

September 21, 2022

Alberta Transportation
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 S003; H22:16 km 9.9 Cochrane
Section C – 2022 Spring Readings**

1 GENERAL

One slope inclinometer (SI) (SI18-01) and one pneumatic piezometer (PN) (BH2007-02) were read at the S003 site in Southern Region on May 2, 2022, by Mr. Gabriel Bonot, E.I.T. of Klohn Crippen Berger Ltd. (KCB). Three vibrating wire piezometers (VWPs) (VW18-01 through VW18-03) were read on July 7, 2022, by Mr. Guerin White, E.I.T. of KCB. These instruments were read as part of the Southern Region Geohazard Risk Management Program (GRMP). The site is located on Hwy 22:16 km 9.9, south of Cochrane, Alberta, approximately 1 km south from the Bow River bridge. The approximate site coordinates are 5672089 N, 676024 E (UTM Zone 11, NAD 83), and the legal land description for the site is SW 34-25-4-W5. A site plan is presented in Figure 1.

The geohazard at the S003 site consists of a landslide along the south slope of the Bow River valley. The landslide encroaches approximately 3 m into the northbound lane of Hwy 22:16. Previous remedial actions at this site include construction of a ditch berm (date unknown) in the northeast (northbound lane) ditch to reduce surface water runoff from discharging onto the landslide. However, in late-2020, ongoing movement of the slide area had caused settlement of the ditch berm such that ditch flows were directed onto the slide area.

Geotechnical site investigations, which included installing instruments, were conducted at the S003 site in 1991, 1994, 2007, and 2009 by the previous consultants. In March 2018, KCB conducted a geotechnical site investigation during which instruments were installed to monitor movement and groundwater conditions, respectively. Drilling was completed by Mayfield Drilling and Environmental Service Ltd. The encountered stratigraphy during the 2018 investigation was as follows: medium-plastic clay, overlying medium-plastic clay till.

1.1 Instrumentation

KCB has been reading the instruments at this site since 2016. 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.

Between 1991 and 2007, 11 SIs and 2 piezometers were installed at the site by the previous consultants to monitor movement and groundwater conditions, respectively. By May 2020, most of these instruments were inoperable (e.g., destroyed, sheared, or lost).

The remaining operable instruments, including those installed by KCB in 2018, are protected by either a flush-mounted or an above-ground casing protector.

KCB changed the SI reading equipment in May 2022 after the previous equipment became inoperable. Currently, KCB is reading the SIs with a metric RST Digital MEMS Inclinometer System.

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

Table 1.1 Instrumentation Installation Details

Instrument ID	Instrument Type	Date Installed ¹	UTM Coordinates ² (m)		Ground Surface Elevation (m)	Stick Up (m)	Depth (mbgs ³)	Condition
			Northing	Easting				
SI#1	SI	Sep. 1991	Unknown	Unknown	Unknown	Unknown	Unknown	Inoperable
SI#2	SI	Sep. 1991	Unknown	Unknown	Unknown	Unknown	Unknown	Inoperable
SI#3	SI	Sep. 1991	Unknown	Unknown	Unknown	Unknown	Unknown	Inoperable
SI#2	SI	Sep. 1994	Unknown	Unknown	Unknown	Unknown	23.7	Inoperable
SI#3A	SI	Sep. 1994	Unknown	Unknown	Unknown	Unknown	Unknown	Inoperable ⁴
SI#4	SI	Sep. 1994	Unknown	Unknown	Unknown	Unknown	Unknown	Inoperable ⁴
SI#5	SI	Sep. 1994	Unknown	Unknown	Unknown	Unknown	28.6	Inoperable
SI#6	SI	Sep. 1994	Unknown	Unknown	Unknown	Unknown	Unknown	Inoperable ⁴
SI#7	SI	Sep. 1994	Unknown	Unknown	Unknown	Unknown	20.2	Inoperable
SI2007-1	SI	Mar. 2007	Unknown	Unknown	Unknown	Unknown	19.7	Inoperable ⁴
SI2007-3	SI	Mar. 2007	Unknown	Unknown	Unknown	Unknown	14.9	Inoperable
SI2009-1	SI	Jul. 2009	Unknown	Unknown	Unknown	Unknown	19.0	Inoperable ⁴
SI18-01	SI	Mar. 2018	5672120	676028	1174.0	0.8	21.3	Operable
VW18-01	VWP	Mar. 2018	5672120	676028	1174.0	N/A	13.7	Operable
VW18-02	VWP	Mar. 2018	5672056	676047	1176.0	N/A	10.1	Operable
VW18-03	VWP	Mar. 2018	5672048	676027	1176.5	N/A	4.6	Operable
BH2007-02	PN	Mar. 2007	5672117	676020	1173.8	N/A	5.6	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 confirmed by KCB with a handheld GPS. The handheld GPS had a horizontal accuracy of +/- 5 m.

³ Meters below ground surface (mbgs). Bottom casing depth for SIs and tip depth for piezometers.

⁴ SI#3A, SI#4, SI#6, SI2007-1, SI2009-1 have all sheared at depths between approximately 1.8 m and 4.0 m, respectively.

2 INTERPRETATION

2.1 General

For the operable SI, the cumulative displacement, incremental displacement, and displacement-time data was plotted in the A-direction (i.e., the direction of the A0-groove) and X-direction (i.e., the direction of maximum movement obtained at a skew angle from the A0-grooves). SI18-01 has a skew angle of 20° measured clockwise from the direction of the A0-grooves.

For the piezometers, the recorded porewater pressures were converted to an equivalent water/piezometric elevation and plotted relative to ground surface elevation each instruments tip elevation.

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. 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 TWP026-04-W5.

2.2 Zones of Movement

Movement was previously recorded in the now inoperable SIs at depths between 1.0 m and 4.0 m below ground surface (approximately El. 1172.5 m to El. 1170.0).

Distributed movement is being recorded in SI18-01 from ground surface to an approximate depth of 2.3 m below ground surface (approximately El. 1173.6 m to El. 1171.7), and possible discrete movement between 2.3 m and 3.8 m (approximately El. 1171.7 m to El. 1170.2). The casing also appears to be settling or buckling between an approximate depth of 3.8 m and 8.8 m as discussed below. SI18-01 is located near the middle of the slide on the downslope side of the highway.

2.3 Interpretation of Monitoring Results

The settlement or buckling observed in SI18-01 (from approximately 3.8 m and 8.8 m below ground surface) could be an indication that the instrument is poorly grouted with a possible grout void. The readings along this segment also do not stabilize, which further indicates a possible issue with the grout or damage to the casing. The movements of the slide mass and interpretation of the SI data is complicated by the potential for settlement or buckling of the SI casing in the poorly grouted casing segment.

The rate of movement recorded in SI18-01 has been relatively steady (approximately 3 mm/year to 11 mm/year) since the fall 2020 reading. However, last year and the spring of 2021 were relatively dry (see monthly precipitation data on piezometer plots in Appendix I). During the previous periods of wet weather in 2019 and 2020, the rate of movement had increased to approximately 4 mm/year and 62 mm/year, respectively. Increased movement may occur again in response to prolonged or heavy rainfall, resulting in higher groundwater conditions, especially now that the ditch berm has settled and has reduced capacity to divert surface water flows away from the slide area.

It is noted that during the last inspection in 2020, after the previous periods of wet weather in 2019 and 2020, the site was observed to have deteriorated with additional settlement and cracking of the pavement surface. The movement appeared to be shallow but may have been linked to deeper-seated movement in the slide area downslope of the highway embankment. Historically, only a shallow movement (between ground surface and 4.0 m below ground surface) has been recorded in the SIs. However, based on the available installation depths, the SIs were not installed below bottom-of-river elevation to assess if a deeper basal failure plane underlies the S003 site.

Approximately 160 mm of cumulative movement has been recorded in SI18-01 since installation. We expect this instrument may shear soon. SI18-01 was installed to support design of a H-pile wall and drainage improvements to mitigate the impacts of the slope movement on Hwy 22:16. The H-pile wall design is complete, and the tender is waiting for release. If the SI becomes unreadable or unreliable, readings can cease, and monitoring can be conducted on pavement surface deformations until the H-pile wall and drainage improvements are constructed.

Water levels recorded in BH2007-02 (Serial No. 60223) fluctuate seasonally (with the spring readings being lower than fall readings) from approximately 4.3 m to 5.6 m below ground surface.

The initial readings for the VWP (VW18-01 through VW18-03) were taken immediately following grouting operations, and KCB believes that the initial water levels recorded in the VWPs were artificially high due to grouting. Water levels recorded in these instruments decreased up to 12 m within a month of installation.

Excluding the first reading, water levels recorded in VW18-01 (located within the slide mass, downslope from the highway) have varied from 8.8 m and 12.0 m below ground surface, and water levels in VW18-02 (located within the slide mass, on the east shoulder of the highway) have varied from approximately 7.7 m and 10.1 m below ground surface. These water levels are below the depth of movement recorded in the SIs (between ground surface and 4.0 m below ground surface). The data indicates slide movements are like in response to periods of increased precipitation when surface water infiltrates into the top few meters destabilizing the slope.

Water levels recorded in VW18-03 (located in the west highway ditch) have been near ground surface (± 0.1 m) since June 2021. Periods of increased water levels were recorded in 2019, 2021, and 2022 and can most likely be attributed to periods of increased precipitation.

Overall, the July 2022 readings for PN and VWPs were consistent with historical trends observed in these instruments. More data is needed to assess long-term trends for the piezometers installed in 2018.

Table 2.1 Slope Inclinometer Reading Summary

Instrument ID	Date				Ground Surface Elevation (m)	Depth of Movement (mbgs ¹)	Direction of Movement, Skew Angle	Movement (mm)			Rate of Movement (mm/year)		
	Initialized ³	Previous Maximum Cumulative Movement Recorded	Previous Reading	Most Recent Reading				Maximum Cumulative	Incremental Since Previous Maximum Cumulative	Total	Previous Maximum	Most Recent Reading	Change from Previous Reading
SI18-01	Oct. 23, 2018	Jun. 17, 2021	Jun. 17, 2021	May 2, 2022	1174	0.0 – 5.5	X-Direction, 20°	160.0	13.7	173.7	263.4	15.7	7.7

Note:
¹ Meters below ground surface (mbgs).
² Skew angle of X-direction measured clockwise from the A-direction.
³ Initialized on October 23, 2018 due to an anomalous upslope deformation after installation.

Table 2.2 Pneumatic Piezometer Reading Summary

Instrument ID	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)
BH2007-2	Apr. 5, 2007	Jun. 21, 2021	May 2, 2022	1173.8	5.6	5.3	5.4	-0.2

Note:
¹ Meters below ground surface (mbgs).

Table 2.3 Vibrating Wire Piezometer Reading Summary

Instrument ID	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)
VW18-01	Mar. 5, 2018	Jun. 17, 2021	Jul. 07, 2022	1174.0	13.7	10.8	12.4	-1.6
VW18-02	Mar. 5, 2018	Jun. 17, 2021	Jul. 07, 2022	1176.0	10.1	9.3	9.1	0.2
VW18-03	Mar. 5, 2018	Jun. 17, 2021	Jul. 07, 2022	1176.6	4.7	0.2	-0.1	0.3

Note:
¹ Meters below ground surface (mbgs).

3 RECOMMENDATIONS

3.1 Future Work

The operable instruments should continue to be read once per year (spring).

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

A H-pile-wall design was completed by KCB in late-2021. This design also includes repair of the ditch berm. A draft tender has been prepared by KCB (Tender No. 20856), but it has not yet been released by AT for bidding. Construction is anticipated to begin in 2023.

3.2 Instrument Repairs and Maintenance

Between May and July 2022, the above-ground tubing for BH2007-02 was damaged and the tip for the instrument was missing. KCB will replace the tip during the fall 2022 readings, and assess if the instrument is still operable.

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 (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.
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.

Courtney Mulhall, M.Sc., P.Eng.
Geotechnical Engineer

James Lyons, P.Eng.
Civil Engineer

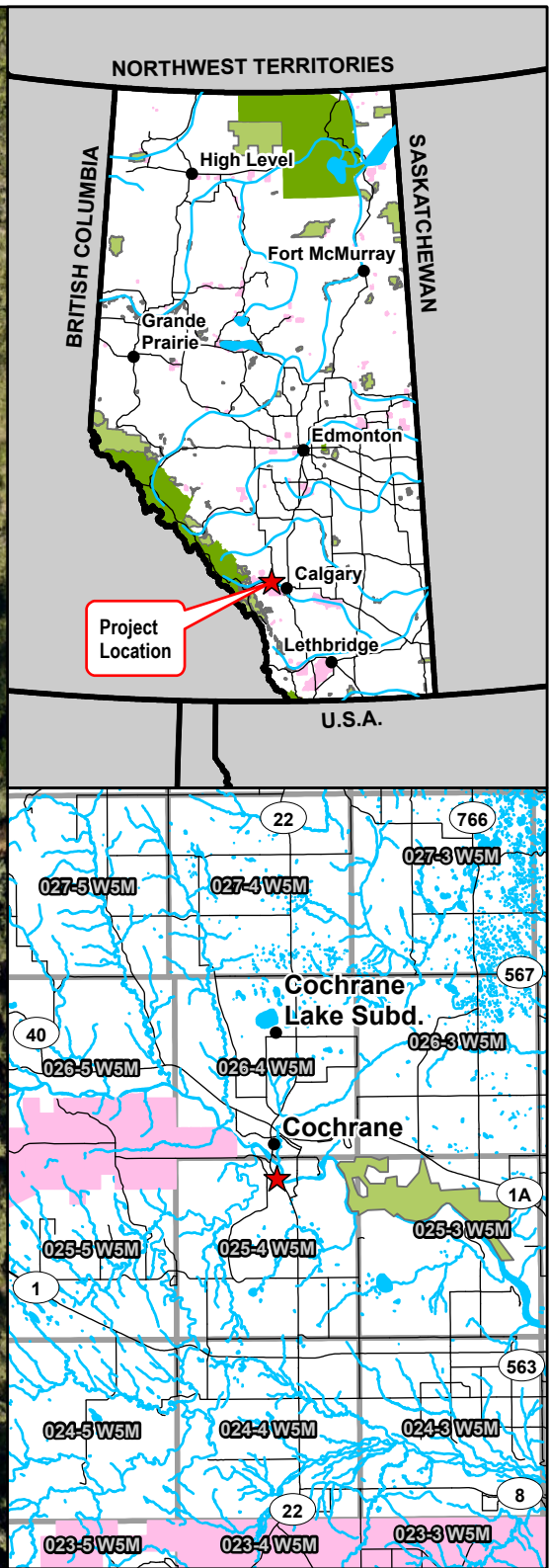
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ATTACHMENTS

Figure
Appendix I Instrumentation Plots

DRAFT

FIGURE



Legend

- ◆ Pneumatic Piezometer (PN)
- Slope Inclinator (SI)
- ⊗ Vibrating Wire Piezometer (VW)
- ➡ Flow Direction
- ⏏ Scarp
- ~~~~ Crack
- Ditch Berm

NOTES:
 1. HORIZONTAL DATUM: NAD83
 2. GRID ZONE: UTM ZONE 11N
 3. IMAGE SOURCE: TOWN OF COCHRANE, AB

CLIENT



PROJECT
SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE
Site Plan
S003 - Cochrane
Hwy 22:16, km 9.875

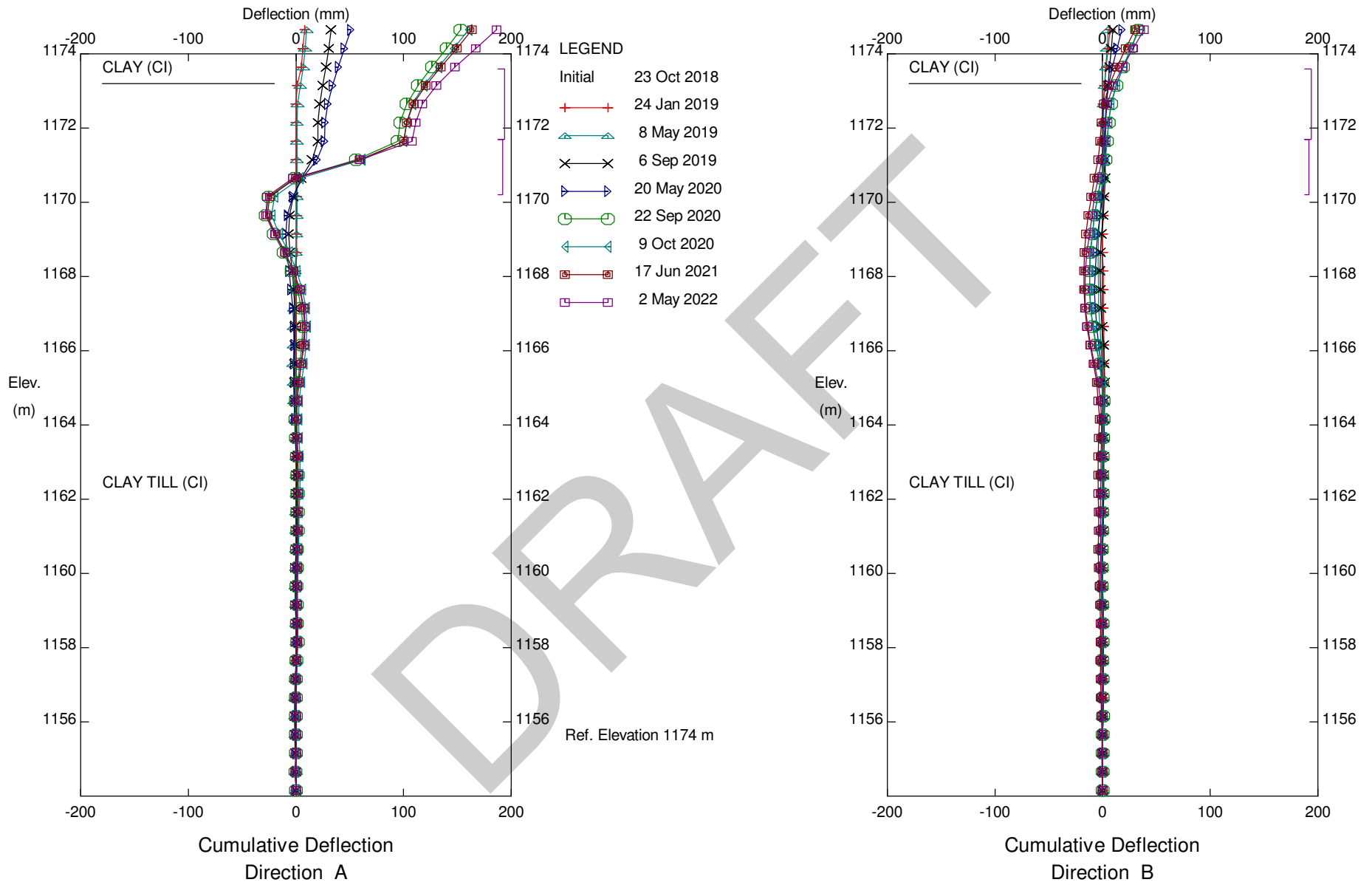
SCALE 1:1,000 PROJECT No. A05116A03 FIG No. 1



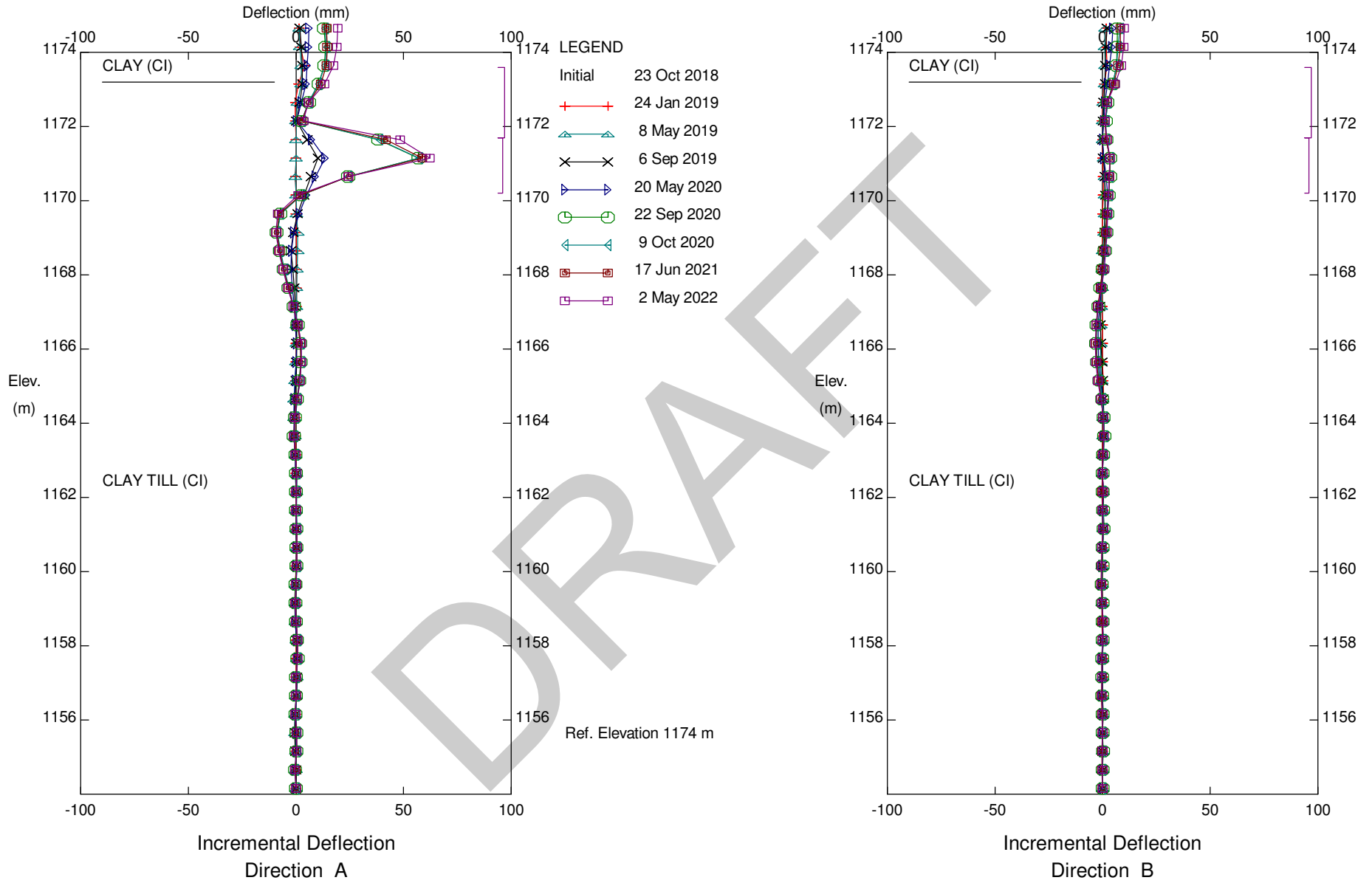
DRAFT

APPENDIX I
Instrumentation Plots

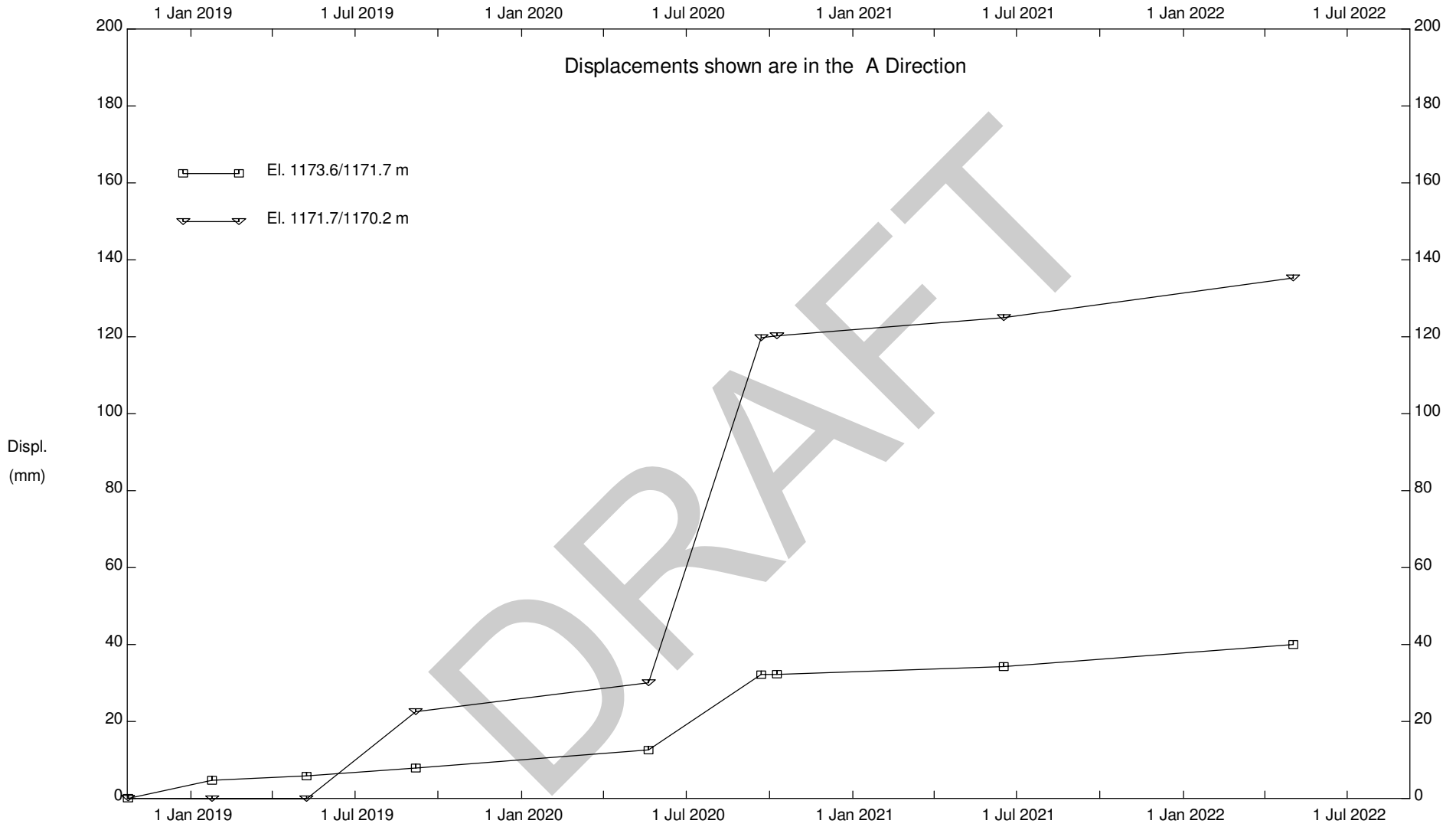
Klohn Crippen Berger - Calgary



Klohn Crippen Berger - Calgary



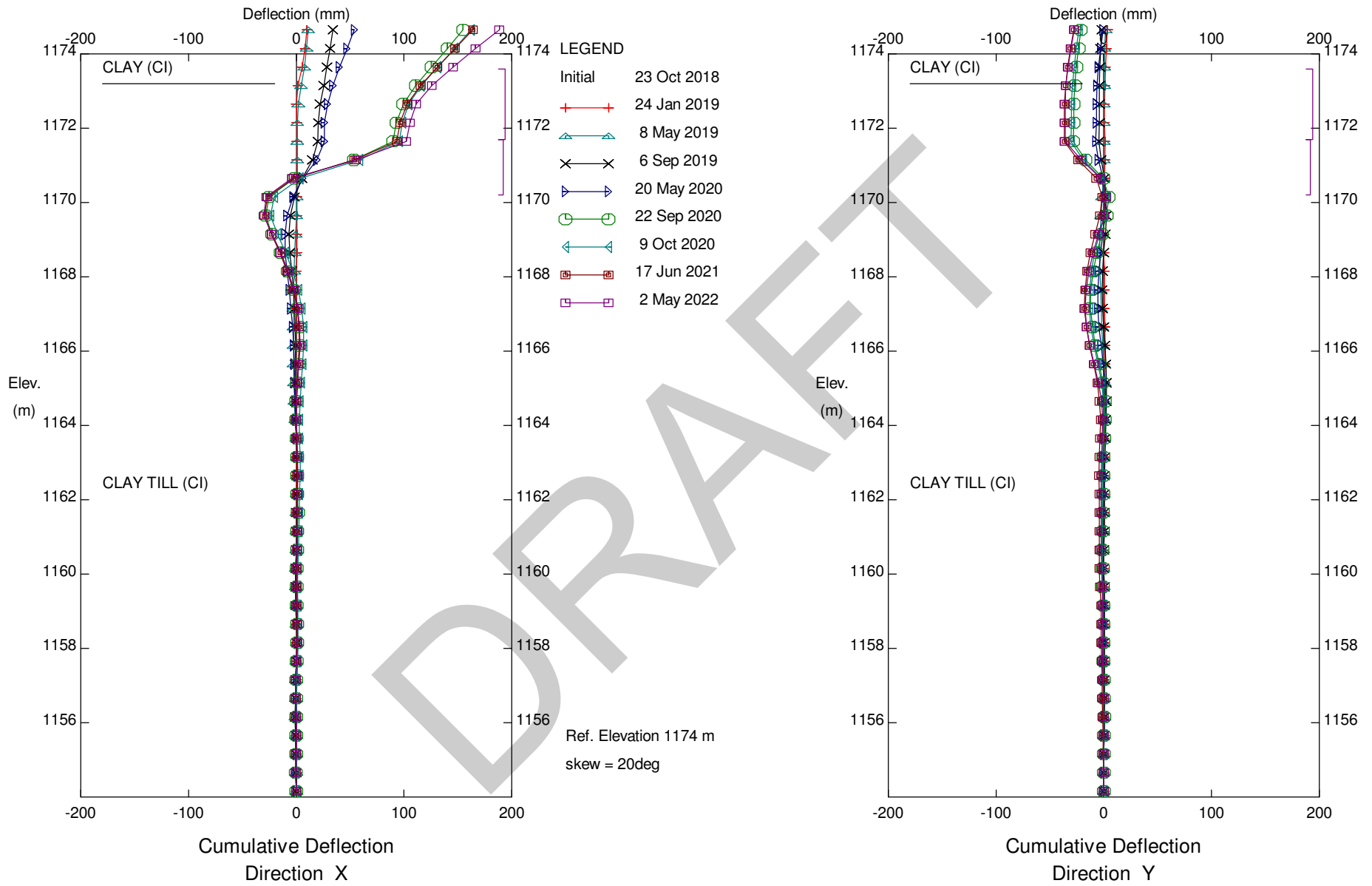
Klohn Crippen Berger - Calgary



S003; H22:16, Cochrane, Inclinator SI18-01

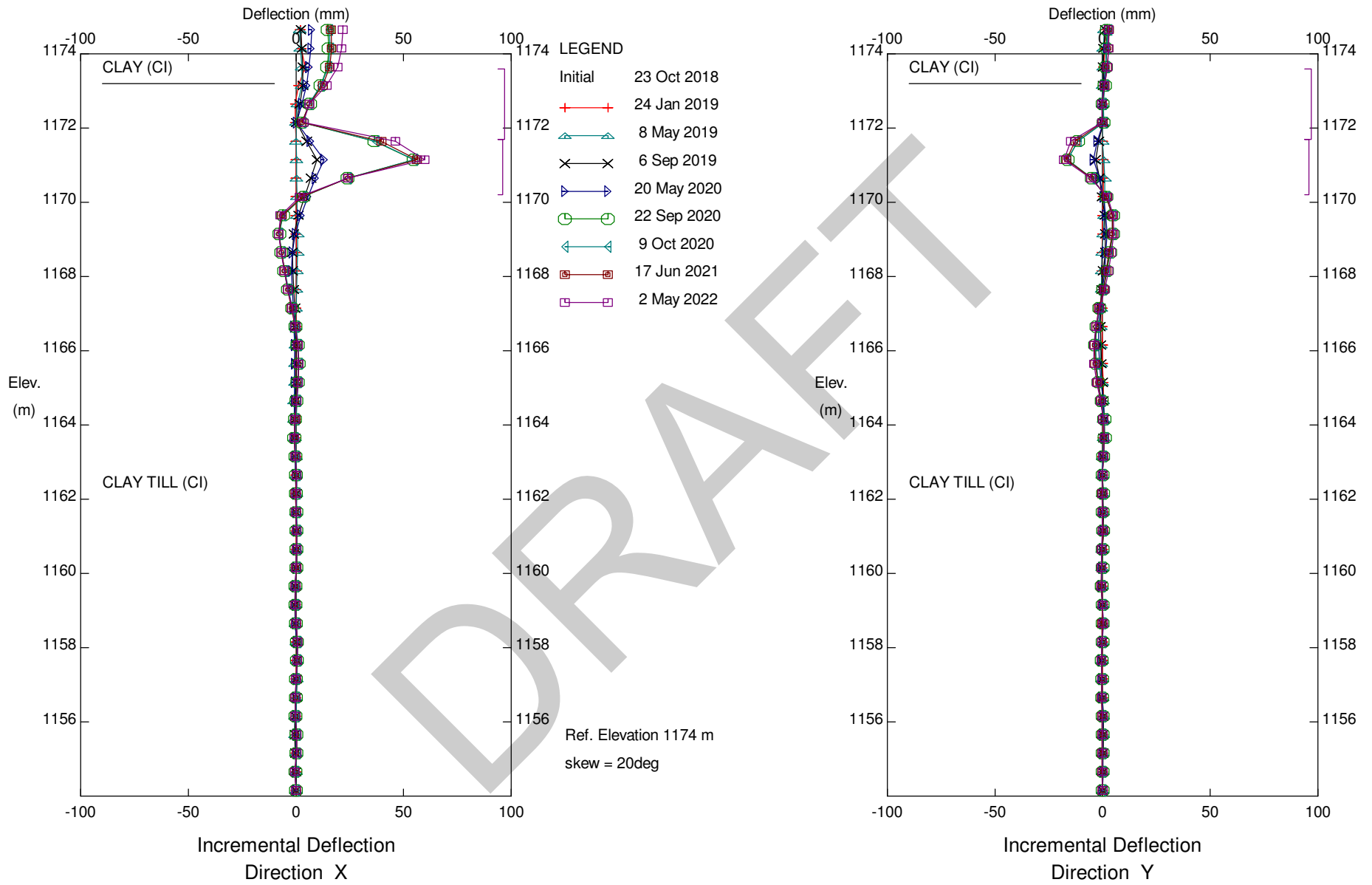
Alberta Transportation

Klohn Crippen Berger - Calgary

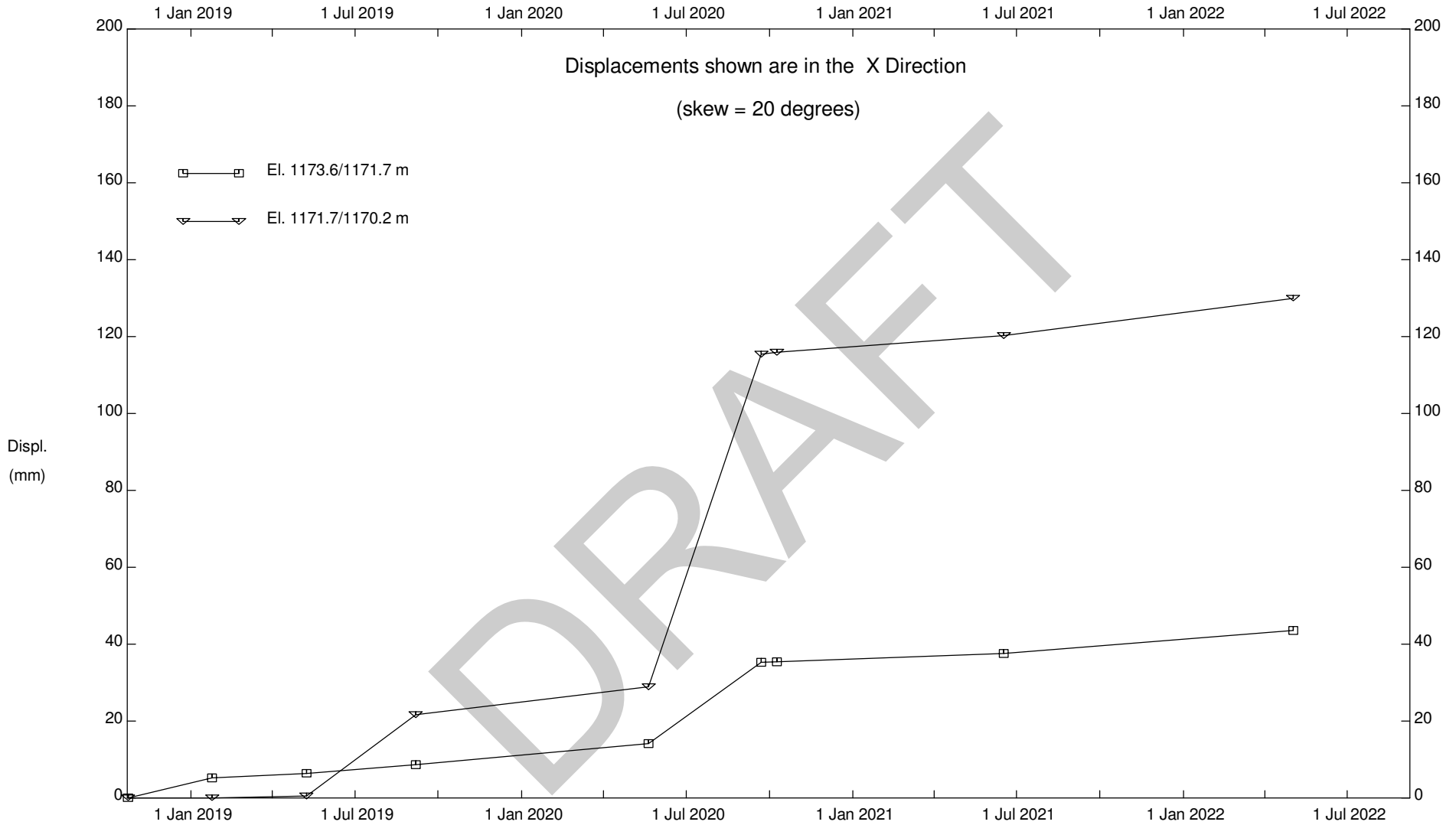


S003; H22:16, Cochrane, Inclinometer SI18-01
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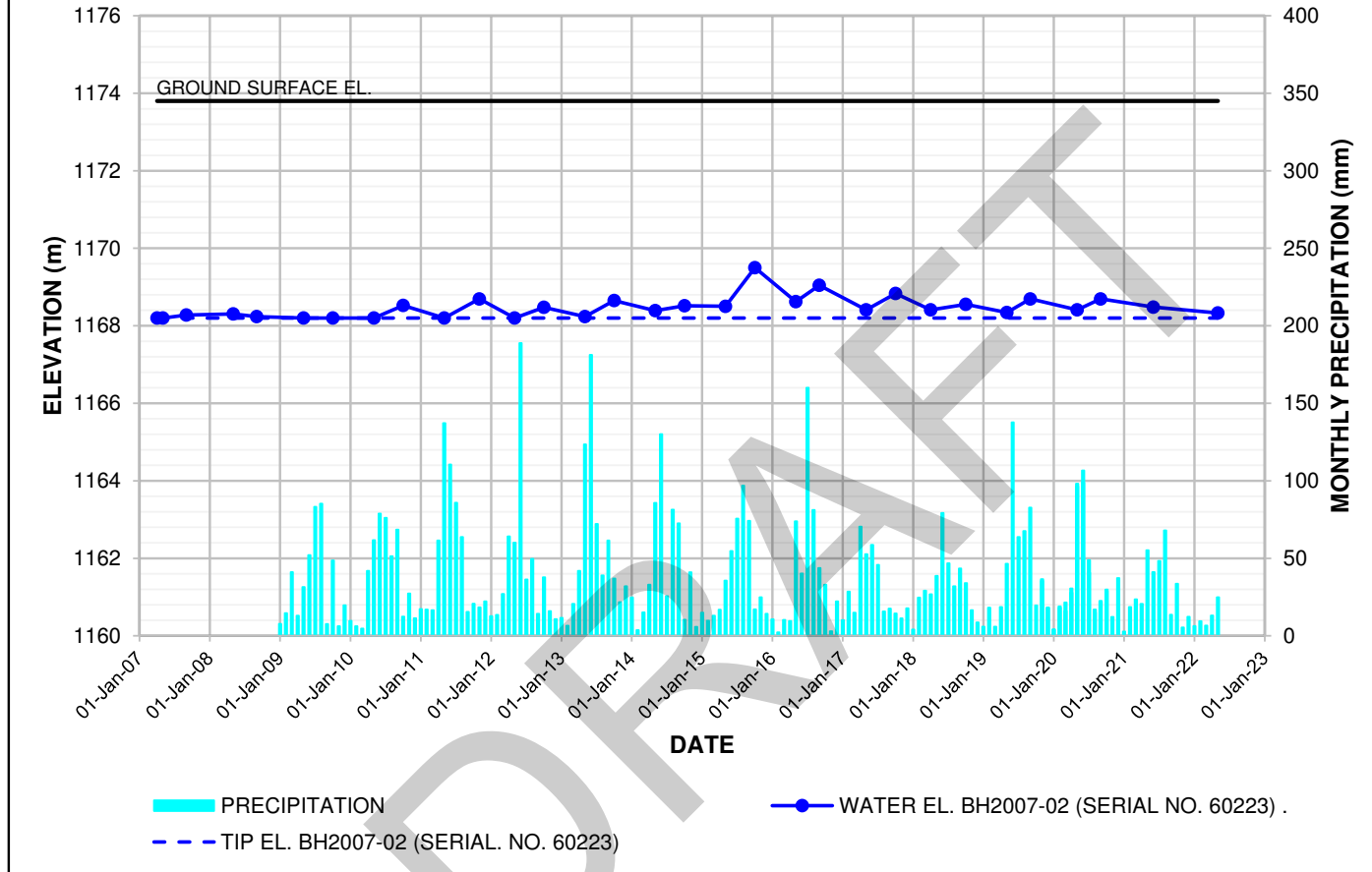
Klohn Crippen Berger - Calgary



S003; H22:16, Cochrane, Inclinator SI18-01

Alberta Transportation

BH2007-02 (SERIAL NO. 60223)



NOTES:

1. MONTHLY PRECIPITATION DATA OBTAINED FROM THE ALBERTA CLIMATE INFORMATION SERVICE (ACIS) DATABASE, REFERENCING LEGAL SUBDIVISION T026R04W5.

CLIENT



PROJECT

SOUTHERN REGION GEOHAZARD RISK
MANAGEMENT PROGRAM

TITLE

Pneumatic Piezometer Data
S003 - Cochrane
Hwy 22:16, km 9.9

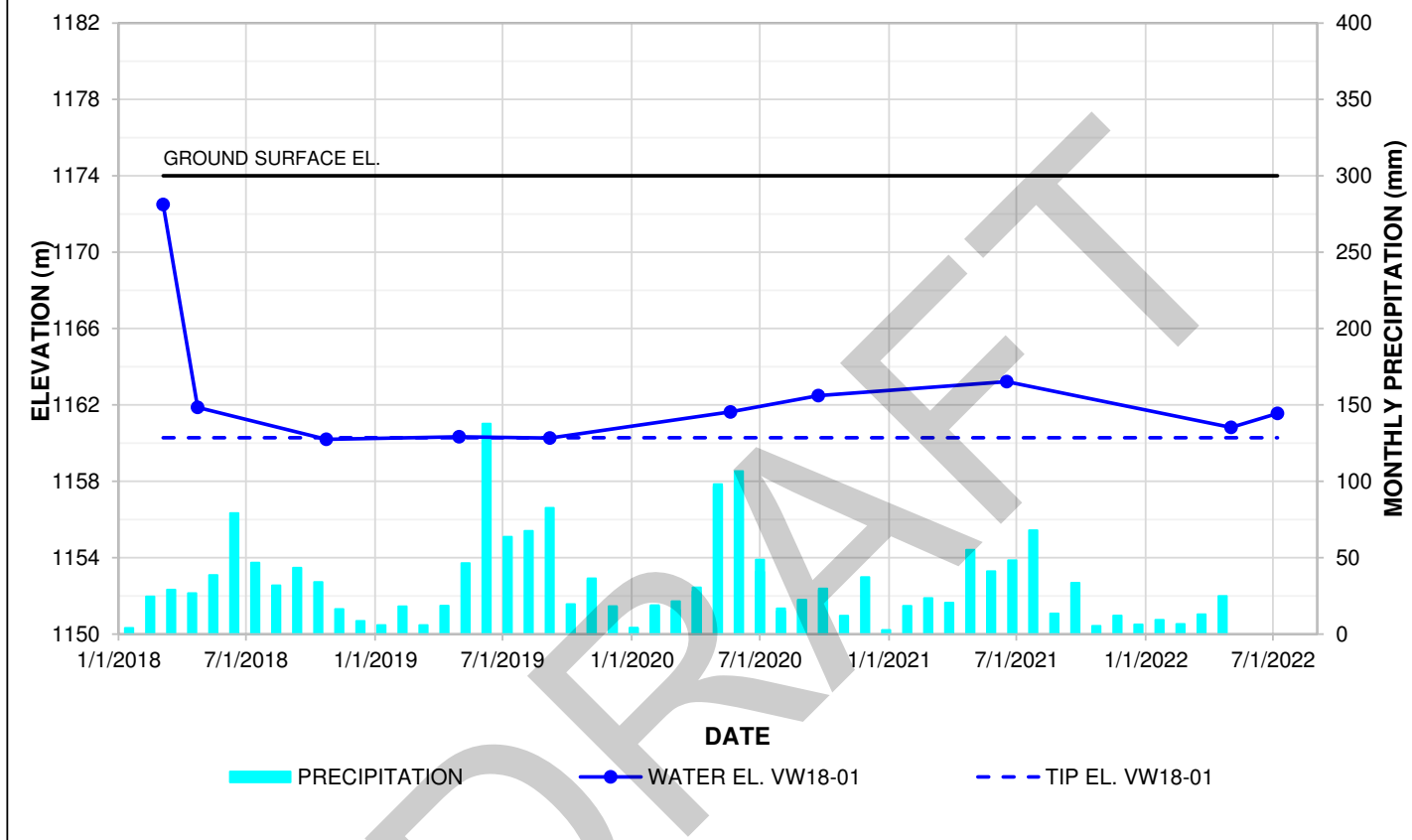
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PROJECT No.

A05116A03



FIG No.

VW18-01 (SERIAL NO. 1800200)

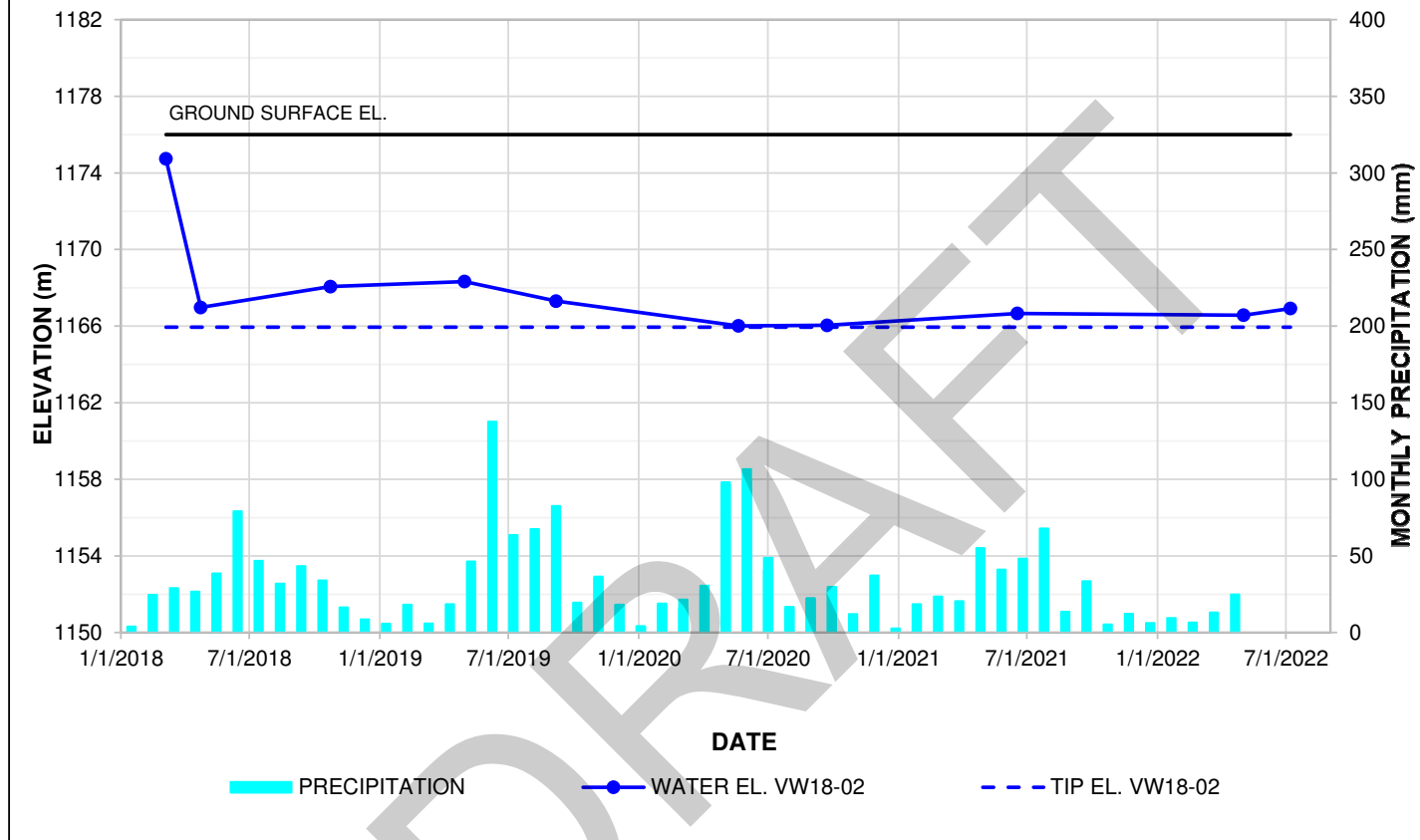


NOTES:

1. MONTHLY PRECIPITATION DATA OBTAINED FROM THE ALBERTA CLIMATE INFORMATION SERVICE (ACIS) DATABASE, REFERENCING LEGAL SUBDIVISION T026R04W5.



CLIENT  	PROJECT SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM	
	TITLE Vibrating Wire Piezometer Data S003 - Cochrane Hwy 22:16, km 9.9	
SCALE	PROJECT No. A05116A03	FIG No.

VW18-02 (SERIAL NO. 1800202)

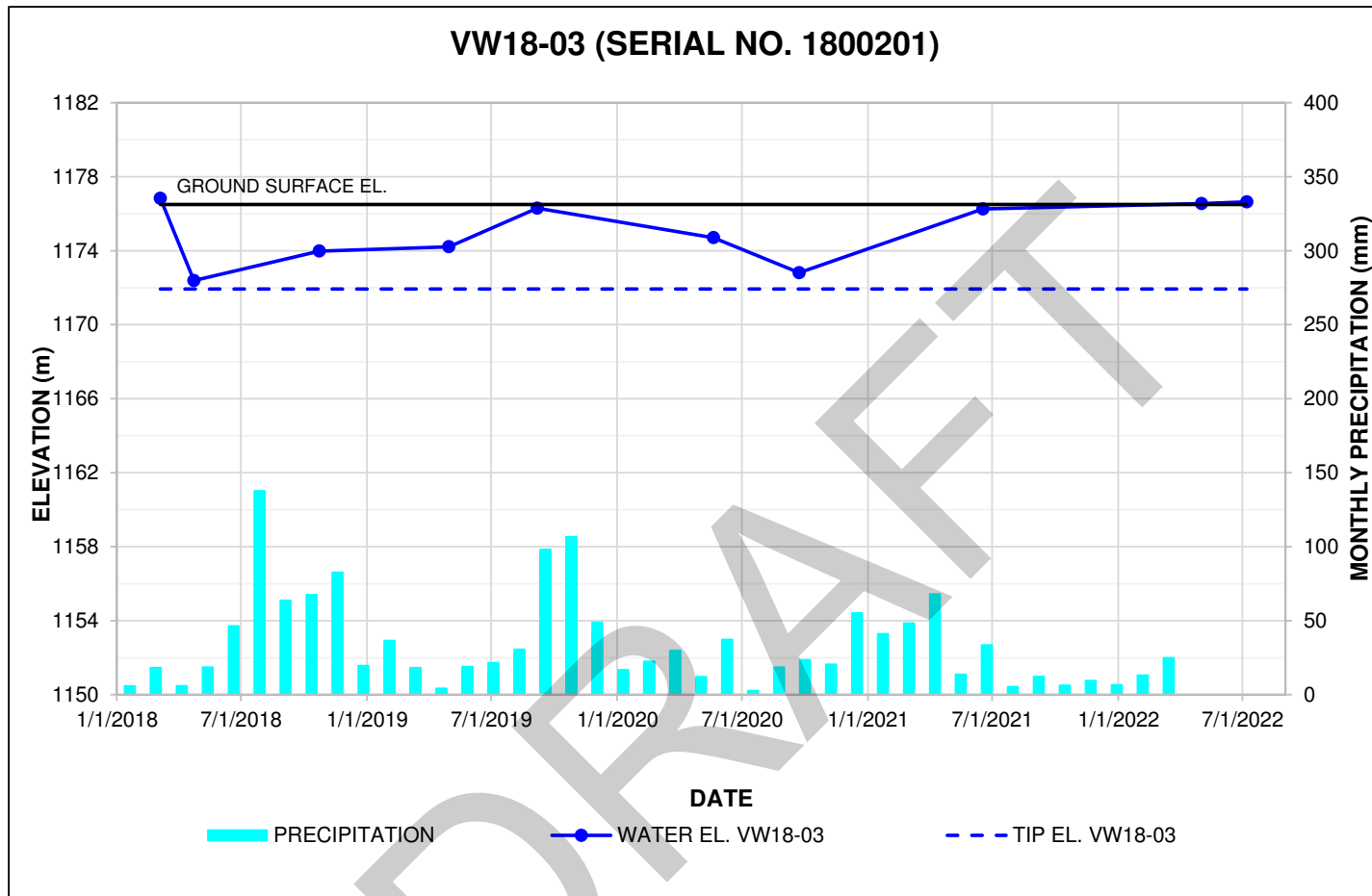


NOTES:

1. MONTHLY PRECIPITATION DATA OBTAINED FROM THE ALBERTA CLIMATE INFORMATION SERVICE (ACIS) DATABASE, REFERENCING LEGAL SUBDIVISION T026R04W5.



CLIENT  	PROJECT SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM	
	TITLE Vibrating Wire Piezometer Data S003 - Cochrane Hwy 22:16, km 9.9	
SCALE	PROJECT No. A05116A03	FIG No.

VW18-03 (SERIAL NO. 1800201)



NOTES:

1. MONTHLY PRECIPITATION DATA OBTAINED FROM THE ALBERTA CLIMATE INFORMATION SERVICE (ACIS) DATABASE, REFERENCING LEGAL SUBDIVISION T026R04W5.

CLIENT  	PROJECT SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM	
	TITLE Vibrating Wire Piezometer Data S003 - Cochrane Hwy 22:16, km 9.9	
SCALE	PROJECT No. A05116A03	FIG No.