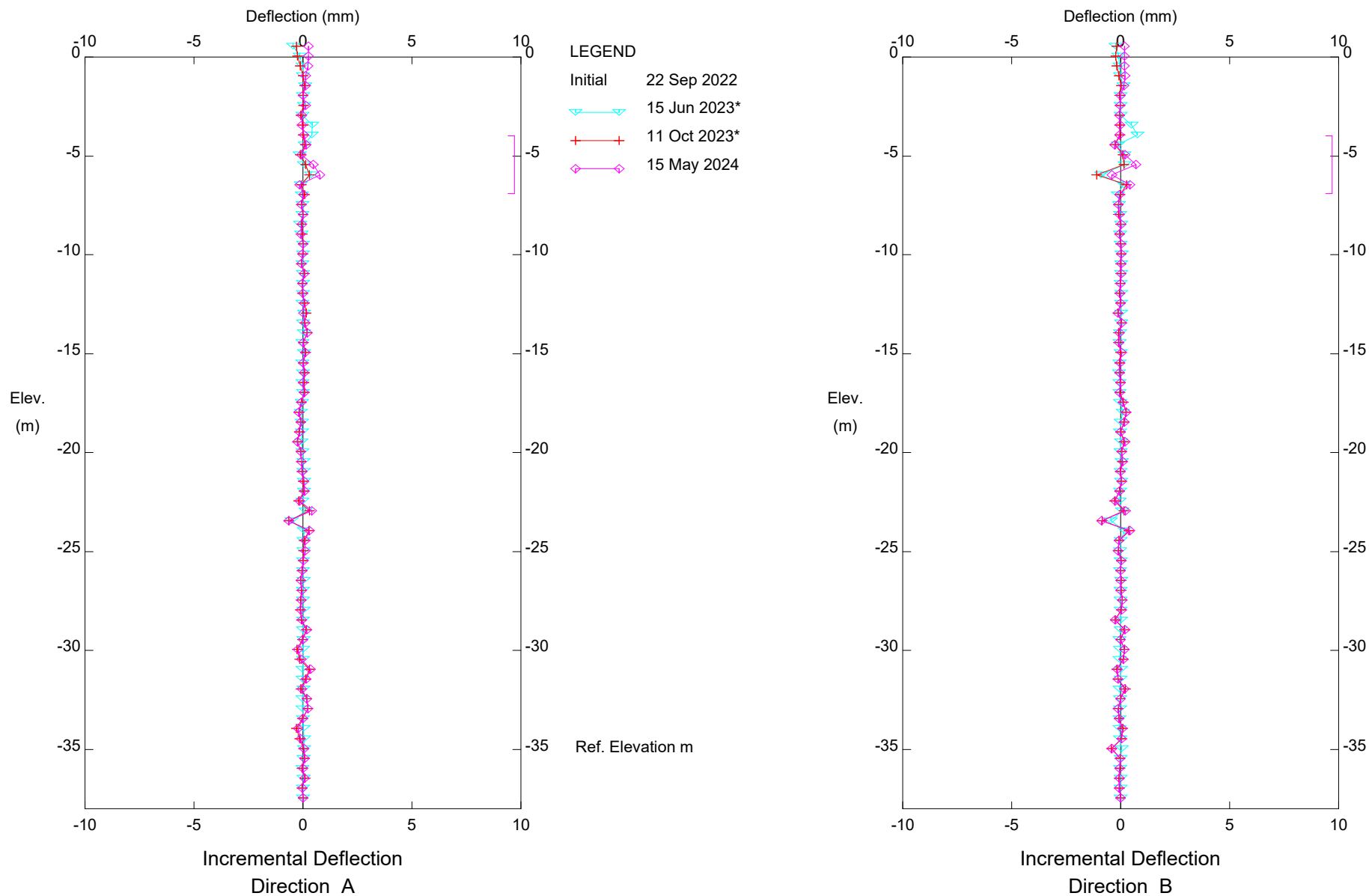
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Alberta Southern Region, Inclinator S04 SI-10A

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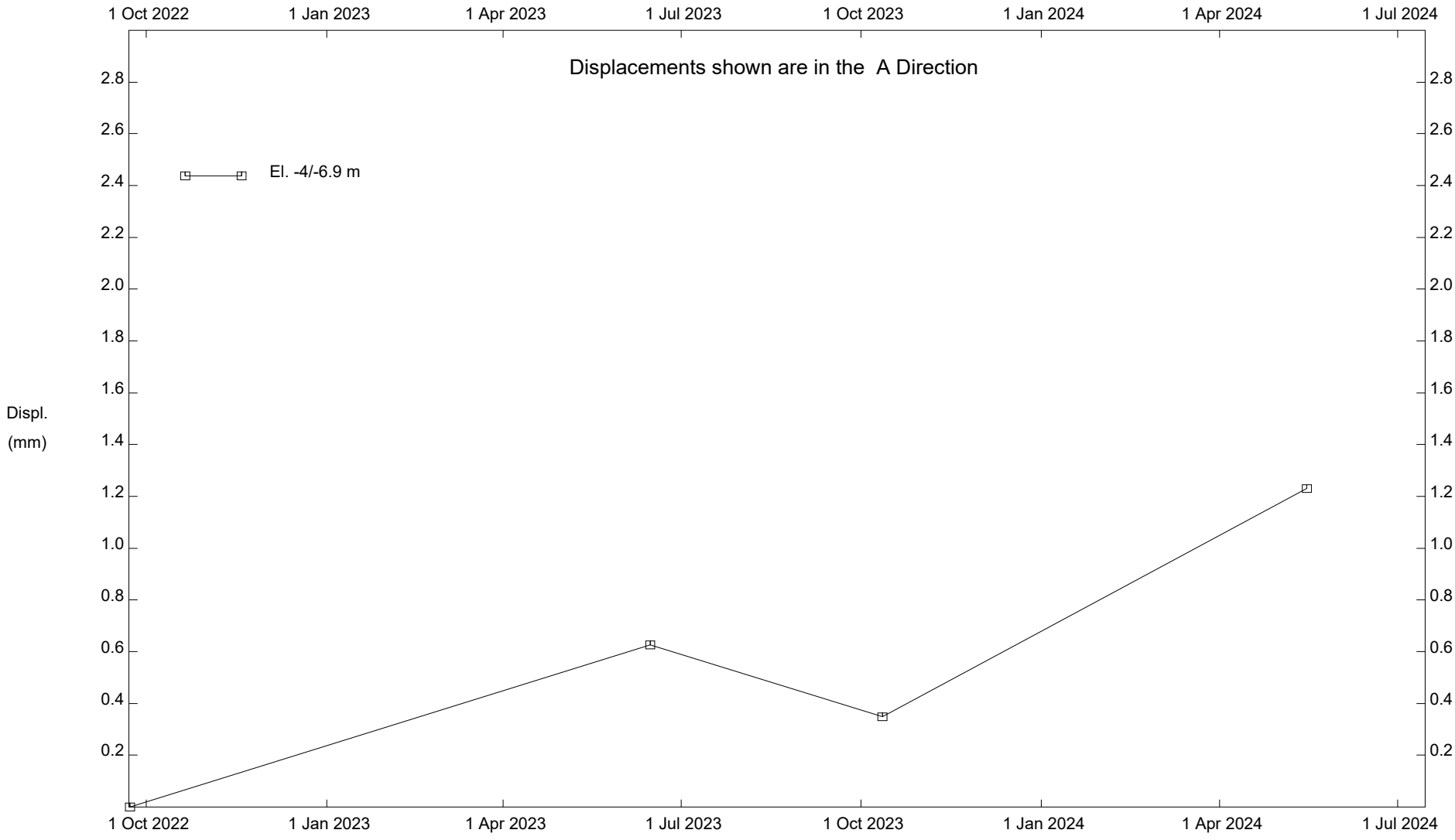
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Alberta Southern Region, Inclinator S04 SI-10A

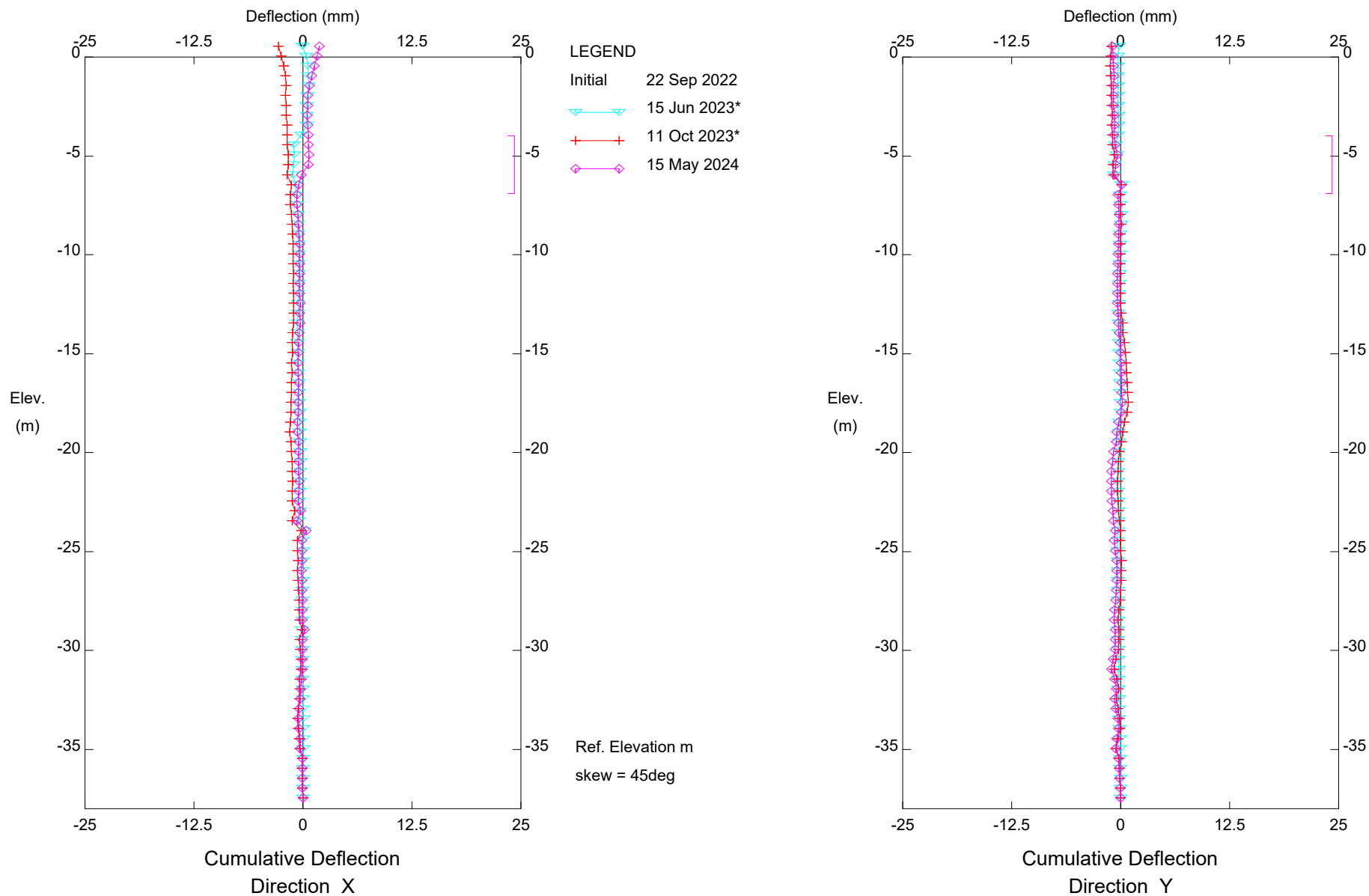
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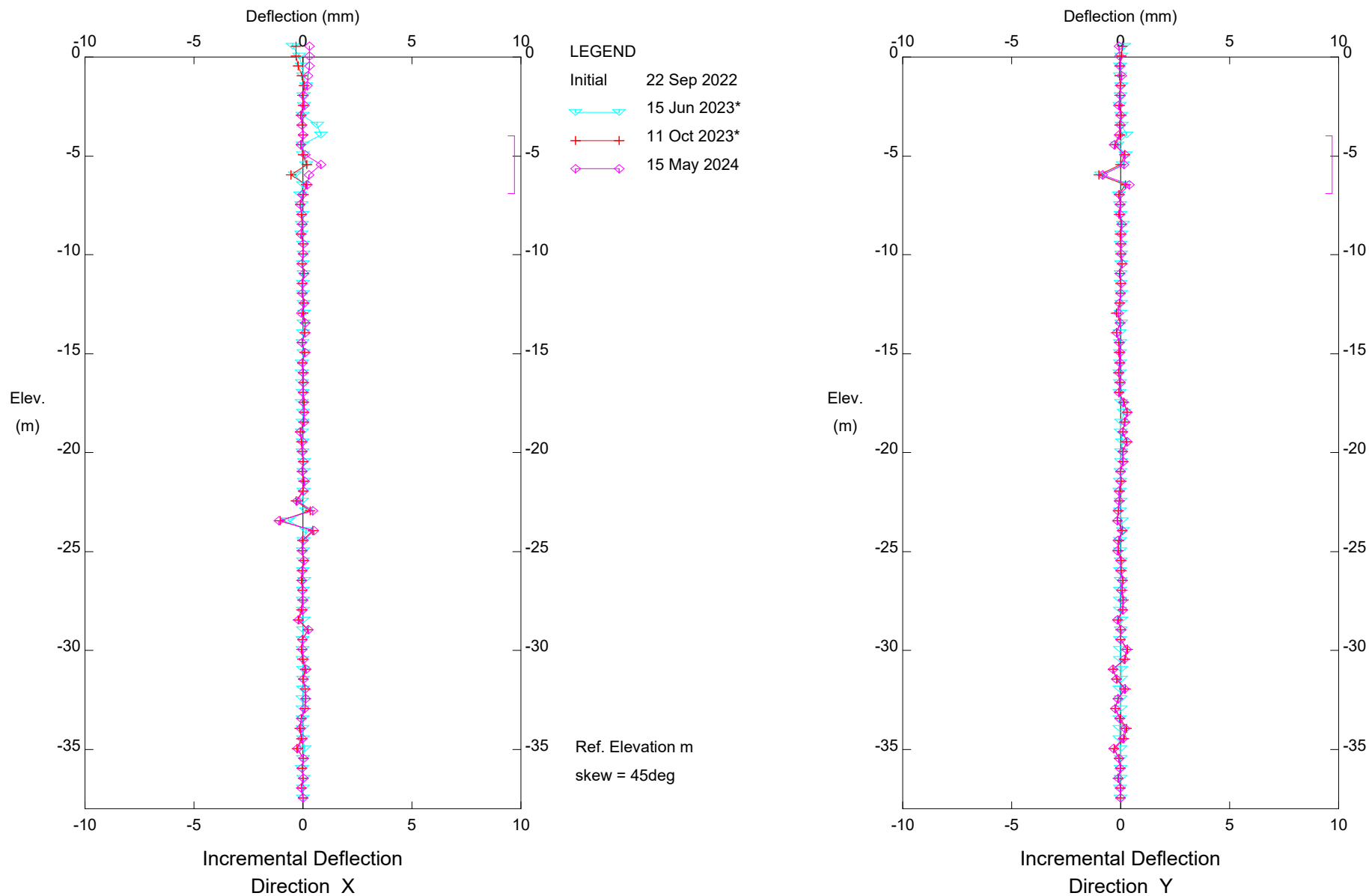
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Alberta Southern Region, Inclinometer S04 SI-10A

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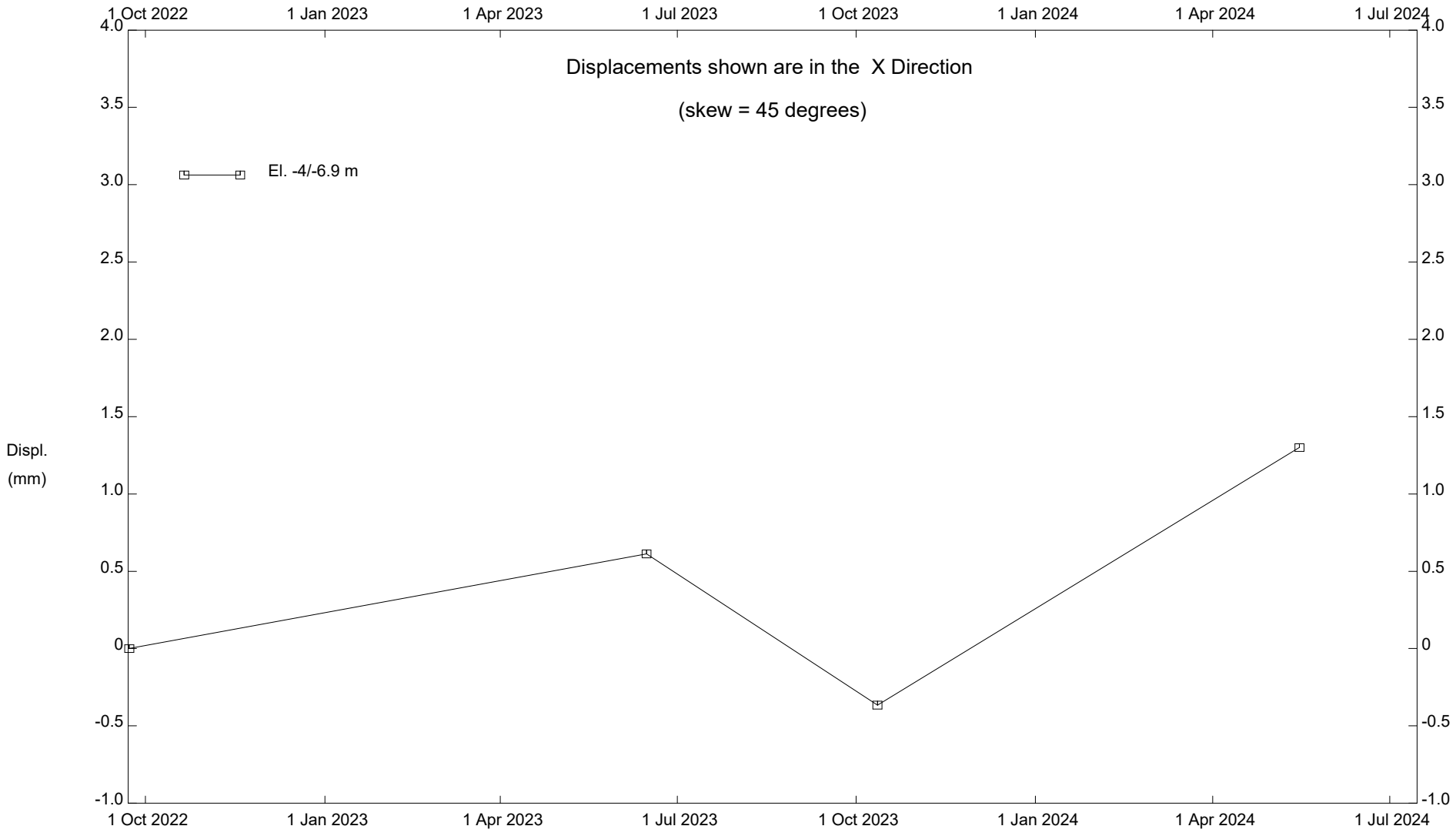
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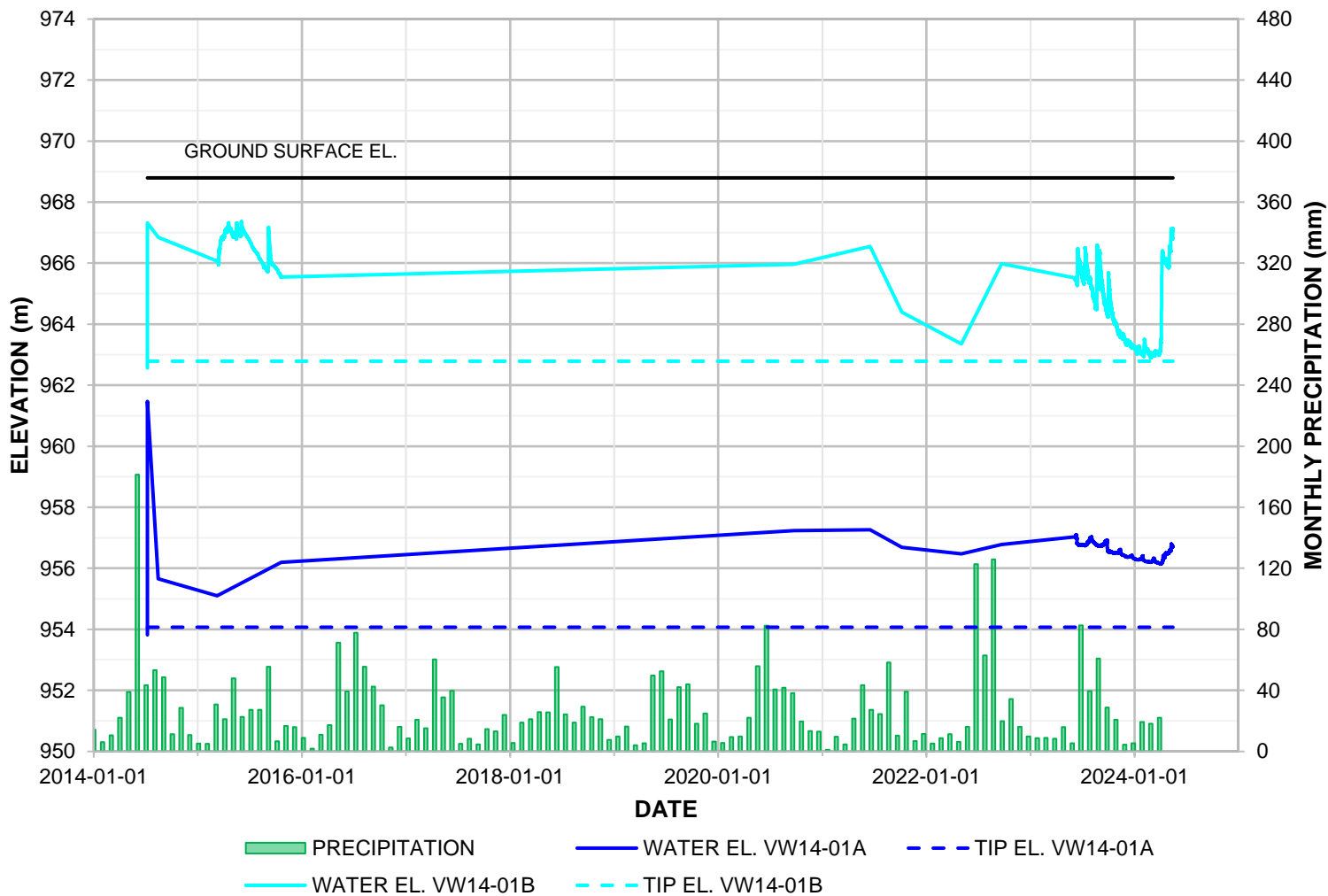
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Alberta Southern Region, Inclinometer S04 SI-10A

VW14-01A AND VW14-01B



NOTES:
 1. MONTHLY PRECIPITATION DATA OBTAINED FROM THE ALBERTA CLIMATE INFORMATION SERVICE (ACIS) DATABASE, REFERENCING LEGAL SUBDIVISION TWP009-26-W4.
 2. THE INSTRUMENTS WERE NOT READ BETWEEN OCTOBER 2015 AND SEPTEMBER 2020.

CLIENT

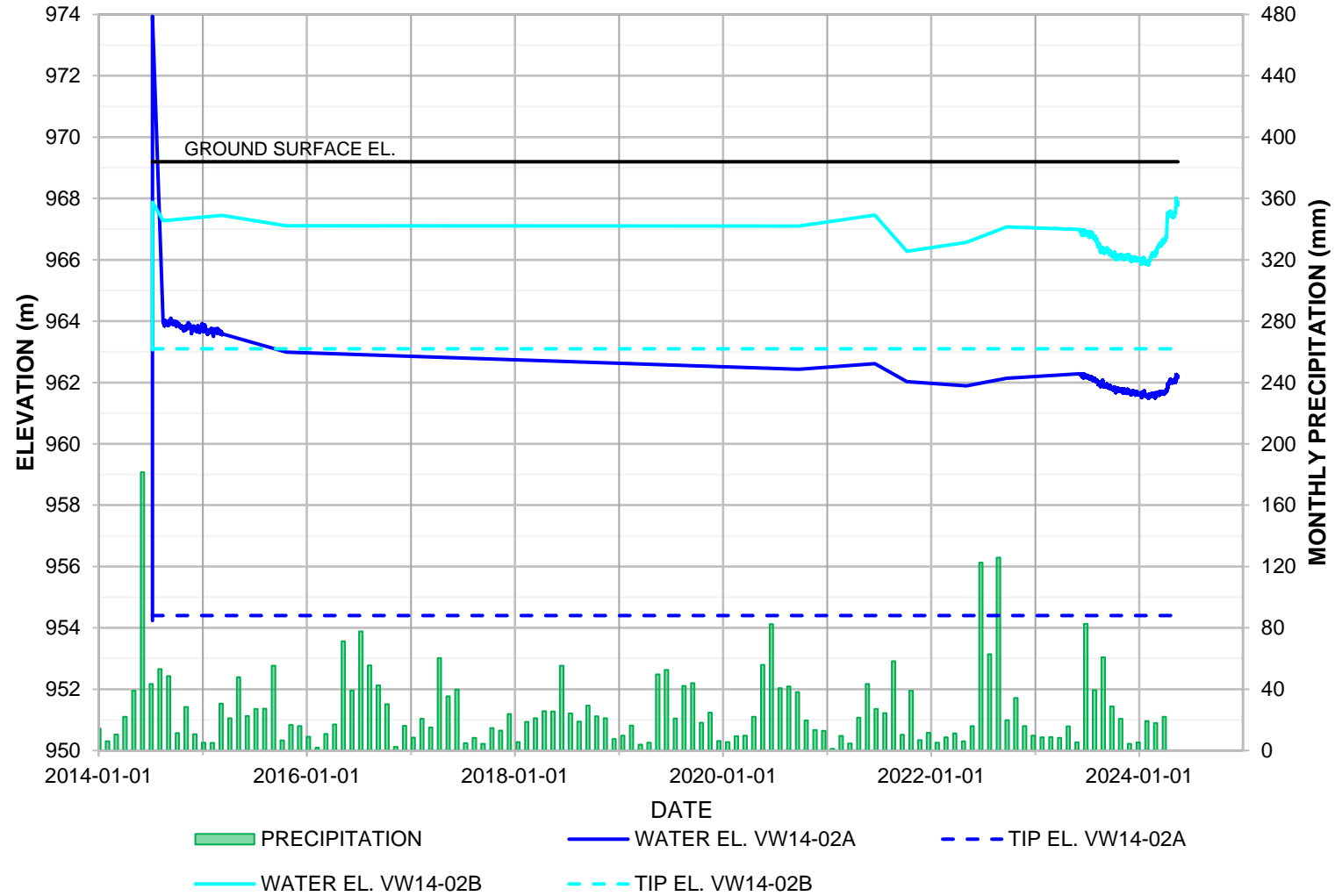



PROJECT
 SOUTHERN REGION GEOHAZARD RISK
 MANAGEMENT PROGRAM

TITLE
 Vibrating Wire Piezometer Data
 S004 - Willow Creek
 Hwy 02:08, km 6.284

SCALE PROJECT No. A05116A03 FIG No.

VW14-02A AND VW14-02B



NOTES:
 1. MONTHLY PRECIPITATION DATA OBTAINED FROM THE ALBERTA CLIMATE INFORMATION SERVICE (ACIS) DATABASE, REFERENCING LEGAL SUBDIVISION TWP009-26-W4.
 2. THE INSTRUMENTS WERE NOT READ BETWEEN OCTOBER 2015 AND SEPTEMBER 2020.

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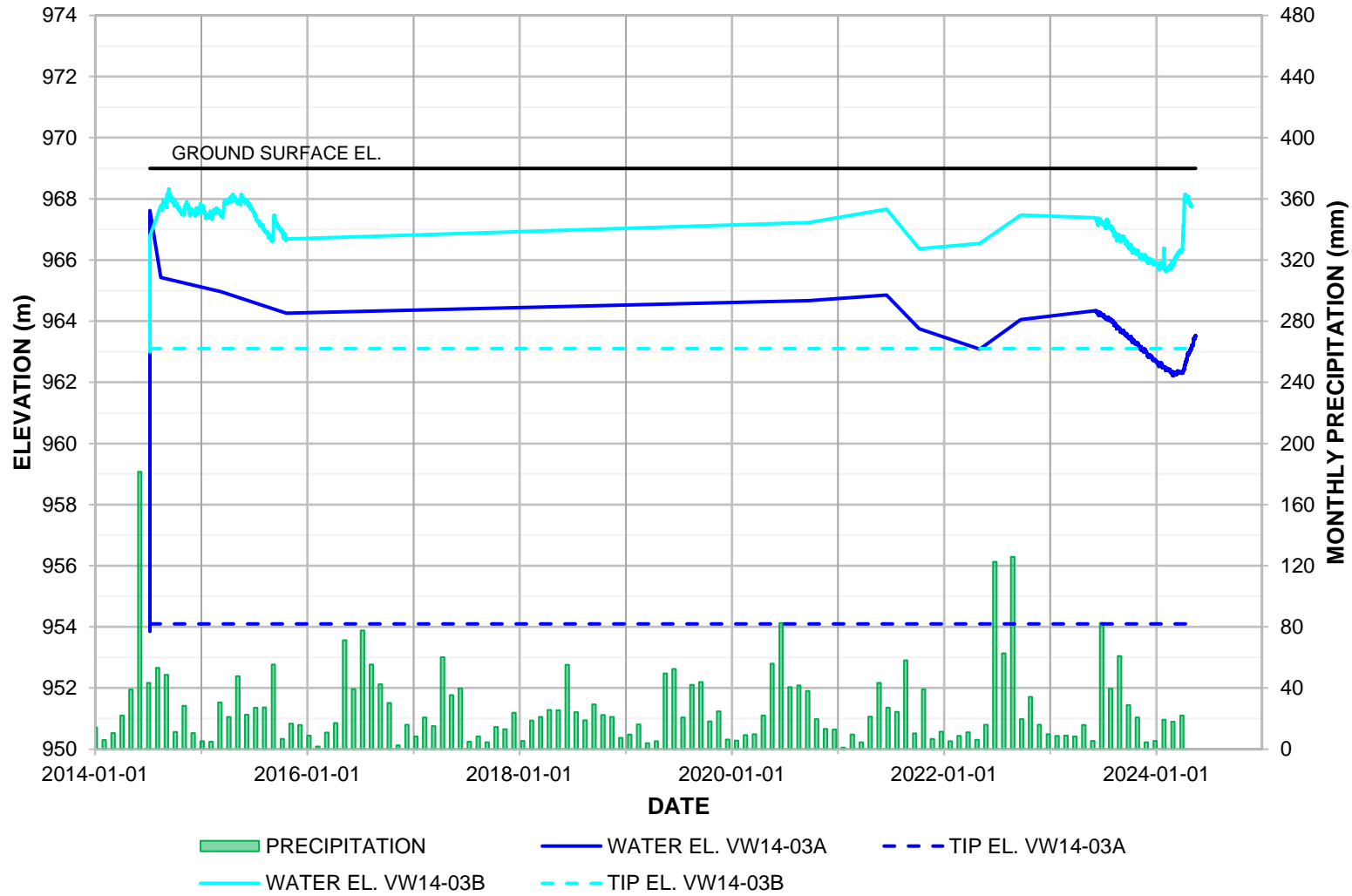



PROJECT
 SOUTHERN REGION GEOHAZARD RISK
 MANAGEMENT PROGRAM

TITLE
 Vibrating Wire Piezometer Data
 S004 - Willow Creek
 Hwy 02:08, km 6.284

SCALE PROJECT No. A05116A03 FIG No.

VW14-03A AND VW-03B



NOTES:
 1. MONTHLY PRECIPITATION DATA OBTAINED FROM THE ALBERTA CLIMATE INFORMATION SERVICE (ACIS) DATABASE, REFERENCING LEGAL SUBDIVISION TWP009-26-W4.
 2. THE INSTRUMENTS WERE NOT READ BETWEEN OCTOBER 2015 AND SEPTEMBER 2020.

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PROJECT

SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE

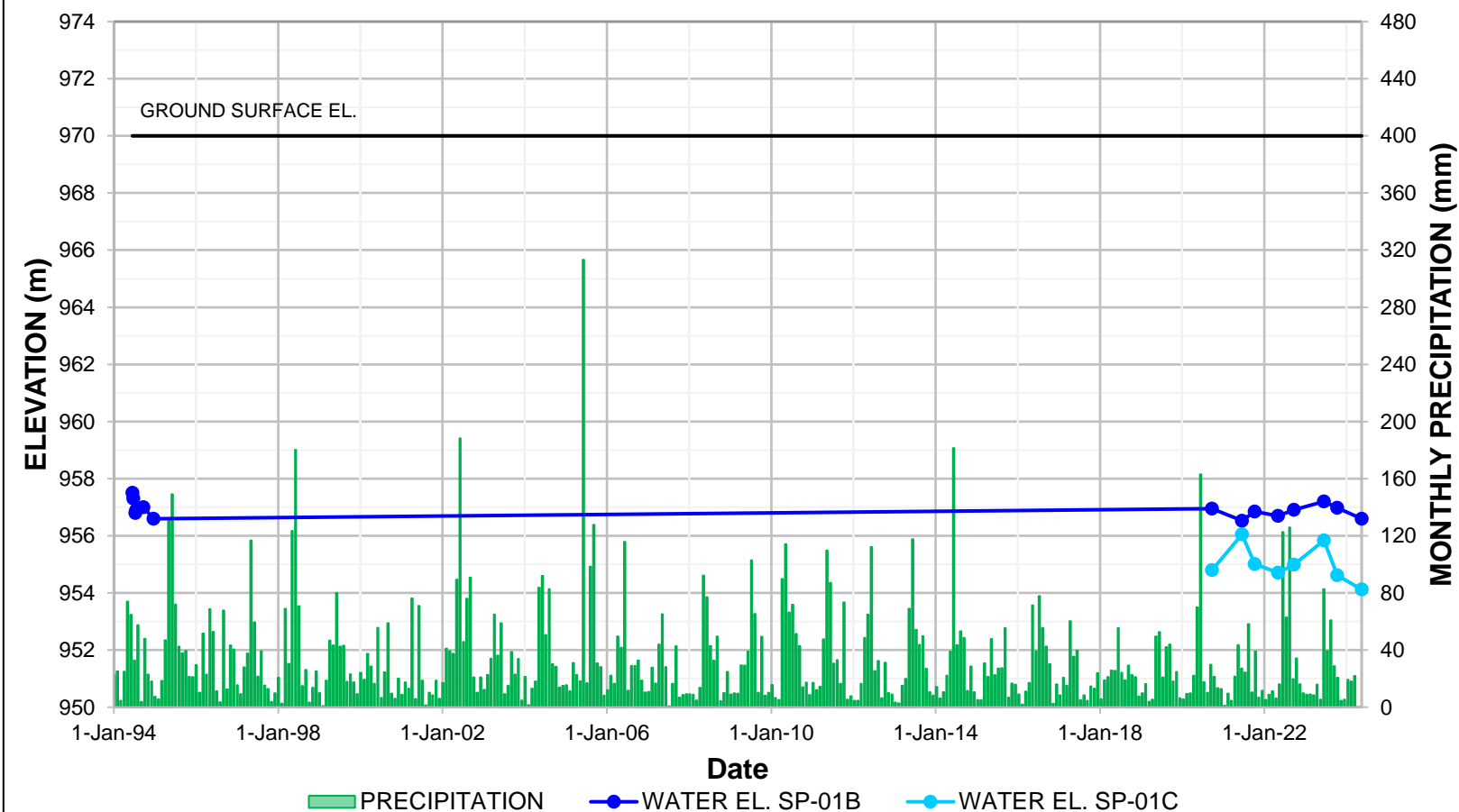
Vibrating Wire Piezometer Data
 S004 - Willow Creek
 Hwy 02:08, km 6.284

SCALE

PROJECT No. A05116A03

FIG No.

SP-01B AND SP-01C



NOTES:

1. MONTHLY PRECIPITATION DATA OBTAINED FROM THE ALBERTA CLIMATE INFORMATION SERVICE (ACIS) DATABASE, REFERENCING LEGAL SUBDIVISION TWP009-26-W4.
2. THE INSTRUMENTS WERE NOT READ BETWEEN OCTOBER 2015 AND SEPTEMBER 2020.

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SOUTHERN REGION GEOHAZARD RISK
MANAGEMENT PROGRAM

TITLE

Standpipe Piezometer Data
S004 - Willow Creek
Hwy 02:08, km 6.284

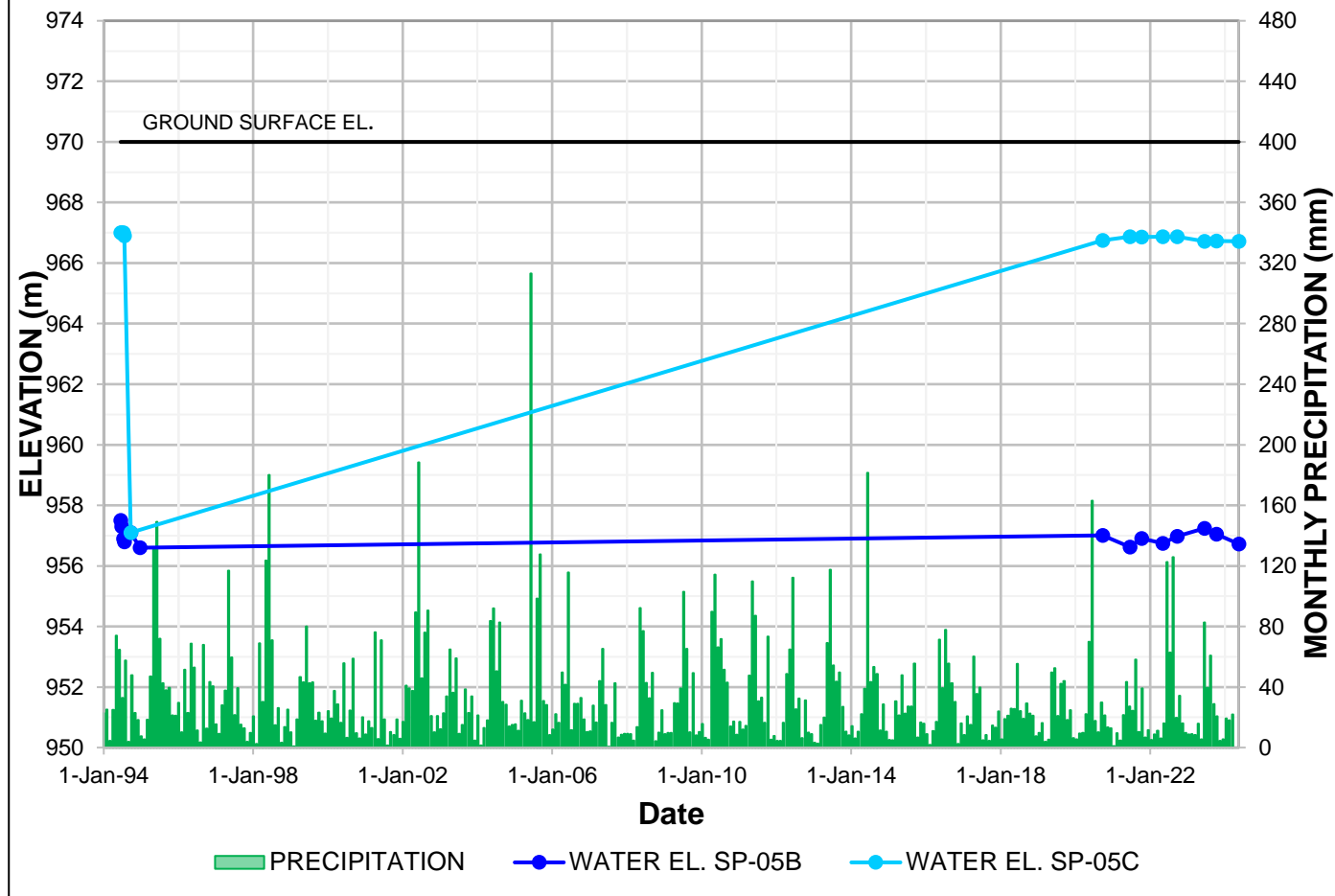
SCALE

PROJECT No.

A05116A03

FIG No.

SP-05B AND SP-05C

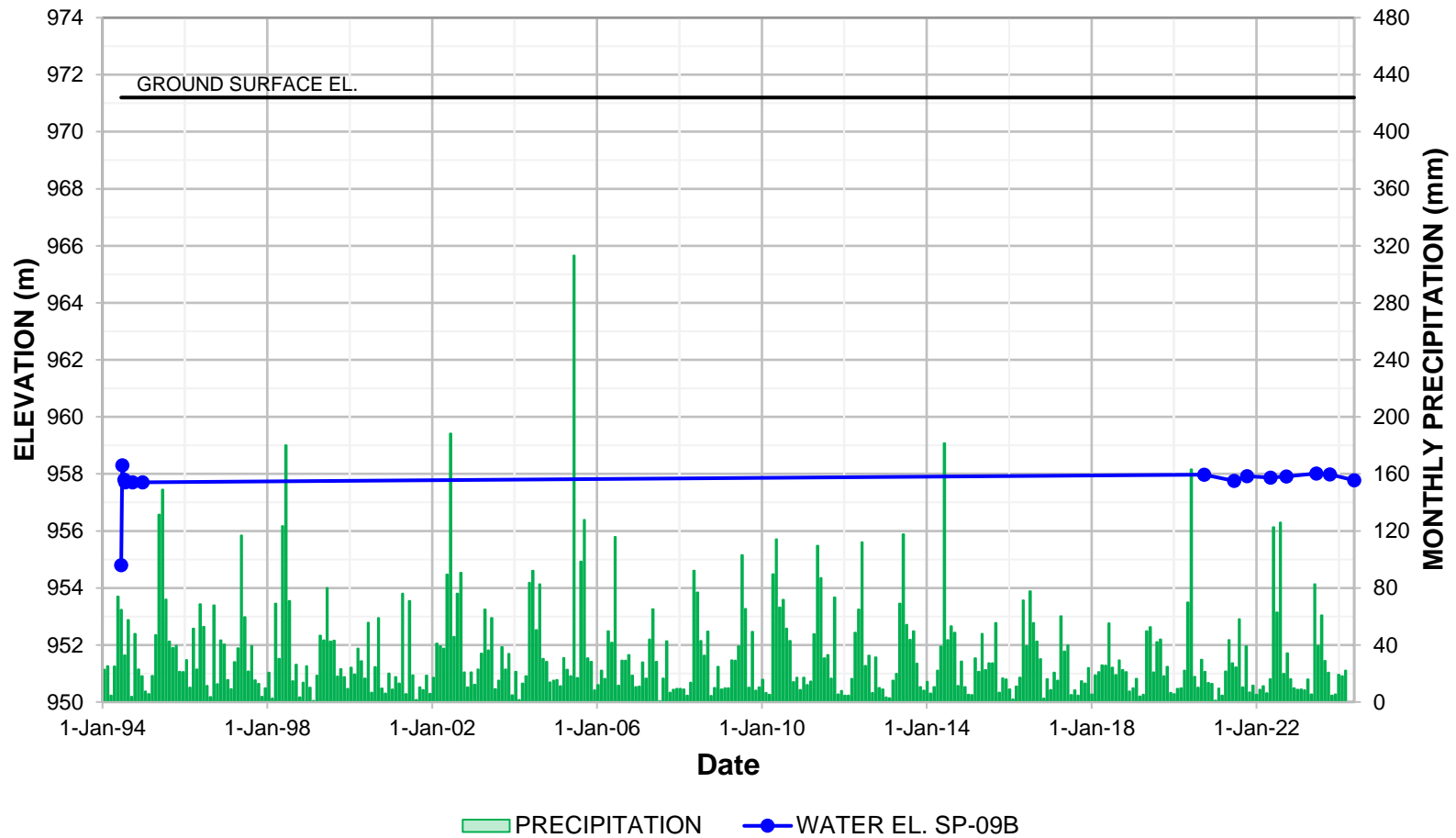


NOTES:

1. MONTHLY PRECIPITATION DATA OBTAINED FROM THE ALBERTA CLIMATE INFORMATION SERVICE (ACIS) DATABASE, REFERENCING LEGAL SUBDIVISION TWP009-26-W4.
2. THE 1994 READING FOR SP-05C APPEARS TO BE BAD DATA.
3. THE INSTRUMENTS WERE NOT READ BETWEEN OCTOBER 2015 AND SEPTEMBER 2020.

CLIENT 	PROJECT SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM		
	TITLE Standpipe Piezometer Data S004 - Willow Creek Hwy 02:08, km 6.284		
SCALE	PROJECT No.	A05116A03	FIG No.

SP-09B



NOTES:

1. MONTHLY PRECIPITATION DATA OBTAINED FROM THE ALBERTA CLIMATE INFORMATION SERVICE (ACIS) DATABASE, REFERENCING LEGAL SUBDIVISION TWP009-26-W4.
2. THE INSTRUMENTS WERE NOT READ BETWEEN OCTOBER 2015 AND SEPTEMBER 2020.

CLIENT



PROJECT

SOUTHERN REGION GEOHAZARD RISK
MANAGEMENT PROGRAM

TITLE

Standpipe Piezometer Data
S004 - Willow Creek
Hwy 02:08, km 6.284

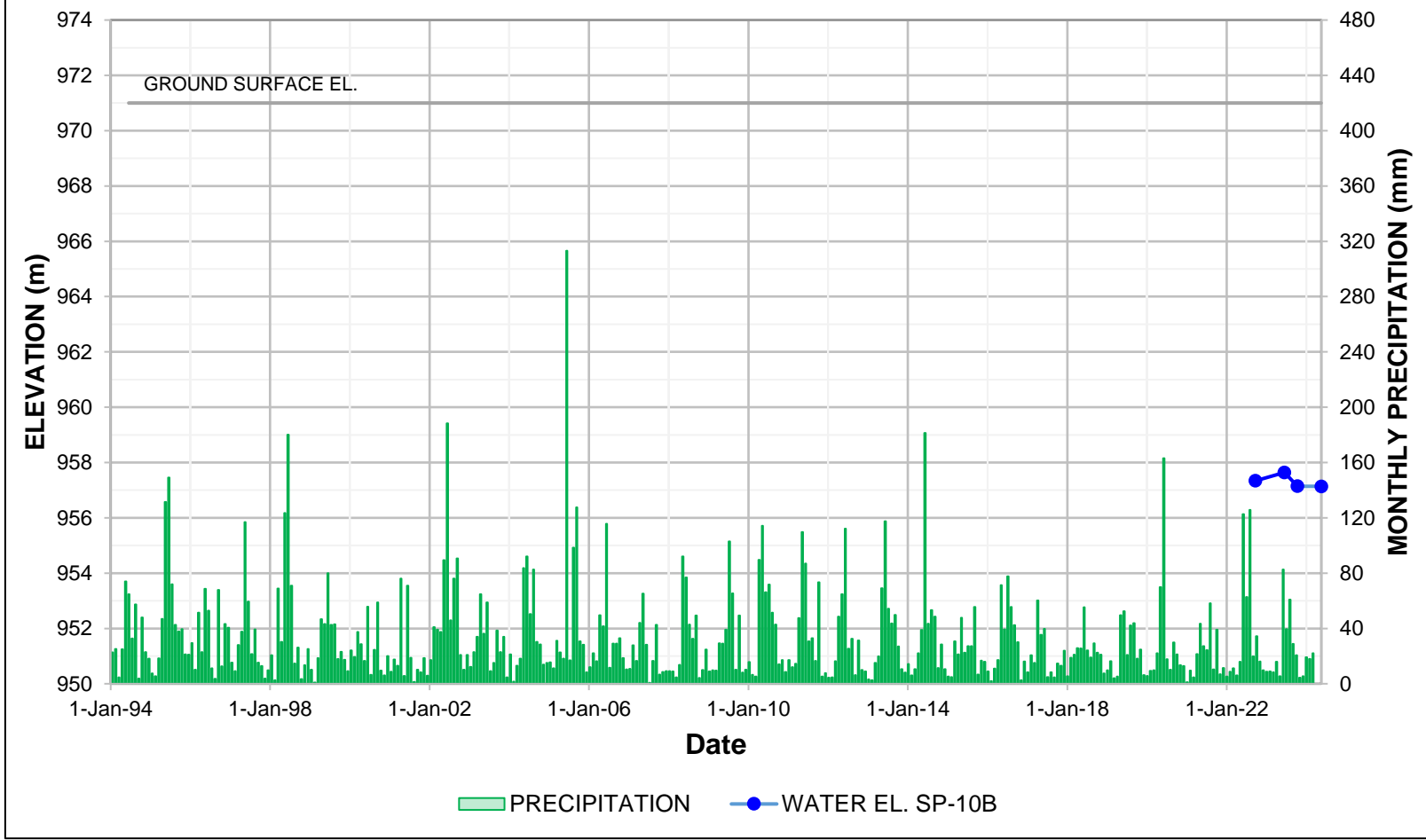
SCALE

PROJECT No.



A05116A03

FIG No.

SP-10B



NOTES:
 1. MONTHLY PRECIPITATION DATA OBTAINED FROM THE ALBERTA CLIMATE INFORMATION SERVICE (ACIS) DATABASE, REFERENCING LEGAL SUBDIVISION TWP009-26-W4.
 2. THE INSTRUMENTS WERE NOT READ BETWEEN OCTOBER 2015 AND SEPTEMBER 2020.

CLIENT 	PROJECT SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM		
	TITLE Standpipe Piezometer Data S004 - Willow Creek Hwy 02:08, km 6.284		
	SCALE	PROJECT No.	FIG No.
		A05116A03	